

April 23, 1935.

G. H. ROCKWOOD, JR., ET AL

1,998,884

ELECTRIC DISCHARGE DEVICE

Filed Feb. 11, 1931

3 Sheets-Sheet 1

FIG. 1

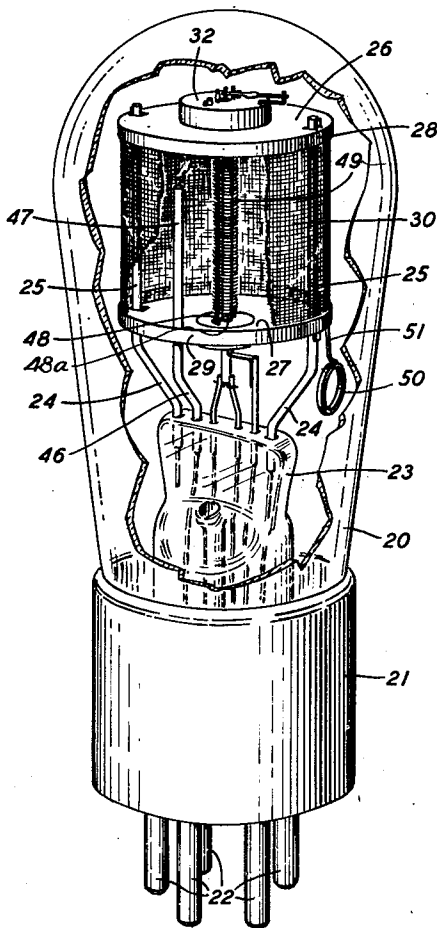


FIG. 2

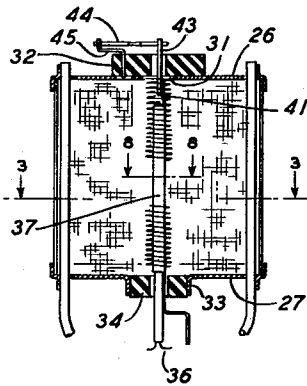


FIG. 3

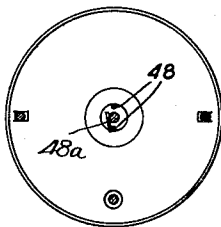


FIG. 4

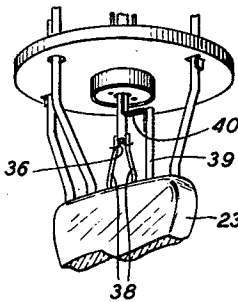


FIG. 5

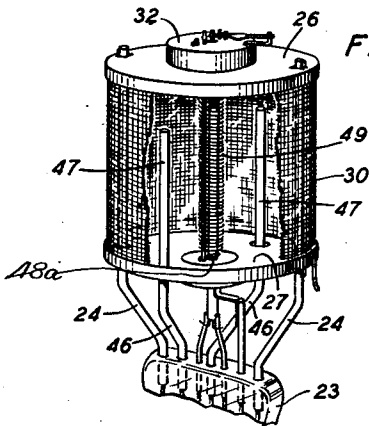
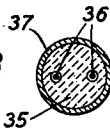


FIG. 8



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3 Sheets-Sheet 2

FIG. 7

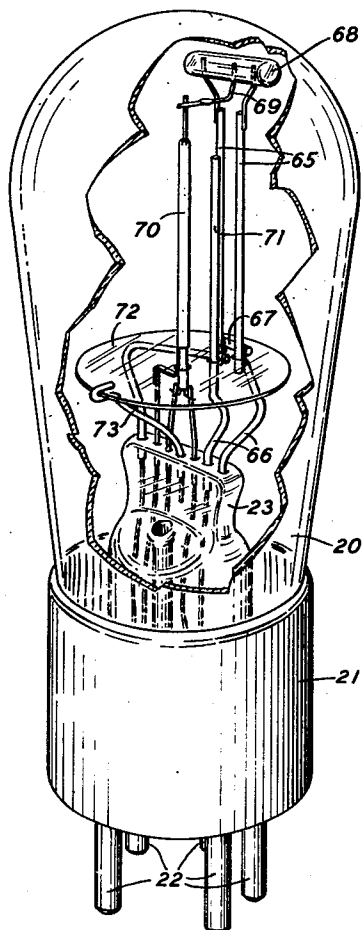
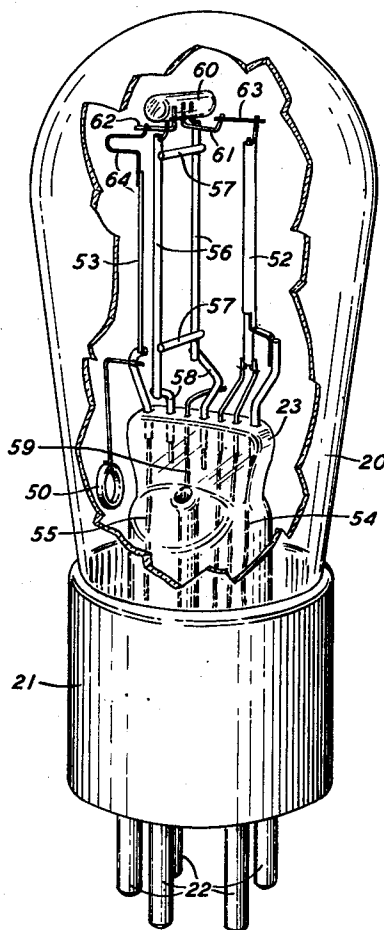


FIG. 6



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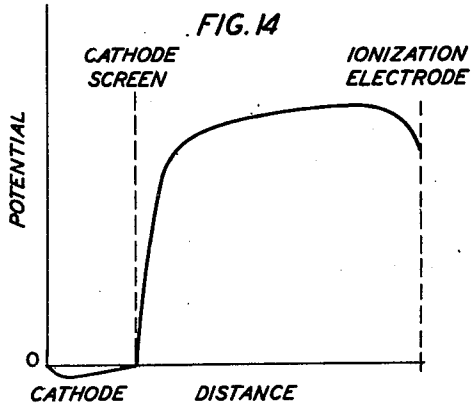
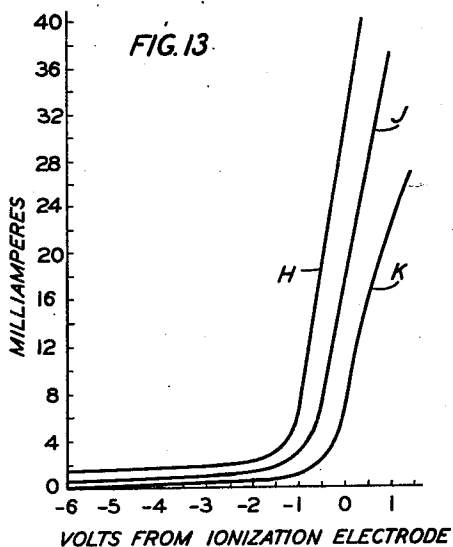
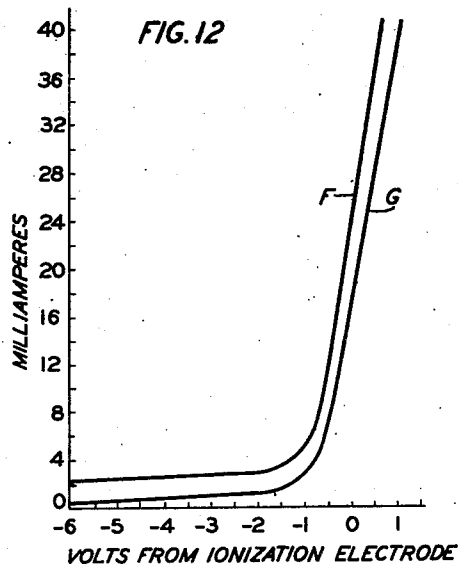
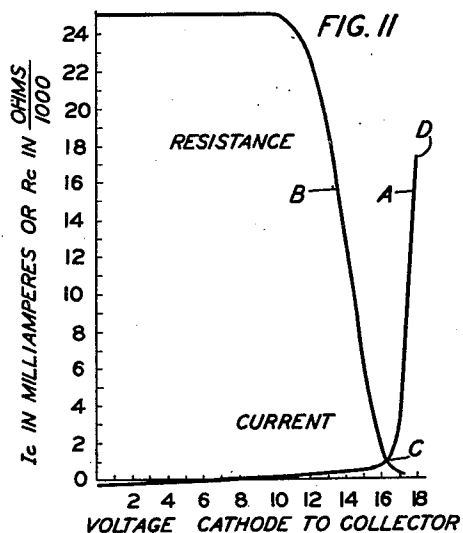
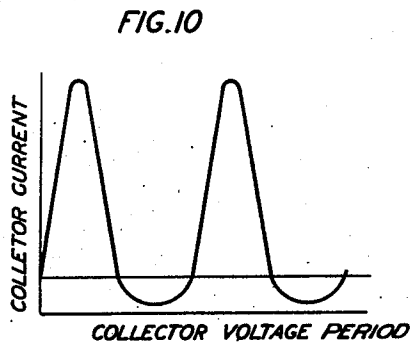
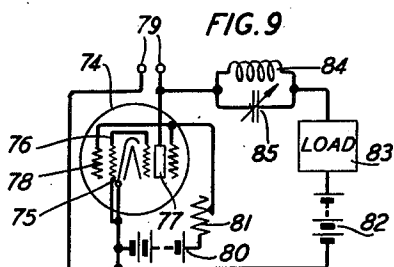
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ELECTRIC DISCHARGE DEVICE

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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

1,998,884

## ELECTRIC DISCHARGE DEVICE

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New York, N. Y., a corporation of New York

Application February 11, 1931, Serial No. 514,931

29 Claims. (Cl. 250-27)

This invention relates to electric discharge devices and more particularly to gaseous detectors and rectifiers incorporating an incandescent cathode.

5 It is desirable in many instances that discharge devices utilized in the detection and rectification of radio frequency impulses have a substantially linear characteristic, that is, that the rectified current vary directly as the applied or signal voltage. It is also desirable that the impedance of the device be low on the conducting half cycle and high on the inverse cycle and furthermore, from a standpoint of efficiency that the filament power be comparatively small.

10 It has been found in discharge devices employing a filling of an inert gas that the characteristic of the devices is largely dependent upon the form of ionization prevalent in the devices and that the form of ionization varies with the magnitude of the load current. In gaseous discharge devices of the type known heretofore, the transition from one form of ionization to another form is usually accompanied by discontinuities and pronounced curvatures in the characteristics so that the rectified current is not a linear function of the applied voltage. It follows, therefore, that in radio telephony, for example, any change in the form of ionization during the cycle of either the modulating or the carrier frequency results in distortion and an unstable reproduction of the applied or signal voltage.

15 An object of this invention, therefore, is to improve the characteristics of gaseous discharge devices and to reproduce signal voltages faithfully and without distortion.

20 Another object of this invention is to increase the efficiency and operating life of electron discharge devices of the gas filled type.

25 The discharge device of this invention comprises an enclosing vessel in which are mounted an electron emitting cathode, a cathode screen, one or more collector electrodes, which may take the form of a single wire rod, and an ionization electrode. The vessel is filled to a low pressure with an inert gas or vapor such as argon.

30 The ionization electrode in one embodiment of the invention comprises a cylindrical wire mesh encircling the cathode, cathode screen and collector electrode and arranged concentrically with respect to the cathode.

35 In another embodiment of the invention the ionization electrode takes the form of a rectangular frame comprising two upright rods spaced equally distant from and parallel to the cathode and two cross-rods welded to the upright

rods. In this embodiment the ionization electrode may be disposed either between the cathode and the collector electrode or beyond the collector electrode.

40 In the operation of a discharge device made in accordance with this invention, the ionization electrode is maintained strongly positive with respect to the cathode and a continuous ionization current is thereby produced between the cathode and the ionization electrode. The signal voltage is impressed upon the collector electrode, which is also preferably at a positive potential with respect to the cathode, suitable signal indicating means being coupled to the cathode-collector or collector-ionization electrode circuit. It has been found that if the ionization current is maintained at a sufficient magnitude, the form of ionization will be substantially constant and unaffected by variations in the load current. This factor together with the proper dimensioning and positioning of the collector electrode and the proper choice of gas pressure and collector electrode bias provides a detector or rectifier for radio and audio frequency impulses having a substantially linear characteristic over a wide range of collector currents and capable of operation at relatively high efficiencies.

45 The several features of this invention will be understood more clearly from the following detailed description with reference to the accompanying drawings in which:

50 Fig. 1 is an elevational view in perspective of one form of electric discharge device constructed in accordance with this invention with portions broken away to show details of construction more clearly;

55 Fig. 2 is an elevational view of the device shown in Fig. 1 partly in section and partly broken away to show the electrode assembly and the spacing of the electrodes;

Fig. 3 is a cross-sectional view along line 2-3 of Fig. 2 showing the space relation and configuration of the electrodes;

Fig. 4 is a fragmentary, perspective view showing the mounting of the electrodes upon the press in the embodiment of this invention shown in Fig. 1;

Fig. 5 is an elevational view of a device embodying two collector electrodes;

60 Figs. 6 and 7 are elevational views in perspective of other forms of a discharge device constructed in accordance with this invention;

Fig. 8 is an enlarged cross-sectional view along line 8-8 of the equi-potential cathode shown in Fig. 2;

Fig. 9 is a schematic view showing one form of a circuit arrangement incorporating a discharge device made in accordance with this invention;

Fig. 10 illustrates the collector voltage current relation through several cycles in a discharge device in accordance with this invention;

Fig. 11 shows typical characteristic curves for a discharge device made in accordance with this invention;

Fig. 12 shows characteristic curves for several discharge devices in accordance with this invention having different spacing of the electrodes;

Fig. 13 shows characteristic curves for several discharge devices made in accordance with this invention incorporating collector electrodes of different effective areas; and

Fig. 14 illustrates the potential distribution in a discharge device made in accordance with this invention.

Referring to the drawings, an electric discharge device in one embodiment of this invention as shown in Fig. 1 comprises an enclosing vessel 20 cemented or otherwise suitably attached to an insulating base 21 which is provided with terminal pins 22 for associating the device with an external electrical circuit. The enclosing vessel 20 is formed with a reentrant stem portion terminating in a substantially rectangular press 23 from which all the electrodes are mounted. Two rigid metallic rods are embedded in the press 23 each rod having a portion 24 bent outwardly and upwardly near the stem and a rectilinear portion 25 extending substantially to the opposite end of the enclosing vessel 20, the portions 25 being parallel to each other. Two metallic discs 26 and 27 having turned edges 28 and 29 respectively directed toward each other are mounted in spaced relation between the parallel portions 25 of the metallic rods and support a cylindrical mesh ionization electrode 30, the ends of which are seated within the turned edges 28 and 29 of the discs 26 and 27 respectively. The disc 26 is provided with a circular central aperture 31 as shown more clearly in Fig. 2 and carries a circular block 32 of insulating material, such as "lavite". The disc 27 is formed with an annular outwardly projecting extension 33 defining a central opening in which there is positioned a circular block 34 of insulating material, such as "lavite". A linear equi-potential type cathode extends through a central aperture in the insulating block 34 and comprises a drilled quartz rod 35, shown in cross-section in Fig. 8, through which a heater wire 36, preferably of tungsten, is threaded and a metallic sleeve 37, preferably of nickel, crimped about the quartz rod 35 and coated with a thermionically active material, such as alkaline earth oxides, capable of emitting electrons when heated. As is shown clearly in Fig. 4 the ends of the heater wire 36 are welded to leading-in wires 38 which are embedded in the press 23 and connected to a pair of the terminal pins 22, and another leading-in wire 39, likewise embedded in the press 23 and connected to one of the terminal pins 22, is welded to an extending strip 40 integral with the sleeve 37. Another extending strip 41 integral with the sleeve 37 is welded to a wire 43 projecting through the aperture 31 in the disc 26 and through a centrally disposed aperture in the insulating block 32. The wire 43 is affixed to a thin flexible wire 44 which is affixed to a bent wire 45 embedded in the block 32.

The collector electrode consists of a single rigid rod embedded in the press having an outwardly and upwardly bent portion 46 adjacent

the press and a rectilinear portion 47 extending through an aperture in the disc 27 and positioned parallel to the cathode.

A pair of parallel rigid wires 48 extend and are mounted between the insulating blocks 32 and 34 and support a screen 49 which may take the form of a helical grid as shown in Figs. 1, 2 and 3 or may take the form of a cylindrical wire mesh screen. The cathode screen 49 may be electrically connected to the metallic sleeve 37 by a metallic strip 49a and serves two purposes in the operation of the device, namely, it decreases the velocity of the electrons emitted from the cathode and also protects the sensitive emitting surface against positive ion bombardment. The cathode screen also reduces the magnitude of the required ionization current.

A troughed getter mount 50 carrying a quantity of vaporizable material such as magnesium for fixing undesirable gases and vapors in the vessel 20 is supported from the disc 27 by an arm 51.

In the fabrication of the device the vessel 20 is evacuated to a high degree by any suitable method and means and a quantity of mercury vapor or an inert gas, such as argon at low pressure, for example, of the order of 0.1 mm. of mercury, is introduced into the vessel 20. It is to be understood, however, that other gases or vapors, such as caesium or sodium vapor may be employed.

Fig. 5 shows a modified form of the device shown in Fig. 1 suitable for full wave rectification, in which two collector electrodes are employed, each having a rectilinear portion 47 parallel to the cathode and equally spaced therefrom.

In another embodiment of this invention shown in Fig. 6 the discharge device comprises the usual enclosing vessel 20 and insulating base 21 carrying terminal pins 22. The enclosing vessel is formed with a reentrant stem terminating in a rectangular press 23 from which there are mounted an equi-potential type cathode 52 and a collector electrode 53 in the form of a single rectilinear wire rod or ribbon parallel to the cathode. The electrodes are appropriately connected to certain of the terminal pins 22 by the leading-in conductors 54 and 55. In this embodiment of the invention the ionization electrode takes the form of a rectangular frame comprising upright rods 56 parallel to each other and to the collector electrode and cathode, and two cross-rods 57 welded to the upright rods 56 at or near the ends thereof. The ionization electrode is supported above the press 23 by bent rods 58 embedded in the press, one of the rods 58 being connected to one of the terminal pins 22 by a leading-in wire 59.

An insulator 60 is mounted on the ionization electrode and has embedded therein two bent wires 61 and 62 which have welded thereto flexible link wires 63 and 64. The wire 63 is welded to the free end of the cathode 52 and the wire 64 is welded to the free end of the collector electrode 53.

In still another embodiment of this invention shown in Fig. 7 the ionization electrode consists of two parallel upright rods 65 supported from the press 23 by bent wire rods 66, one of which is electrically connected to one of the terminal pins 22. A tie rod 67 is welded to the rods 65 at one of their ends. An insulating member 68 is mounted on the rods 65 and has embedded therein a bent wire 69 which engages an end of an equi-potential cathode 70. A collector elec-

trode 71 is supported from the stem 23 and has a portion parallel to the cathode and ionization electrode and is disposed adjacent the ionization electrode and equally spaced from the rods 65.

A disc 72 of insulating material, such as mica, is supported on the wire rods 66 and a supporting rod 73 embedded in the press, and prevents the extension of the discharge to the press and between the electrode leading-in wires.

It is, of course, possible to modify the devices shown in Figs. 6 and 7 to include two collector electrodes and two ionization electrodes for full wave rectification. A cathode screen may also be incorporated in these embodiments of this invention.

In the operation of a discharge device made in accordance with this invention, the ionization electrode is maintained strongly positive with respect to the cathode and a continuous ionization current is thereby produced between the cathode and the ionization electrode. The signal voltage is impressed between the collector electrode and the cathode, and a load, such as a suitable signal indicating means, is associated either in shunt or series with the cathode-collector circuit or in the collector-ionization electrode circuit. It has been found that in a device made in accordance with this invention, if the ionization current is maintained at a proper magnitude, the form of ionization will be substantially constant over a wide range of collector currents. By proper dimensioning and positioning of the collector electrode and the proper choice of gas pressure and the collector bias a continuous ionization device may be provided which will operate satisfactorily as a linear detector or rectifier over a wide range of collector voltages and currents.

The method of operation may be understood more clearly from one application of a discharge device in accordance with this invention as shown diagrammatically in Fig. 9. In this figure a discharge device of the type comprehended in this invention is generally designated as 74 and includes an equi-potential cathode 75, a cathode screen 76, a collector electrode 77, and an ionization electrode 78. The input voltage is impressed across the terminals 79 one of which is connected to the cathode 75 and the other of which is connected to the collector electrode 77. A source of potential, such as a battery 80, is connected between the ionization electrode 78 and cathode 75, in series with a resistance 81 for establishing an ionization current of a desired magnitude between the cathode and ionization electrode. A series circuit including a source of potential, such as a battery 82, a load 83 and a tuning circuit including an inductance 84 and shunt capacity 85 is connected between the cathode 75 and collector electrode 77. The load may of course be either resistive, reactive or combined resistive and reactive in character. For example, in one embodiment the input may be obtained from the antenna in a broadcast transmitter and the load may be a distortion measuring device.

The characteristic curves for a discharge device made in accordance with this invention are shown in Fig. 11 wherein curve A illustrates the variation of collector current with the cathode-collector voltage and curve B illustrates the resistance of the device as compared with the cathode-collector voltage. It is evident that the collector current voltage characteristic comprises two rectilinear portions converging at an angle of greater than 90° and that substantially linear

rectification of high order may be obtained between collector voltages corresponding to the points C and D on the curve. The collector bias may of course be so chosen that the discharge device will be substantially non-conductive on one half of the input voltage cycle and very conductive on the other half of the cycle. This may be clearly seen from Fig. 10 which shows diagrammatically the collector current variation with a sinusoidal collector voltage of one volt in magnitude, reference being had to the characteristic shown in Fig. 11. The constant current component due to the collector bias of say 16½ volts is approximately 1.2 milliamperes. At a collector voltage of 17.5 volts the collector current is approximately 9 milliamperes and at a collector voltage of 15.5 volts the current is but .5 milliamperes.

The magnitude of the constant direct current component due to the collector bias is of importance and in accordance with a feature of this invention the discharge device may be so constructed that an optimum value for this component may be obtained depending upon the application in which the device is to be utilized.

The factors effecting the magnitude of the direct current component of the collector current may be understood with reference to Figs. 12 and 13. Curves F and G in Fig. 12 show respectively the volt-ampere characteristic for similar devices in which the collector-cathode distances were different, the distance being least in the device represented by curve F and greatest in the device shown by curve G. It is seen from these characteristic curves that the position of the collector has substantially no effect upon the form of the characteristic. However the position determines the point of saturation and also increases or decreases the collector current by a substantially constant amount, an increase in the collector-cathode spacing decreasing the current and hence lowering the saturation point. Thus, it is possible by moving the collector away from the cathode to make the constant direct current component of almost negligible magnitude.

Fig. 13 shows characteristic curves for several discharge devices in accordance with this invention embodying collectors of different areas. In this figure curve H shows the volt-ampere characteristic of a device in which the collector area was the greatest and curves J and K show respectively the volt-ampere characteristic of devices in which the collector area was less, being least in the device represented by curve K. From these curves it is seen that the area of the collector affects the saturation current and also affects somewhat the constant direct current component of the collector current.

The collector area to be used in any particular device is somewhat dependent upon the tendency of the collector to pick up positive ions on the reverse half of the cycle of the signal voltage applied to the collector electrode. It has been found that if the diameter of the collector electrode is large in comparison to the mean free path of the molecules of the vapor in the device that ion pick-up on the reverse half of the cycle becomes objectionable.

In any device, therefore, in accordance with this invention it is possible to ascertain optimum values for the effective collector area and cathode-collector spacing for any particular application in which the device is to be utilized. The spacing and effective area will be determined largely

by the maximum collector current required in any particular application, the preferred magnitude of the constant direct current component of the collector current, and the saturation point of the device.

A physical picture of conditions extant in discharge devices in accordance with this invention may be had from Fig. 14 which illustrates the approximate potential distribution in a device in accordance with the embodiment of the invention shown in Fig. 1, the abscissæ denoting distance from the cathode and the ordinates denoting potential. In the operation of the device the luminous portion of the discharge is substantially confined between the ionization electrode and the cathode screen and the major portion of the voltage drop occurs between the cathode screen and a point immediately adjacent thereto. The collector electrode is positioned in the luminous portion of the discharge and it has been found desirable to position the collector in the positive column of the discharge and preferably so that it is at a point where the potential gradient is substantially zero.

It is desirable from a standpoint of efficiency that the ionization current be small. Furthermore, it has been found that the lower the ionization current the less is the curvature at the convergence of the two linear portions of the volt-ampere characteristic of the device, such as shown by curve A in Fig. 11. The proper form of ionization and hence magnitude of ionization current is dependent upon the pressure of the gas or vapor within the device and may for any given gas pressure be determined experimentally by coupling a signal indicating means, such as a telephone receiver, into the ionization circuit. The proper ionization current is prevalent at the point at which the circuit is perfectly quiet as indicated by the telephone receiver.

The adjustment of the ionization current may be effected by varying either the resistance 81, or the voltage of the source 80, or both. It is desirable for the purpose of attaining stable operation that the resistance 81 be maintained at least at a certain minimum value, which may be determined experimentally by the operations described in the preceding paragraph.

It is to be understood that the various characteristics, current and voltage values, and collector dimensions and spacing are merely given to illustrate the principles of this invention and that the scope of this invention is not to be limited thereby except as specified in the appended claims.

What is claimed is:

1. A gaseous discharge device comprising a cathode capable of emitting electrons when heated, an ionization electrode, and a collector electrode, the collector electrode area, electrode spacing and gas pressure being such that with proper potentials applied between said ionization electrode and cathode to maintain a continuous ionization current therebetween, and between said cathode and collector electrode to sustain a current therebetween, the collector voltage-collector current characteristic of the device comprises two linear portions converging at an angle greater than 90°.

2. A gaseous discharge device comprising a cathode capable of emitting electrons when heated, an ionization electrode for maintaining a continuous discharge with said cathode, and a collector electrode, the collector electrode area, electrode spacing, and gas pressure being such

that with normal collector electrode bias the collector current varies substantially linearly with the voltage applied to the collector electrode over a range of potential extending from a low potential to a potential near the saturation potential.

3. In combination, an electric discharge device comprising an enclosing vessel having a gaseous atmosphere therein, a cathode, an ionization electrode, means for maintaining a continuous direct current discharge between said cathode and said ionization electrode, a collector electrode positioned between aligned portions of said cathode and ionization electrode and to be within the positive column of said discharge, and a utilization circuit coupled to said collector electrode.

4. An electric discharge device comprising an enclosing vessel having an ionizable gas therein, a cathode adapted to emit electrons when heated, an ionization electrode for maintaining a continuous discharge with said cathode, said gas being at such a pressure that with a potential between said cathode and said electrode sufficient to maintain a stable discharge between said cathode and said electrode, the field between said cathode and said electrode includes a portion of substantially zero potential gradient, and an electrode positioned in said portion.

5. In combination a gaseous discharge device comprising a cathode adapted to emit electrons when heated, an ionization electrode, a collector electrode, means for establishing a continuous ionization current between said cathode and ionization electrode, means for applying a variable potential to said collector electrode, and a load circuit coupled to said collector electrode.

6. In combination a gaseous discharge device comprising a cathode adapted to emit electrons when heated, an ionization electrode, a collector electrode, means for maintaining a constant ionization current between said cathode and ionization electrode, and an input and an output circuit coupled to said collector electrode.

7. An electric discharge device comprising an enclosing vessel having a gas therein, a cathode adapted to emit electrons when heated, a screen electrode disposed adjacent said cathode, an ionization electrode operatively associated with said cathode, said gas being at such pressure that with said screen electrode operated at substantially cathode potential and with a potential between said cathode and said ionization electrode sufficient to maintain a stable discharge between said cathode and said ionization electrode, the luminous portion of said discharge is confined to the space between said ionization and screen electrodes, and a unitary input and output electrode disposed in the luminous portion of said discharge.

8. An electric discharge device comprising an enclosing vessel having a gas therein, a cathode adapted to emit electrons when heated, a screen electrode adjacent said cathode, an ionization electrode operatively associated with said cathode, said gas being at such pressure that with a potential between said cathode and said ionization electrode sufficient to maintain a stable discharge between said cathode and said ionization electrode, the space between said screen and ionization electrodes includes a portion of substantially zero potential gradient, and an output electrode disposed in said portion.

9. A linear detector comprising an enclosing vessel having a gaseous atmosphere therein, a cathode adapted to emit electrons when heated,

a screen electrode about said cathode, an ionization electrode for maintaining a continuous discharge with said cathode, and a collector electrode positioned in the positive column of said discharge.

10. A gaseous discharge device comprising an equi-potential cathode, an ionization electrode and a collector electrode associated with said cathode, a screen electrode adjacent said cathode, and an electrical connection between said screen electrode and said cathode.

11. In combination, a gaseous discharge device comprising a cathode capable of emitting electrons when heated, a screen electrode adjacent said cathode and connected thereto, an ionization electrode, a collector electrode, means for establishing a continuous ionization current between said cathode and ionization electrode, and a utilization circuit connected to said cathode and collector electrode, the collector electrode area, electrode spacing and gas pressure being such that the collector current-collector voltage characteristic of the device comprises two linear portions converging at an angle greater than  $90^\circ$ .

12. A gaseous discharge device comprising a cathode capable of emitting electrons when heated, a screen electrode encircling said cathode, an ionization electrode, and a collector electrode, the collector electrode area, electrode spacing, and gas pressure being such that with normal collector electrode bias the collector current varies substantially linearly with the voltage applied to the collector electrode between a low potential and a potential near the saturation potential.

13. An electric discharge device comprising an enclosing vessel having a stem, a cathode adapted to emit electrons when heated, supported from said stem, an electrode cooperating with said cathode to maintain an ionization current to said cathode, and a collector electrode consisting of a single rod mounted from said stem.

14. A gaseous discharge device comprising an enclosing vessel having a stem, a rectilinear equi-potential cathode mounted upon said stem, a screen electrode encircling said cathode, an ionization electrode disposed about said cathode and screen electrode and concentric with said cathode, and a collector electrode between said screen and ionization electrodes.

15. The method of effecting rectification of a signal voltage by a gaseous discharge device having a plurality of electrodes therein, one of said electrodes serving as an output electrode for said device, which comprises maintaining a substantially constant ionization current between two of said electrodes other than said output electrode, and impressing said signal voltage between said output electrode and one of said two electrodes.

16. The method of effecting rectification of a signal voltage by a gaseous discharge device including a cathode adapted to emit electrons when heated, and an ionization and a collector electrode operatively associated with said cathode, said device having a volt-ampere characteristic including a linear portion, which comprises maintaining a constant ionization current between said cathode and ionization electrode, applying a positive bias to said collector electrode, and impressing said signal voltage between said cathode and collector electrode, said collector bias being of a magnitude corresponding to a point in the linear portion of said characteristic of said device.

17. A gaseous discharge device comprising a cathode adapted to emit electrons when heated, an ionization electrode encircling said cathode and a plurality of collector electrodes positioned between said cathode and ionization electrode.

18. In combination a gaseous discharge device comprising a cathode adapted to emit electrons when heated, an ionization electrode, and a collector electrode, means maintaining a continuous ionization current between said cathode and ionization electrode, an input circuit impressing voltage variations between said cathode and said collector electrode, and a utilization circuit connected between said cathode and collector electrode and carrying current of a frequency characteristic different from that of said impressed voltage variations.

19. In combination, an electric discharge device comprising an enclosing vessel having a filling of argon therein, a cathode capable of emitting electrons when heated, an ionization electrode, a collector electrode, means for establishing a continuous ionization current between said cathode and ionization electrode, means for applying a variable potential to said collector electrode, and a utilization circuit coupled to said collector electrode, the collector electrode area, electrode spacing and argon pressure being such that the collector current-collector voltage characteristic of the device includes two linear portions converging at an angle greater than  $90^\circ$ .

20. An electric discharge device comprising an enclosing vessel having a filling of argon therein, a cathode capable of emitting electrons when heated, an ionization electrode for maintaining a continuous discharge with said cathode, and a collector electrode, the collector electrode area, electrode spacing, and argon pressure being such that with normal collector electrode bias the collector current varies substantially linearly with the voltage applied to the collector electrode over a range extending from a low potential to a potential near the saturation potential.

21. An electric discharge device comprising an incandescent cathode, an output electrode associated with said cathode, a screen electrode immediately adjacent said cathode, and a conductor electrically connecting said screen electrode to said cathode.

22. An electric discharge device comprising an enclosing vessel having a stem, a rectilinear equi-potential cathode supported above said stem, and a collector electrode consisting of a single rod embedded in said stem, said collector electrode having a rectilinear portion parallel to said cathode.

23. An electric discharge device comprising an enclosing vessel having a stem, an ionizable medium in said vessel, a rectilinear equi-potential cathode mounted upon said stem, a screen electrode concentrically disposed about said cathode, a conductor electrically connecting said cathode and said screen electrode, an ionization electrode concentrically disposed above said cathode and screen electrode, and a collector electrode between said screen and ionization electrodes, said collector electrode having a rectilinear portion parallel to said cathode.

24. In combination, a gaseous discharge device comprising a pair of cooperative electrodes defining a rectifying element, an ionization electrode operatively associated with one of said electrodes, means for maintaining a substantially constant ionization current between said ionization electrode and said one electrode, and a



utilization circuit connected to said cooperative electrodes.

25. An electric discharge device comprising an enclosing vessel having a gas therein, an incandescent cathode, a pair of collector electrodes in juxtaposition to said cathode, and an ionization electrode surrounding said cathode and collector electrode including a cylindrical portion concentric with said cathode and end portions substantially closing said cylindrical portion.

26. An electric discharge device in accordance with claim 28 in which the gas pressure, the dimensions of the collector electrodes and the electrode spacing are such that with normal bias upon the collector electrodes, the cathode-collector currents vary substantially linearly with the voltage applied to the collector electrodes over a range extending from a low potential to a potential near the saturation potential.

27. An electric discharge device comprising an enclosing vessel having a stem, a filling of argon within said vessel, a substantially rectilinear cathode mounted upon said stem, a plurality of collector electrodes each having a rectilinear portion parallel to said cathode, and an ionization

electrode structure including a pair of parallel disc members supported from said stem and a cylindrical wire mesh portion between said disc members and encircling said cathode and said collector electrodes.

28. An electric discharge device comprising an enclosing vessel having a reentrant stem, a substantially rectilinear cathode upon said stem, a plurality of collector electrodes, each having a rectilinear portion parallel to said cathode, a plurality of supporting members extending from said stem, a pair of spaced parallel disc members supported between said supporting members, an ionization electrode between said disc members disposed about said cathode and collector electrodes, and a screen electrode supported between said disc members and concentrically disposed about said cathode and located between said cathode and collector electrodes.

29. An electric discharge device in accordance with claim 28 including a conductive member electrically connecting said cathode to said screen electrode.

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