Dec. 31, 1940. A. G. CLAVIER ET AL 2,226,696

ELECTRON DISCHARGE DEVICE

Filed June 22, 1938

Fig. 1.

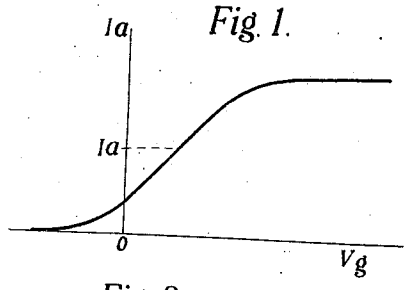


Fig. 2.

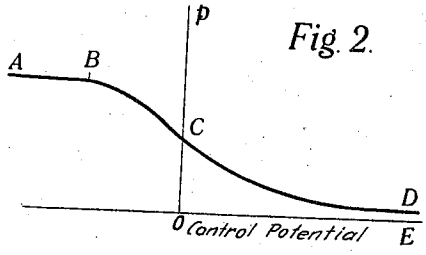


Fig. 3.

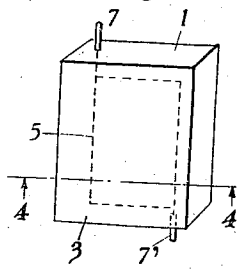


Fig. 4.

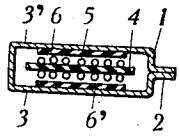


Fig. 5.

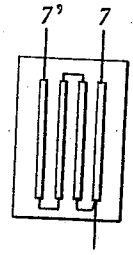


Fig. 6.

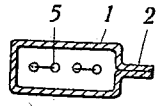


Fig. 9.

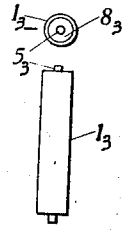


Fig. 8.

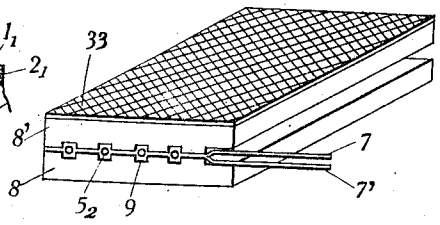


Fig. 7.

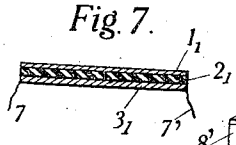
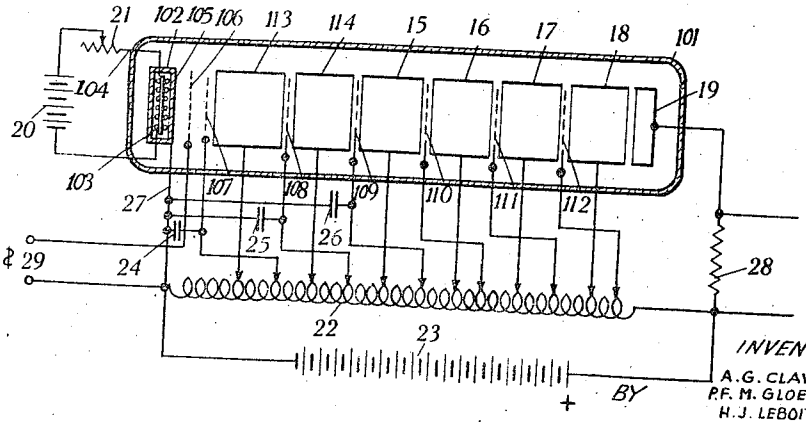


Fig. 10.



INVENTORS
A. G. CLAVIER
P. F. M. GLOESS
H. J. LEBOITEUX

E. A. Robinson
ATTORNEY

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ELECTRON DISCHARGE DEVICE

Andre Gabriel Clavier, Paul Francois Marie Gloess, and Henri Jean Le Boiteux, Paris, France, assignors to International Standard Electric Corporation, New York, N. Y.

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3 Claims. (Cl. 250—27.5)

The present invention relates to electron discharge devices particularly applicable to the amplification of electrical variations, particularly in the case in which the tension to be amplified is of extremely high frequency and/or has components extending over a considerable frequency band.

The invention is also concerned with the amplification of tensions of very low amplitude, these tensions being of very high frequency or otherwise.

The present invention in particular provides a method of amplification in which the emissive properties and the emissive conditions of the cathode or cathodes utilised are adapted for the optimum operation of the discharge device in the specified conditions of use, particularly those arising out of the amplification of a very high frequency or a very wide frequency band.

The amplification of low tensions of very high frequencies and/or those extending over a considerable frequency band by the means known at the present time of amplification by multi-electrode valves entails difficulties resulting from the fact that all these amplification means require the introduction between their various stages of impedances difficult to achieve if it be desired to keep a sufficient amplification or to maintain low the distortion over the whole range of the frequencies to be amplified.

However, amplification systems are known based on the use of secondary-electron emission which escape this criticism since they do not require the use of said impedances.

It has now been noticed that the adaptation of amplifier systems employing secondary emission to the amplification of low tensions of high frequency meets with difficulties which are connected with the absolute temperature of operation of the cathode. These difficulties are overcome in accordance with one feature of the invention by reducing as much as possible the temperature of the cathode employed, but nevertheless maintaining a sufficient electronic emission; for this purpose the invention describes, in accordance with another feature, various types of cathodes adapted to operate at low temperature with a satisfactory electronic emission.

The invention will be understood better by means of the following description during which reference will be made to the attached drawing, in which:

Fig. 1 represents the curve of variation of the anode current as a function of the potential of the control electrode of a thermionic device;

Fig. 2 represents the variation of a magnitude designated under the name of logarithmic slope as a function of the control tension E;

Figs. 3 to 9 represent various cathode constructions; and

Fig. 10 represents a device employing the secondary emission and improved in accordance with certain features of the present invention.

In order to define more clearly the methods and means of amplification comprising the object of the present invention, it is necessary to point out that in the amplification devices making use of the properties of secondary emission, the mean current employed at the input of the apparatus is amplified at the same time as the useful current and that from this fact for a given dimension the mean current at the output will be one of the characteristics limiting the possibilities of use of said device. The result is that if I_{max} is the mean output current, the problem consists in ensuring an output signal of maximum value ΔI, but the ratio ΔI_{max} to I_{max} is maintained in all the parts of the device and must consequently result directly from the application, to the input of the device, of the tension to be amplified. Now, this first part of the device contains a thermionic electron source and a control element operating as a grid in the manner usually employed in vacuum tubes with several electrodes, that is to say the control is effected by the limitation of the current caused by the reduced potential existing on the grid by the space charge existing between the cathode and said grid,

It is equally obvious that it is possible to describe the relation between the various characteristic elements of the input amplifier as follows:

$$\frac{\Delta I}{I}=\frac{\Delta I}{\Delta V_g}\times\frac{1}{I}\times\Delta V_g=\frac{s}{I}\times\Delta V_g$$

in which I is the mean current in the grid-anode space; ΔI is the variation of this current caused by the control potential ΔV_g available, i. e. the varying potential supplied to the control grid s is the slope of the characteristic curve of the device.

In order to obtain a ratio

$$\frac{\Delta I}{I}$$

as high as possible when a tension ΔV_g fixed by the continuous operation to which the device is

subjected has to be amplified, it is necessary to obtain as great as possible a ratio

$$\frac{s}{I}$$

this ratio p representing a characteristic magnitude of the amplifier device which it is convenient to call the logarithmic slope of the input element. A detailed consideration shows that for a given cathode, it is impossible to obtain a value of this logarithmic slope p greater than a limiting value.

Fig. 1 recalls the characteristic of operation of a tube, that is to say the variation of the anode current I_a as a function of the grid potential V_g.

Fig. 2 shows the variation of the factor p as a function of the control potential E.

It will be seen that the factor p is constant for a zone of negative values of the control potential, that is to say in the region AB in which the electrons are emitted in accordance with Maxwell's law of distribution, and then decreases in a continuous manner in the region CD in which the grid-anode current is limited by the space charge. It is in this latter region that it is necessary to employ the tube for amplification, because it is in this region that the control of the current by the grid potential is correctly effected.

It will be seen that the maximum value which it is possible to reach for the logarithmic slope p is given by the value of this factor in the zone AB and that in practice in order to obtain a correct amplification without distortion even this value cannot be attained

Moreover, in the region in which the current emitted obeys the Maxwell law, we have:

$$I_a = I_0 e^{-E/E_0}$$

in which e is the base of natural logarithms, E is the control potential and E_0 the potential corresponding to the mean output speed of the electrons. This potential is given by:

$$E_0 = 8.61.10^{-5}T$$

T being the absolute temperature of operation of the cathode

The maximum logarithmic slope is thus:

$$p_{max} = \frac{d \log I_a}{dE} = \frac{1}{E_0} = \frac{1}{8.61.10^{-5}T}$$

The cathodes normally employed work at a relatively high temperature T. Thus a cathode of the so-called "oxide filament" type which has the lowest utilisation temperature operates in the vicinity of $T=1{,}000$ degrees absolute.

The maximum logarithmic slope which can be obtained is thus:

$$p_{max} = \frac{1}{8.61.10^{-5}.10^3}$$

Its value is thus in the vicinity of 11.

This value of p does not permit the effective amplification of low alternating potentials of the order for example, of several hundredths of a volt. It is possible to cause a cathode of a usual type to operate at a lower temperature than the normal, but its emission then very rapidly decreases and at the same time the stability of this emission almost wholly disappears.

There have now been found certain suitably prepared surfaces capable of emitting thermionic electrons at very low temperature, practically as low as 100 degrees centigrade (or 373 degrees absolute). Such temperatures correspond to a logarithmic slope of about 30,

It has also been found that under these conditions the stability of the emission is as great as that of the normal cathodes operated at high temperature.

These properties are offered by metallic surfaces covered with very fine films of alkaline or alkaline earth metals, such for example as those prepared to have a photo-electric sensitivity.

By way of example, a plate of silver previously oxidised, then covered with a film of caesium in accordance with the well-known manner is suitable to emit in a satisfactory manner from a temperature of about 100° centigrade. Towards 130°–140°, this thermionic emission is of the same order as the photo-electric emission under average illumination.

In accordance with one of the aspects of the present invention in amplifier devices intended for the amplification of very weak alternating potentials, surfaces, prepared as mentioned above and provided with devices permitting the heating at a suitable temperature of the order of 100° to 150° centigrade to be insured, are used as cathodes.

The control of the thermionic emission of such cathodes may then be ensured by a grid in the usual way.

Figs. 3 to 9 represent various examples of cathodes incorporating characteristics of the invention.

Fig. 3 shows in perspective a type of cathode of which Fig. 4 shows a sectional view.

In this drawing a sheet of silver 1, of suitable thickness, is bent on itself and soldered at points at 2 so as to form a hollow parallelepiped. The surface or the two surfaces 3, 3' of this body are treated in the well-known manner so as to give them a photoelectric sensitivity, for example by oxidisation, then covered with a fine film of caesium or another alkaline or alkaline earth metal.

Inside the hollow body then formed is arranged an insulating plate 4 for example of mica, on which has been wound a suitable length of resistance wire 5 for example of the ferro-nickel commonly used for the construction of heating resistances.

Other insulating plates 6 and 6' are intended to insulate the winding from the internal surfaces of the silver plate.

At 7 and 7' are arranged the conductors for leading the current into the heating wire.

Another embodiment of the invention is shown in Fig. 5 in elevation and Fig. 6 in section. Inside the hollow body 1 similar to that of Fig. 3 are arranged ordinary graphite resistances in the form of rods 5. These rods are rigidly maintained in position by any suitable supporting means not shown, or may be carried directly by the lead-in conductors 7, 7'.

Another type of cathode incorporating the characteristics of the invention is shown in section in Fig. 7.

This cathode is composed of a photosensitive layer 1_1, supported by an insulating plate 2_2, itself in one piece with a metal plate 3_1 of suitable specific resistance. These plates are shown in the form of plane rectangular plates, but it is clear that their shape may be any desired one and adapted to the devices for which they are intended to be used. The metal plate 3_1 receives the current through the conductors 7, 7' which are directly connected thereto and thus play the part of heating element.

It is clear that an element such as that of

Fig. 7 may be combined with similar elements so as to give desired polyhedric emissive surfaces.

For such a cathode, it is well to employ a unit having a high heat inertia which permits the temperature to be maintained as constant as possible in spite of slight variations of the heating current.

Fig. 8 shows a form of cathode particularly adapted to this latter condition.

The cathode body is formed of moulded insulating material, for example of the two parts 8, 8', in the form of plates and having notches or grooves 9 inside which are arranged the heating element 5_2, supplied with heating current by the connections 7, 7'. The electron emitting photo-sensitive layer is formed in the well-known manner on the surface 33 on the insulating member 8'.

Although the unit is shown in the form of a parallelepiped sensitised on one surface only, and the heating wires are shown connected to each other and to common current leads, it is obvious that the form given to the body of moulded material may be modified for its use in a particular structure, that one or more surfaces may be sensitised and that the current in the heating elements and the form given to these elements themselves may be provided so as to obtain either uniform heating, or a desired distribution of the temperature in the cathode.

Fig. 9 shows in plan and in elevation a structure in which the cathode is of cylindrical form and consists of a body of moulded material 8_3, externally sensitised as indicated at 1_3, the heating element 5_3 being placed in the axis of the cylindrical insulating body. This structure permits the use of such cathodes in tubes of the known types with concentric arrangement of the elements.

Various obvious modifications can be made to this latter embodiment; its form may be that of a hollow polygonal body of moulded material, a plurality of filaments, etc.

The various arrangements provided by the invention and employing the cathode forms shown or directly derived from these may be combined with all known systems in which it is necessary to arrange a source of electrons. Nevertheless, as the emission currents concerned remain of a relatively low order, generally less than a milliampere, the invention provides a method of application permitting considerable output currents to be obtained, particularly in the amplification of very low tensions of the order of a hundredth of a volt and less.

Moreover, the use of these devices permits where necessary the interpolation of high impedances in the circuit, which in the usual case in the amplification of very low currents is to be avoided.

For this purpose a cathode incorporating the characteristics of the invention, associated with a control grid, is arranged at the input of any electronic amplifier structure employing secondary emission.

The electron current produced by the said thermionic cathode is received on the first emissive plate of the amplifier device where its arrival causes the emission of secondary electrons. The amplification continues in the structure in the usual manner.

Under these conditions the primary current from the cathode may be of the order of about ten microamperes for example. Such a current is efficiently controlled with a suitable rate of modulation by a tension of the order of the hundredth of a volt and plays the part of input current for the secondary emission amplifier device. In this way it is easy to obtain at the output of the apparatus a current reaching several milliamperes whose variations faithfully reproduce those of the alternating tension applied to the control grid. Moreover, there is thus obtained an amplifier system in which the ratio signal to fundamental noise is very great without high impedances being used in the circuit.

Fig. 10 represents by way of example an electronic amplifier device employing secondary emission.

In this drawing, a sheath 101, which has been evacuated to a very high degree, contains a cathode of a type in conformity with the characteristics previously mentioned and comprising for example a body 102, heating elements 103, and connections 104, the surface 105 being sensitised as above described, a control grid 106 and an amplifier structure comprising secondary emission electrodes in the form of grids 107 to 112. There are also provided concentration cylinders or electrodes 13 to 18 and a collecting electrode 19 at the opposite end to the cathode.

The heating current of the cathode is supplied by the battery 20 connected to the current leads 104 through an adjusting resistance 21. This battery may be replaced by any suitable source of current.

A potentiometer 22, fed by a battery 23, permits the suitable tensions to be applied to the various electrodes of the device. Capacities such as 24, 25 and 26 are connected between the cathode connection 27 and the connections of the secondary emission grids, for example 107, 108, 109, respectively. The collecting electrode 19 is connected to an output resistance 28 on the terminals of which the utilisation circuit is branched. The tension whose variations are to be amplified is applied between the control grid 106 and the cathode.

Although the invention has been described in connection with electronic amplifier systems, it is clear that it might find application in generator or modulator systems and other electronic devices.

What is claimed is:

1. An electron discharge device for amplifying high frequency energy comprising a cathode of photo-sensitive material, heater means for maintaining said cathode at a temperature between 100° and 150° C. to produce a primary emission of electrons, an anode, a secondary electron emitting electrode between said anode and said cathode, and a control grid for controlling the number of primary electrons reaching said secondary emitting electrode arranged between said electrode and the cathode.

2. An electron discharge device according to claim 1, wherein said photo-sensitive material is caesium.

3. An electron discharge device according to claim 1, wherein said cathode comprises a resistive carrier body, and a film of photo-sensitive material coated on said body, and said heater means comprises means for passing heating current through said resistive body.

ANDRE GABRIEL CLAVIER.
PAUL FRANCOIS MARIE GLOESS.
HENRI JEAN LE BOITEUX.