

Jan. 14, 1941.

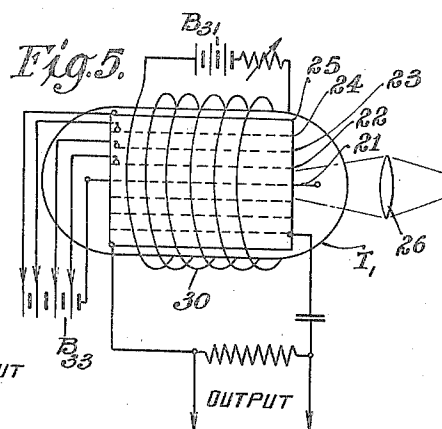
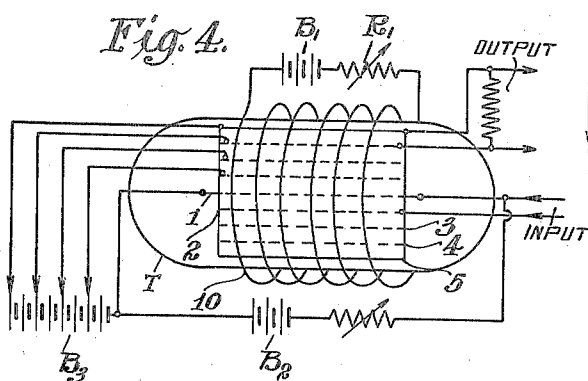
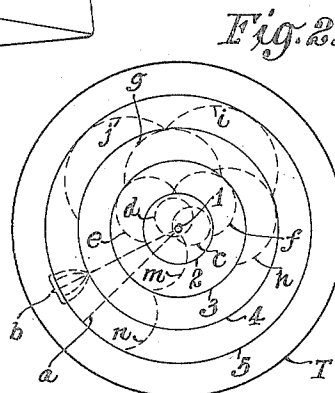
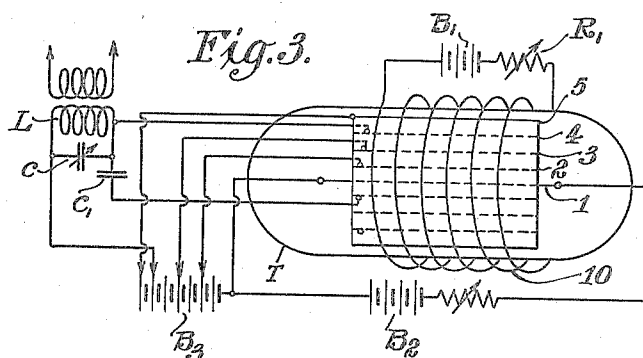
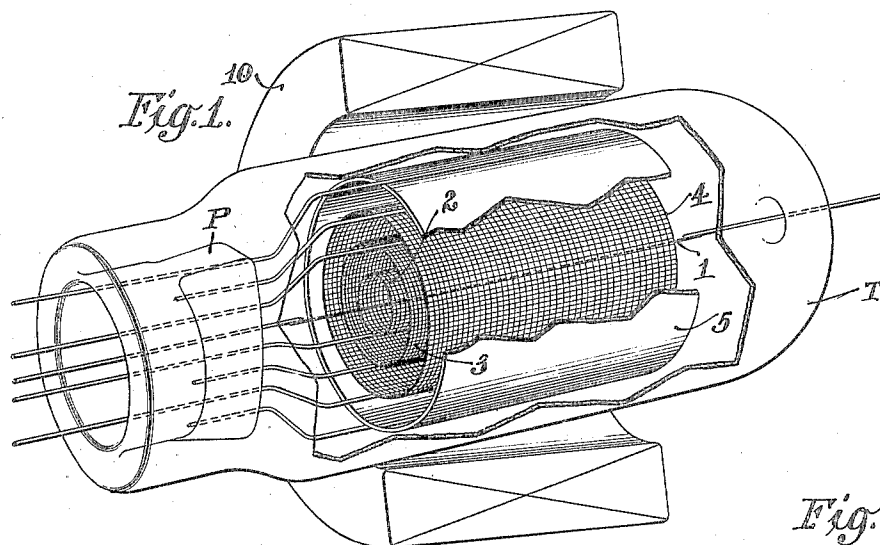
E. G. LINDER

2,228,895

ELECTRICAL TRANSLATING DEVICE

Filed Feb. 28, 1935

2 Sheets-Sheet 1



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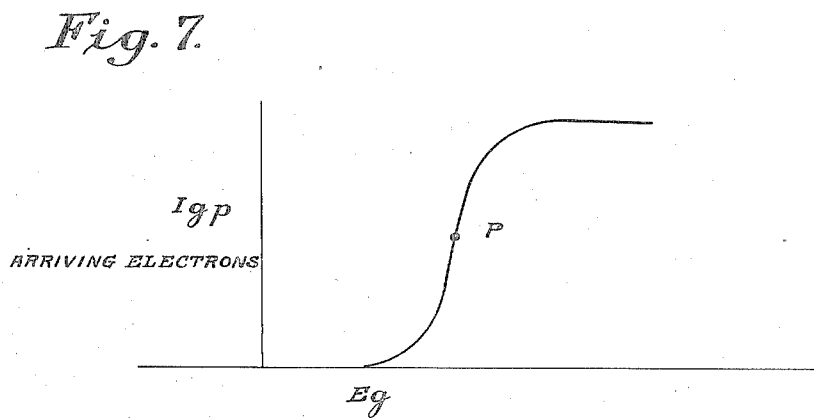
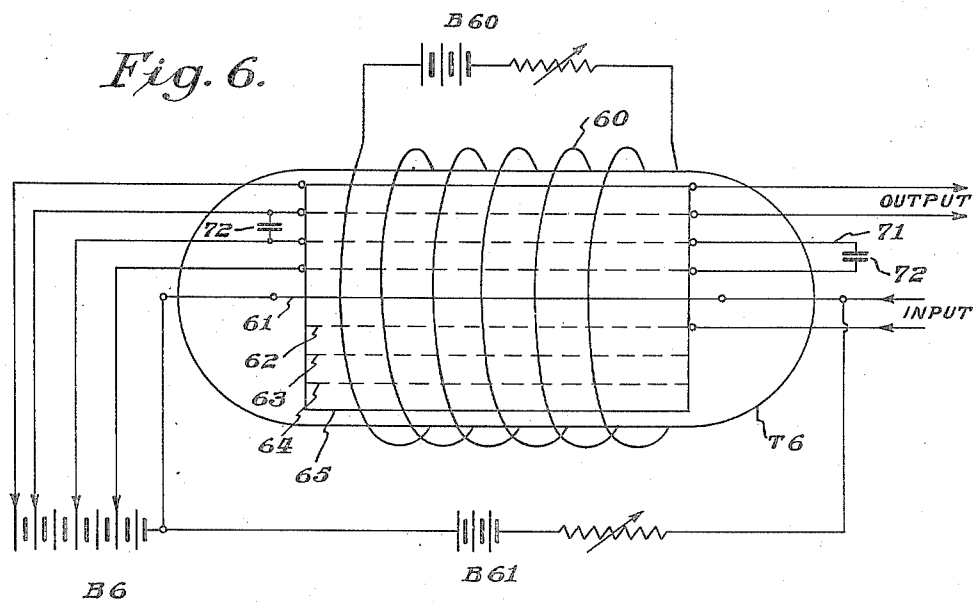
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ELECTRICAL TRANSLATING DEVICE

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2,228,895

ELECTRICAL TRANSLATING DEVICE

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Application February 28, 1935, Serial No. 8,646

1 Claim. (Cl. 179—171)

The present invention relates to improvements in electrical translating devices and methods of operating the same, particularly to so-called electron multipliers of the magnetron type disclosed in United States Patent 1,564,852 to Hull, issued December 8, 1925.

The basic invention disclosed in the above-mentioned patent resides in the construction and operation of a high vacuum tube having a negative resistance characteristic induced by electron multiplication. The patent discloses a three electrode device having the usual electron emitting cathode, an anode and a controlling grid enclosed in an evacuated receptacle. In accordance with the theory of operation, electrons emanating from the cathode are accelerated toward the plate and in their passage impinge upon the grid, releasing secondary or impact electrons which travel directly to the more positive anode. As a result, the current produced in the output circuit of the device may be several times the current produced therein by the primary electrons emitted by the cathode. When the device is employed as an amplifier this desired operating characteristic is utilized to increase the amplification obtained. The negative resistance characteristic, which in the Hull device is a usual concomitant to secondary emission from the single grid, may be utilized to generate oscillations.

The principal object of the present invention is to provide improvements in devices of this general type.

With this object in view, I have discovered that by providing one or more auxiliary electrodes, suitably arranged and energized, and by causing the primary electron stream and the several secondary electron streams, which are of successively increasing magnitude, to traverse predetermined paths each within a separate inter-electrode column, I am able to exceed the performance of the earlier tubes.

Other objects will be apparent and the principle and apparatus of the invention will be more readily understood by reference to the following description taken in connection with the accompanying drawings, wherein:

Figure 1 is a partly broken away perspective view disclosing the complete assembly of a thermionic electron multiplier within the invention,

Fig. 2 is a diagrammatic end view of the tube of Fig. 1 with several electron paths plotted thereon to visually indicate the principle of the device,

Fig. 3 represents diagrammatically the device

and circuits therefor, adapted for use as an oscillator,

Fig. 4 is a view similar to that of Fig. 3 but shows the device adapted for use as an amplifier,

Fig. 5 is a diagrammatic view of a discharge tube within the invention employing a light-sensitive cathode, and circuit connections therefor,

Fig. 6 is a diagrammatic view of an electron tube within the invention and shows how the several grids may be tuned to compensate for electron transit time, and

Fig. 7 is a curve illustrative of certain electrical characteristics of the device of Fig. 6.

Referring now to Fig. 1, an enclosing highly evacuated receptacle or bulb is designated T. The bulb contains a press P above which are mounted the several electrode members supported in a suitable manner. The cathode or primary emitter 1, here shown as a filament extending along the longitudinal axis of the tube, has one terminal extending through a wall opposite the press P. A plurality of tubular electrodes 2, 3, 4 and 5 are mounted in surrounding relation to the cathode 1. The outermost electrode 5 is the anode; it is preferably formed of solid material, as shown. The intermediate grid electrodes 2, 3 and 4 are conveniently of wire cloth of suitable mesh; they may, however, consist of a plurality of wires or metallic strips all parallel to the cathode and without any cross wires. As will hereinafter more fully appear, these foraminous electrodes 2, 3 and 4 are sources of useful secondary or "impact" electrons and are, therefore, preferably formed of a substance having a relatively high secondary emissive characteristic e. g. caesium—caesium oxide—silver.

An external magnet preferably in the form of a solenoid 10 surrounds all these electrodes. In the embodiment of Fig. 1, coil 10 is shown tilted at an angle to the axis of symmetry of the tube. The coil is so disposed for a purpose explained in connection with Fig. 2.

The principle and operation of the tube of Fig. 1 will best be understood by reference to Fig. 2.

In the absence of any force tending to bend or otherwise distort the path of the negatively charged particles emanating from the filament 1, they will be drawn in a substantially straight line to the anode 5, which latter electrode may be assumed to be positively charged with respect to both the filament 1 and the auxiliary electrodes 2, 3 and 4. As the total area of the openings in the intervening meshed electrodes 2, 3 and 4 is usually substantially greater than the effective

area of the surrounding electrode wires, a great many of the electrons will, in the absence of a magnetic field, pass directly from the cathode through the openings without initiating any secondary emission whatsoever. This condition is indicated by the dotted line *a*. On the other hand, the electrons which do, by chance, strike one of the grids, say grid 4, will release secondary electrons from its surface which will likewise be drawn to the plate 5 as indicated by lines *b*.

As each impact will usually set free several secondary electrons, and as the number of electrons available adjacent the anode is a measure of the efficiency of the device, it will be apparent that the electrons which in their travel fail to impinge upon the secondary electrodes 2, 3 and 4 do not attain their maximum usefulness.

As previously set forth, it is a prime object of the invention to increase secondary or impact emission (and hence the efficiency of the device), and to this end electrons from the primary source 1 and from the secondary sources 2 and 3 are constrained to travel in curvilinear or arcuate paths within the column adjacent their point of generation until they have fulfilled their function, i. e. until they strike the next adjacent grid and each electron releases an additional number of electrons from the grid surface. Such a path is shown by lines *c*, *d*. The direction and contour of the electron trajectory is determined by a proper coordination of the direction and intensity of the magnetic field, the potential distribution among the several electrodes, and the spacing of the electrodes. With a magnetic field of proper intensity the curvilinear paths *c*, *d* will ordinarily be obtained with the solenoid positioned with its axis parallel to the axis of symmetry of the tube.

The outer circumference of paths *c* and *d* just touches grid 2 and the electron trajectory therefore is such that the electrons strike this grid at an oblique angle. Electrons which in their first cycle fail to strike the surface of grid 2 will continue to circumscribe similar paths until they too accomplish their function. Electrons emanating from the several secondarily emissive electrodes are similarly confined within their own respective inter-electrode columns.

Secondary electrons released by the impact of electrons from primary emitter 1 against grid 2 are drawn through the grid openings by the attraction exerted by electrode 3, which is maintained at a positive potential with respect to grid 2. These electrons are shown traveling in paths *e*, *f*, in column 2—3.

The secondary electrons released in column 2—3, by the first family of secondary electrons are in like manner drawn through grid 3 by the forces created by the relative potentials of grids 3 and 4, travel in paths *g*, *h*, and release additional electrons in the column between the grids. These electrons 3—4 are in turn drawn through grid 4 by the more positive potential on plate 5. The curvilinear electron paths in space between the grid 4 and anode 5 are designated *i*, *j*.

It will be apparent that since electrons from primary source 1 and from secondary sources 2, 3 and 4 each release several additional electrons that the total quantity available adjacent the anode will be a rather enormous multiple of the number emanating from the cathode alone. All of these electrons may be utilized in appropriate circuits. However, it is not always necessary or desirable to operate the device at maxi-

imum efficiency and, in accordance with the invention, I find it practical to ensure that electrons from at least one of the sources of emission are directed through the orifices in certain of the grids without impinging thereagainst, so that the number of electrons available adjacent the anode, and hence the efficiency of the device, is less than it would be if these electrons had impinged against the surface of said grids.

One such tortuous electron path is indicated by dotted lines *m*, *n* in Fig. 2, where a substantial percentage of the electrons from cathode 1 are indicated as "skipping" grid 2 and impinging against grid 3. A number of the secondary electrons so released, in turn "skip" grid 4 and pass directly to the anode; the efficiency of the device is, under the circumstance, substantially less than "normal."

The skipping action above described may be accomplished either by tilting the coil 10, as indicated in Fig. 1, at an angle other than normal to the axis of symmetry, or by altering the intensity of the magnetic field.

The current through the device may be modulated either by superimposing the modulating potentials upon the magnetic field, or by means of a grid electrode, in which latter case the grid next adjacent the cathode is preferably selected. When so controlled this grid has a dual function, that is to say, it acts as both an electron secondary source and as a discharge controlling electrode. The controlled electron stream emanating from this grid 2 will impart its variations to the stream of electrons generated by impact with the next outer electrode, that is grid 3.

When suitably controlled, the device is capable of performing any of the usual functions of a discharge tube, e. g. as a detector, amplifier or generator of electrical oscillations.

In Fig. 3 the negative resistance characteristic of the outermost grid is utilized to generate oscillations. As in Figs. 1 and 2 the cathode is designated 1, the anode 5 and the intervening electrodes 2, 3 and 4 respectively. The solenoid surrounding the tube is 10; it is shown energized by a constant source of potential B_1 . A rheostat B_1 is provided in circuit with battery B_1 for regulating the intensity of the magnetic field generated by coil 10. Heating current for filament 1 is derived from source B_2 . The outer cylindrical electrode or plate 5 is connected to a high potential point on source B_3 ; grids 2, 3 and 4 are connected to points on the same source, each less positive than the electrode next remote from anode 5. The L—C circuit determining the frequency of the oscillations generated is preferably connected between the outermost grid 4, and through source B_3 to plate 5, the feed-back circuit is preferably from plate 5 through condenser C_1 to the first grid 2.

Fig. 4 shows the device of the present invention connected for use as an amplifier. In this arrangement the currents to be amplified are impressed between the cathode 1 and grid 2, and the amplified currents withdrawn by an output circuit of suitable design connected between the plate 5 and the outermost grid 4.

So far in this description reference has been made only to tubes employing thermionic cathodes as the primary source of electron emission. The invention, however, is not so limited. I have found it entirely practical to utilize cathodes of other types in which case it is necessary to provide

circuit arrangements for the tube somewhat different from those so far described.

Fig. 5 illustrates diagrammatically a tube T_1 employing a light-sensitive cathode 21 adapted to be actuated by a source of light focused thereon by a suitable lens system 26. Instead of impressing the current to be amplified directly between cathode and grid, as in Fig. 4, the light beam may be modulated by any suitable means, not shown. The rest of the circuit may be the same in all respects with that of Fig. 4, thus the solenoid magnet is designated 30, its energizing source B_{31} , the several grids 22, 23 and 24, and the plate 25 are energized by B_{33} , and the output circuit is connected to the plate 25 and the grid 24 next adjacent thereto. If desired, the light-sensitive cathode 21 may be positioned as the outermost electrode, in which case the anode will be the central or axial element.

In designing the tube for a specific purpose particularly in connection with high frequency currents care should be exercised in determining the electrical and mechanical constants of the tube and associated circuits. For use in connection with waves of high or ultra-high frequencies I may employ a tube having a plurality of flat parallel electrodes, instead of concentric tubular electrodes as in Fig. 1. Regardless of the particular construction of the tube employed for short waves, I prefer to tune the several grid circuits to resonance to ensure that electron transit time is some multiple of a whole period of the resonant oscillation.

A suitable tuning arrangement is illustrated in Fig. 6. The tube is designated T_6 , the magnet is 60, the cathode is 61, the grids 62, 63 and 64 respectively, and the anode is 65. All of these electrodes are shown energized by appropriate direct current sources B_6 , B_{60} and B_{61} . As in Fig. 4, the signal input circuit is connected between the cathode and first grid and the output between the anode and its next adjacent grid. The input circuit may, however, be altered to include the cathode and any one of the grids, or it may be between selected of the grids; similarly, the output circuit may include a grid other than the grid next adjacent thereto and may, in fact, be connected to one of the grids in the input circuit. In Fig. 6, grid 62 is connected to grid 63 by a Lecher wire system or similar tuned arrangement 71-72, whereby it requires an odd number of half periods for a voltage pulse to travel from grid 62 to grid 63. If the Lecher wire system is used its length should be an odd number of quarter wave lengths. Each grid is connected to its adjacent grid in this manner, hence the alternating current potentials on adjacent grids will be 180° out of phase.

The magnetic field and the potential of each grid is so adjusted that it operates at point P (Fig. 7) on the curve formed by plotting impacting electron current, I_{gp} , against voltage E_g . As the potential of grid 62 becomes more positive P moves upward on the characteristic, simultaneously P for grid 63 moves downward since its voltage is 180° out of phase. This results in an increase of secondary emission from grid 62, and a decrease in secondary emission from grid 63. The other grids behave similarly. The large number of secondary electrons emitted from grid 62 when it is positive, reach grid 63 a half period later when it in turn becomes positive because of the phase relations in the connected resonant circuit. Thus there is a cumulative action, the secondary emission from grid 63 is augmented not only because point P moves upward, this half period later, but also because a greater than normal number of secondary electrons are arriving from the preceding grid. This action is repeated at each grid.

The amplification obtained with a tuned circuit of the type described is greater than in the untuned case, since in the untuned case point P remains stationary except for the control grid 62.

By the words "nonimpinging electrons" is meant: those electrons which in any given excursion fail to strike the electrode toward which they are initially directed.

As a number of possible embodiments may be made of the above invention, and as changes may be made in the embodiments set forth without departing from the spirit and scope of the invention, it is to be understood that the foregoing is to be interpreted as illustrative and not in a limiting sense, except as required by the appended claim and by the prior art.

What is claimed is:

Method of regulating the efficiency of an electron discharge tube having a cathode, a plurality of foraminous grids and an anode immersed in a magnetic field the lines of force of which are normally parallel to an axis of symmetry of said electrodes, the operation of the device being normally characterized by electron primary emission from said cathode and by impact electronic emission from each of said foraminous grids, which comprises altering the direction of said lines of force relative to said axis to direct electrons from one of said sources through the orifices in certain of said grids without impinging thereagainst whereby the number of electrons available adjacent the anode, and hence the efficiency of said device, is less than it would be if said electrons had impinged against said certain of said grids.

ERNEST G. LINDER.