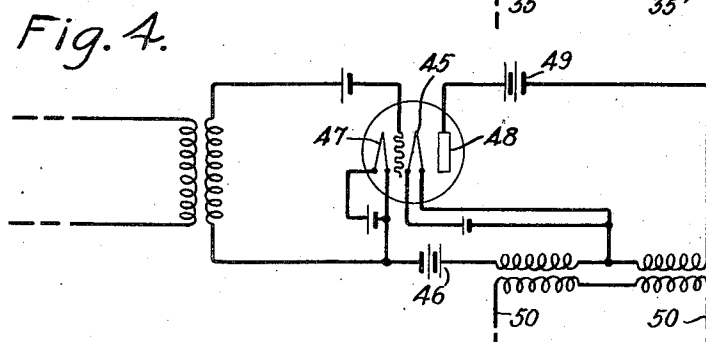
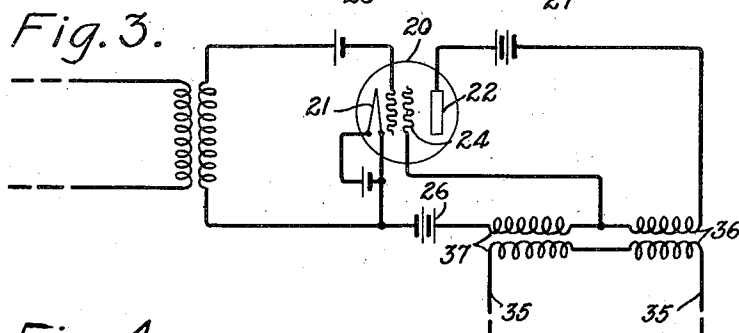
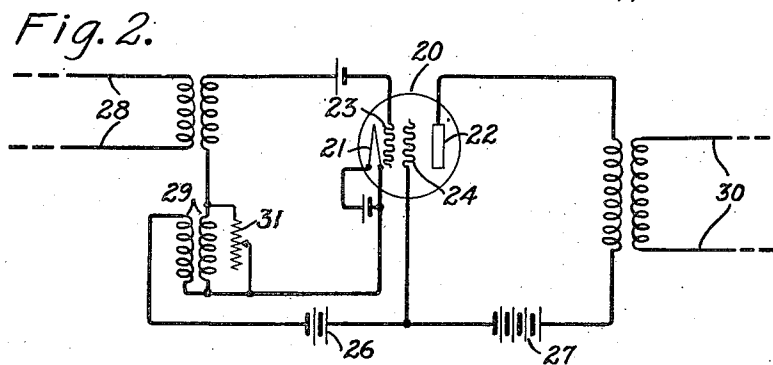
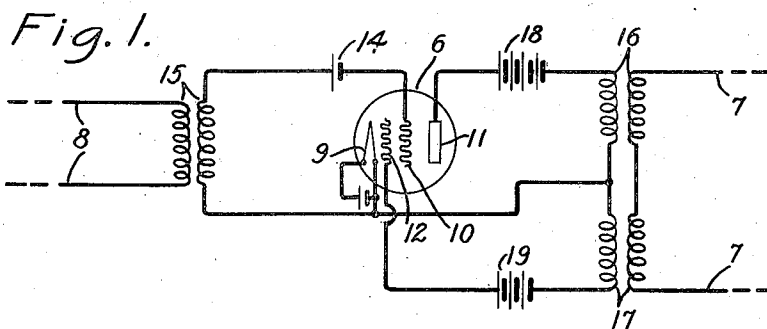


Jan. 1, 1924.

H. J. VAN DER BIJL
ELECTRON DISCHARGE DEVICE

1,479,779

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Inventor:
Hendrik J. van der Bijl.
by W. E. Beatty, Atty.

UNITED STATES PATENT OFFICE.

HENDRIK JOHANNES VAN DER BIJL, OF NEW YORK, N. Y., ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

ELECTRON-DISCHARGE DEVICE.

Application filed July 20, 1920. Serial No. 397,772.

To all whom it may concern:

Be it known that I, HENDRIK J. VAN DER BIJL, a subject of the King of Great Britain, residing at New York, in the county of New York, State of New York, have invented certain new and useful Improvements in Electron-Discharge Devices, of which the following is a full, clear, concise, and exact description.

This invention relates to circuit arrangements for electron discharge devices such as vacuum tube amplifiers, and more particularly it relates to such circuits wherein vacuum tubes are employed having more than three electrodes.

An object of this invention is to provide an improved method and means for increasing the amount of amplification obtainable from a vacuum tube. Other objects will be apparent from the explanation of this invention hereinafter given in detail.

In its specific aspect this invention relates to vacuum tubes of the type wherein the electron current between a cathode and an anode is controlled or varied by a third or control electrode, which may take the form of a grid interposed between the cathode and anode. Variations in the potential of the third electrode produce corresponding variations in the cathode-anode current, whereby the tube may, by connections well known in the art, be made to function as a detector, amplifier, repeater, modulator or generator of electric currents.

In accordance with this invention, two auxiliary electrodes are employed in addition to the cathode and anode of the vacuum tube. In one specific embodiment of this invention the two auxiliary electrodes consist of two grids interposed between the cathode and anode, while in another embodiment the two auxiliary electrodes consist of a grid and a heated filament. One of the grids may be employed as the usual control electrode for producing the desired variations in the space current, while the second auxiliary electrode, which, as above described, may be either a cold electrode such as a grid or a heated electrode such as a filament, is employed as an additional output circuit electrode. By employing the second auxiliary electrode as an auxiliary output electrode, the outgoing circuit from the tube may be made to be cumulatively responsive to variations in the anode-cath-

ode current as well as to the variations in the space current flowing to the auxiliary output electrode.

In the preferred embodiment of this invention, the second auxiliary electrode is located adjacent the cathode and is maintained at a positive potential with respect to the cathode. This arrangement greatly decreases the amount of space charge in the region adjacent the cathode, produced by the concentration of electrons around the cathode, and thereby produces a considerable decrease in the space resistance of the tube,—a result which is greatly to be desired on account of the fact that with a given set of conditions the lower the space resistance between the anode and cathode, the higher will be the amount of amplification obtained from the tube.

If desired, the potential difference between the cathode and the second auxiliary electrode may be made sufficient to cause secondary electron emission from the second auxiliary electrode so that the outgoing circuit from the tube may be made responsive to variations in the secondary electron emission, as well as to variations in the electron emission from the cathode.

This invention will be better understood by reference to the following detailed description taken in connection with the accompanying drawings, in which Figure 1 represents a circuit arrangement of this invention in which the variations in the space current flowing to the second auxiliary electrode and the anode are impressed on the outgoing circuit; Figure 2 is a modification thereof, in which the variations in the space current flowing to the second auxiliary electrode are impressed back on the input circuit of the tube whereby the tube may be employed as a feed back amplifier or a regenerator; Figure 3 illustrates a form of this invention in which the auxiliary electrode, employed as the control electrode, is located between the cathode and the auxiliary output circuit electrode; and Figure 4 is a modification of Figure 3 in which the second auxiliary electrode consists of a heated filament.

Figure 1 illustrates a form of this invention in which the vacuum tube 6 is employed as an amplifier or repeater for impressing on the outgoing line 7, amplified signals impressed on the tube from the incoming line 110

8. Vacuum tube 6, besides containing the usual cathode 9, control electrode 10 and anode 11, also contains an auxiliary electrode 12, which is employed as an auxiliary output circuit electrode. Incoming signals from line 8 are impressed on control electrode 10 by the input transformer 15. Variations in the space current flowing to anode 11 are impressed on outgoing line 7 by transformer 16, while variations in the space current flowing to the second auxiliary electrode 12 are impressed on the outgoing line by a transformer 17. It is obvious that transformers 16 and 17 may be replaced by one transformer having a plurality of windings. 18 is a source of voltage for maintaining a potential difference between the anode 11 and cathode 9, and 19 is a source of voltage for maintaining a potential difference between the second auxiliary electrode 12 and cathode 9. The potentials of these two sources should preferably be adjusted to maintain anode 11 at a positive potential with respect to the second auxiliary electrode 12. Control electrode 10 is normally maintained at a negative potential with respect to cathode 9 by means of a source of voltage 14.

With such a circuit arrangement, part of the electron current from cathode 9 will flow to the second auxiliary electrode 12 and the remainder will flow to the anode 11, the amount flowing in each case being dependent upon the potential of the control electrode 10. If, now, the potential of control electrode 10 should increase, for example, due to an impressed signal from line 8, the electron flow to the anode will be increased, while the electron flow to the auxiliary electrode 12 will be decreased. Since the current flow to the anode 11 and to the auxiliary electrode 12 are differentially related with respect to line 7, it follows that an increase in one of the currents and a decrease in the other of the currents will produce an additive or cumulative effect on line 7. Incoming signals impressed on control electrode 10 will therefore produce amplified variations in the current flowing in the primary windings of transformers 16 and 17, thereby producing corresponding changes in the current in outgoing circuit 7.

By employing an auxiliary output circuit electrode, such as 12, greater amplification is obtained than can be secured from a vacuum tube of the three electrode type. The high output circuit impedance of a vacuum tube of the three electrode type is due chiefly to the space charge produced by the concentration of electrons around the filament. By inserting an auxiliary electrode 12 adjacent the cathode and maintaining the auxiliary electrode at a positive potential with respect to the cathode, the potential difference between the two electrodes may be made such as to give practically a saturation current for the cathode, thereby preventing the undesired concentration of the electrons around the filament and causing a substantial decrease in the output impedance of the tube. Since it has been found that with a given set of conditions the lower the output circuit impedance the higher the amount of amplification obtained, it follows, as above stated, that a vacuum tube, such as tube 6, will impress on outgoing line 7 a more highly amplified form of the incoming signals from line 8 than it is possible to obtain by a vacuum tube of the three electrode type. If desired, the potential difference between the auxiliary electrode 12 and the cathode 9 may be made sufficient to cause auxiliary electrode 12 to emit secondary electrons which will flow to anode 11, since anode 11 is maintained at a positive potential with respect to electrode 12. Under such conditions, signals impressed on control electrode 10 will produce variations in the primary electron current flowing to auxiliary electrode 12 and to anode 11 and will also produce similar variations in the secondary electron emission flowing to the anode 11. Outgoing line 7 will therefore be responsive to the variations in these three currents.

The values which batteries 18 and 19 should have depend upon several factors, chiefly upon the relative spacing of the electrodes and upon the fineness of the grid mesh. In one case where secondary electron emission was not desired and where grid 12 was closely adjacent the filament, satisfactory results were obtained when battery 19 was 10 volts and battery 18 was 50 volts or more. On other cases where secondary electron emission was desired battery 19 was given values between 20 and 100 volts, while battery 18 was assigned values in each case exceeding by 50 volts or more the voltage of battery 19.

Figure 2 illustrates how the electron current flowing to the second auxiliary electrode may be employed to impress potential variations back on the input circuit of the tube, whereby the tube may be employed as a feed back amplifier or a regenerator. Vacuum tube 20 is similar to the vacuum tube 6 of Figure 1 and comprises a cathode 21, anode 22, control electrode 23, and an auxiliary output circuit electrode 24. In Figure 2, however, the auxiliary output circuit electrode 24 is located between the control electrode and the anode instead of between the control electrode and the cathode, as in Figure 1. It is to be understood of course, that the arrangement of Figure 1 may, if desired, be employed as a feed back amplifier circuit similar to that shown in

Figure 2. Batteries 26 and 27 are employed for maintaining auxiliary electrode 24 and anode 22 at positive potentials with respect to the cathode. As in Figure 1, the potentials of these two batteries should be such as to make anode 22 positive with respect to auxiliary electrode 24.

Signal variations impressed on control electrode 23 from line 28 will cause corresponding variations in the space current flowing to the auxiliary electrode 24 and to the anode 22. The variations in the space current flowing to electrodes 22 and 24 by transformer 29 are impressed back on the input circuit of the tube, whereby still greater variations will be made in the space current flowing to anode 22 before being impressed on the outgoing line 30. In order to prevent tube 20 from singing, an adjustable resistance 31 is shunted around the secondary of transformer 29, whereby the energy fed back into the input circuit of the tube may be limited to such an amount that singing is prevented. It is apparent, however, that if it is desired to employ tube 20 as a generator of oscillations, resistance 31 may be made to have such a large value that the energy fed back is large enough to cause tube 20 to sing or produce oscillations.

The modification illustrated in Figure 3 is similar to that of Figure 2 except that the variations in the space current flowing to the auxiliary electrode 24 are impressed on the outgoing line 35, in addition to the variations produced in the space current flowing to the anode 22. Transformer 36 is employed for impressing on line 35 variations in the current flowing to anode 22, and transformer 37 is employed for impressing on line 35 variations in the space current flowing to auxiliary electrode 24. Outgoing line 35 is therefore cumulatively responsive to variations in the space current flowing to these two last-mentioned electrodes.

If desired secondary electron emission may be produced from auxiliary electrode 24 by making source of voltage 26 sufficiently large. As in Figure 1, variations in the amount of secondary emission will be impressed on the outgoing line.

In Figures 1, 2 and 3 the auxiliary output circuit electrode is shown to be in the form of a grid interposed between the anode and the cathode. In Figure 4, however, the auxiliary output circuit electrode is shown to be in the form of a heated electrode 45. Figure 4 is otherwise similar to Figure 3. If desired, the source of voltage 46, located between the second auxiliary electrode 45 and cathode 47, may be of such a value as to cause secondary electron emission from the electrode 45, due to the electron bombardment from cathode 47. Since anode 48,

by means of source of voltage 49, is maintained at a positive potential with respect to auxiliary electrode 45, this secondary electron emission will flow to the anode 48. Outgoing line 50 will therefore be responsive to the primary electron current flowing to auxiliary electrode 45 and to anode 48, and will also be responsive to variations in the secondary electron emission flowing to anode 48.

It is obvious that other modifications of this invention will be apparent to those skilled in the art without departing from the spirit of this invention as defined in the appended claims.

What is claimed is:

1. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, external circuit connections between said anode and cathode and between said cathode and said auxiliary electrode, means for establishing space current to said anode, means for establishing space current to said auxiliary electrode, a control member for controlling said space current, and means responsive to changes in the space current flowing to said anode and responsive to changes in the space current flowing to said auxiliary electrode produced by variations in the potential of said control member.

2. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, external circuit connections between said anode and cathode and between said cathode and said auxiliary electrode, means for maintaining said auxiliary electrode at a positive potential with respect to said cathode, whereby space current to said auxiliary electrode is established, means for maintaining said anode at a positive potential with respect to said auxiliary electrode, whereby space current to said anode is established, a control member for controlling said space current and means responsive to changes in the space current flowing to said anode and responsive to changes in the space current flowing to said auxiliary electrode produced by variations in the potential of said control member.

3. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, external circuit connections between said anode and cathode and between said cathode and auxiliary electrode, means for establishing a flow of direct current to said anode and to said auxiliary electrode, said anode being maintained at a positive potential with respect to said auxiliary electrode, a control member for controlling said space current, and an outgoing line responsive to variations in the space current flowing to said anode and to said auxiliary electrode produced by variations in the potential of said control member.

4. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, external circuit connections between said anode and said cathode and between said cathode and auxiliary electrode, means for establishing space current to said anode and to said auxiliary electrode, said anode being maintained at a different potential with respect to said auxiliary electrode, connections for impressing signaling currents upon said tube, and means responsive to changes in the space current flowing to said auxiliary electrode and to said anode produced by the impression of the signaling currents upon said tube.

5. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, external circuit connections between said anode and said cathode and between said cathode and auxiliary electrode, means for establishing space current to said anode and to said auxiliary electrode, a control member for controlling said space current, said anode being maintained at a different potential with respect to said auxiliary electrode, an outgoing line, and inductive means for impressing on said line changes in the space current flowing to said anode and to said auxiliary electrode.

6. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode, means for establishing space current to said anode and means for establishing space current to said auxiliary electrode, a control member for controlling the said space current, an electric circuit, and means for impressing on said circuit variations in the current flowing to said auxiliary electrode.

7. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode interposed between said anode and cathode, means for establishing a flow of direct current to said anode and to said auxiliary electrode, a control member for controlling said space current, an electric circuit, and means for impressing on said circuit variations in the current flowing to said auxiliary electrode.

8. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode, means for establishing space current to said anode, means for establishing space current to said auxiliary electrode, a control member for controlling said space current, an outgoing circuit, an electric circuit, and means for impressing upon one of said circuits variations in the current flowing to said anode and means for impressing upon one of said circuits variations in the current flowing to said auxiliary electrode.

9. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode interposed between said anode and cathode, means for establishing a flow of

direct current to said anode and to said auxiliary electrode, a control member for controlling said space current, an outgoing circuit, an electric circuit, means for impressing upon one of said circuits variations in the current flowing to said anode and means for impressing upon one of said circuits variations in the current flowing to said auxiliary electrode.

10. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, means for establishing space current to said anode and means for establishing space current to said auxiliary electrode, a control member for controlling said space current, connections between said anode, said cathode and said auxiliary electrode, an input circuit comprising said control member and said cathode, an outgoing circuit, means in said connections for impressing on one of said circuits variations in the current flowing to said anode and means for impressing on one of said circuits variations in the current flowing to said auxiliary electrode.

11. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, means for establishing space current to said anode and means for establishing space current to said auxiliary electrode, a control member for controlling said space current, an input circuit comprising said control member and said cathode, an output circuit comprising said cathode, said anode and said auxiliary electrode, an outgoing circuit, and means for impressing on said outgoing circuit variations in the current flowing to said auxiliary electrode and to said anode.

12. In an electric system, a vacuum tube having an anode, a cathode, and an auxiliary electrode interposed between said anode and said cathode, means for establishing a flow of direct current to said anode and to said auxiliary electrode, a control electrode interposed between said anode and cathode for controlling said space current, connections between said anode, said cathode and said auxiliary electrode, an input circuit comprising said cathode and said control electrode, an outgoing circuit, inductive means in said connections for impressing on one of said circuits variations in the current to said anode and inductive means in said connections for impressing on one of said circuits variations in the current to said auxiliary electrode.

13. In an electric system, a vacuum tube having an anode, a cathode and a plurality of grid electrodes, means for establishing a flow of direct current to said anode and to one of said grids, connections between said anode, cathode and said first grid, an input circuit comprising said cathode and a second of said grids, an outgoing circuit, means in said connections for impressing variations

in the current to said anode upon one of said circuits and means in said connections for impressing variations in the current to said first grid upon one of said circuits.

14. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode, and a control member, means for maintaining an average potential difference between said control member and said cathode, a source of voltage for establishing space current to said anode, a second source of voltage for establishing space current to said auxiliary electrode, an input circuit for said tube comprising said cathode and said control member, an outgoing circuit, means for impressing variations in the current to said anode on one of said circuits and means for impressing variations in the current to said auxiliary electrode on one of said circuits.

15. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode interposed between said anode and cathode, and a control member, means for establishing a flow of direct current to said auxiliary electrode and to said anode, an input circuit comprising said control member and said cathode, an incoming line, means for impressing signals from said line upon said control member whereby variations are produced in said space current, an outgoing circuit, means for impressing on one of said circuits variations in the current to said anode and for impressing on one of said circuits variations in the current to said auxiliary electrode.

16. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode and a control member, means for establishing space current to said auxiliary electrode and to said anode, means for maintaining a constant difference of potential between said anode and said auxiliary electrode, an input circuit comprising said control member and said cathode, an incoming line, means for impressing signals from said line on said control member whereby variations are produced in said space current, an outgoing circuit, means for impressing upon one of said circuits variations in the current to said anode and means for impressing upon one of said circuits variations in the current to said auxiliary electrode.

17. In an electric system, a vacuum tube having a heated cathode, an anode, an auxiliary electrode, and a control member, means between said cathode and said auxiliary electrode for producing secondary electron emission from said auxiliary electrode, connections whereby said secondary electron emission flows to said anode, an electric circuit, an outgoing circuit, means for impressing variations in the current flowing to said auxiliary electrode upon one of said circuits, and means for impressing variations

in the current flowing to said anode upon one of said circuits.

18. In an electric system, a vacuum tube having a heated cathode, an auxiliary electrode, an anode and a control member, a source of voltage between said cathode and auxiliary electrode for producing secondary electron emission from said auxiliary electrode, connections for causing said secondary electron emission to flow to said anode, an outgoing circuit, and means for impressing upon said outgoing circuit variations in the current flowing to said auxiliary electrode and to said anode.

19. In an electric system, a vacuum tube having a primary source of electrons, a source of secondary electron emission, a control member for controlling the intensity of the emission of said primary electrons and the secondary electrons, an electric circuit, an outgoing circuit, and means for impressing upon one of said circuits variations in the intensity of said primary electron emission and for impressing upon one of said circuits variations in the intensity of the emission of said secondary electrons.

20. In an electric system, a vacuum tube having a cathode, an anode, an auxiliary electrode, means for causing an electron flow from said cathode to said auxiliary electrode and for producing secondary emission of electrons from said auxiliary electrode, a control member for controlling said electron flow and said secondary electron emission, an electric circuit, an outgoing circuit, and connections for causing variations in said electron flow to said auxiliary electrode to be impressed upon one of said circuits and for causing variations in said secondary electron emission to be impressed upon one of said circuits.

21. The method of repeating alternating currents, which comprises producing a primary electron stream, producing a secondary electron stream therefrom, varying said streams in accordance with the alternating currents to be repeated and impressing said variations in both of said streams upon an outgoing line.

22. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode and a control member, an input circuit comprising said cathode and said control member, an output circuit comprising said cathode, said anode and said auxiliary electrode, means for maintaining said auxiliary electrode at such a potential difference with respect to said anode that said auxiliary electrode becomes a source of secondary electrons, means for maintaining said anode at a positive potential with respect to said auxiliary electrode whereby space current to said anode is produced by said secondary electron emission, an incoming line, means for impressing upon said

control member signals from said incoming line, an outgoing line, and means for impressing upon said line variations in the current flow to said auxiliary electrode and to said anode.

23. In an electric system, a vacuum tube having an anode, a cathode, an auxiliary electrode and a control member, means for normally maintaining said control member at a negative potential with respect to said cathode, a source of electromotive force between said anode and cathode, a source of electromotive force between said auxiliary electrode and cathode, said source between said auxiliary electrode and said cathode being sufficient to cause said auxiliary electrode to become a source of secondary electron emission, said anode being of such a potential with respect to said auxiliary electrode that said secondary electron emission flows to said anode, an incoming line, means for impressing upon said control member signals from said line, an outgoing line, and means for impressing upon said outgoing line variations in the current flow to said anode and to said auxiliary electrode.

24. In an electric system, a vacuum tube having a cathode, a control member and a plurality of output circuit electrodes, both of said output electrodes being located on the same side of said cathode, a divided output circuit for said tube, a source of current in said output circuit, means for impressing potential variations on said control member, and means whereby a change in the potential of said control member produces a change in the same sense in one branch of said output circuit and a change of the opposite sense in another branch of said output circuit, an outgoing circuit, and means for impressing said changes on said outgoing circuit.

25. In an electric system, a vacuum tube having an anode, a cathode, two gridlike electrodes interposed between said anode and said cathode, means for establishing space current to one of said grids and to said anode, means for impressing potential variations upon the second of said grids, a divided output circuit for said tube, and connections whereby a change in the potential of said second grid produces a change in the same sense in one branch of said output circuit and a change of the opposite in another branch of said output circuit, an outgoing line, and means for impressing upon said line variations in the current to said first grid and to said anode.

26. In an electric system, a vacuum tube

having a cathode, a control electrode and an auxiliary electrode, means for establishing a direct current flow to said auxiliary electrode, said auxiliary electrode being interposed between said cathode and said control electrode, an electric circuit, and means for impressing on said circuit variations in the current to said auxiliary electrode.

27. In an electric system, a vacuum tube having an anode, a cathode and an auxiliary electrode, means for establishing space current to said anode, means for establishing space current to said auxiliary electrode, a control member for controlling said space current, a plurality of circuits, means for impressing upon one of said circuits variations in the current flowing to said anode and means for impressing upon one of said circuits variations in the current flowing to said auxiliary electrode.

28. In an electric system, a vacuum tube having an anode, a cathode, a grid interposed between said anode and cathode, means for establishing space current to said anode, means for establishing space current to said grid, a control member for controlling said space current, and means for utilizing the variations in the current to said grid.

29. In an electric system, a vacuum tube having an anode, a cathode, and an auxiliary electrode, means for establishing space current to said anode, means for establishing space current to said auxiliary electrode, a control member for controlling said space current, and means for utilizing the variations in the current to said auxiliary electrode.

30. In an electric system, an incoming line, an outgoing line, a vacuum tube for impressing on said outgoing line currents substantially of the same wave form as those received by said tube from said incoming line, said tube comprising a heated cathode, an auxiliary electrode, an anode, and a control member, means for maintaining said control member at a negative potential to said cathode, a source of voltage between said cathode and auxiliary electrode for producing secondary electrons from said auxiliary electrodes, connections for causing a current due to said secondary electrons to flow to said anode, and means for impressing on said outgoing line variations in the current to said anode.

In witness whereof, I hereunto subscribe my name this 13th day of July A. D., 1920.

HENDRIK JOHANNES van der BIJL.