Jan. 25, 1938. P. M. HAFFCKE 2,106,172

VACUUM TUBE

Filed July 30, 1936 4 Sheets-Sheet 1

Fig. 1

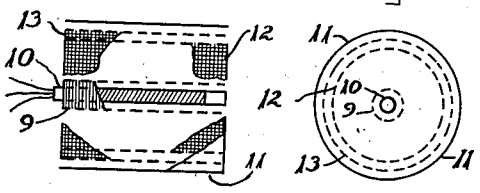
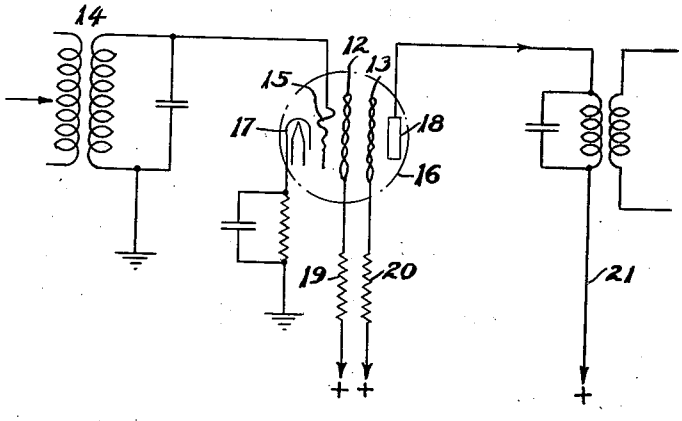


Fig. 1a

Fig. 2



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Filed July 30, 1936 4 Sheets-Sheet 2

Fig. 3

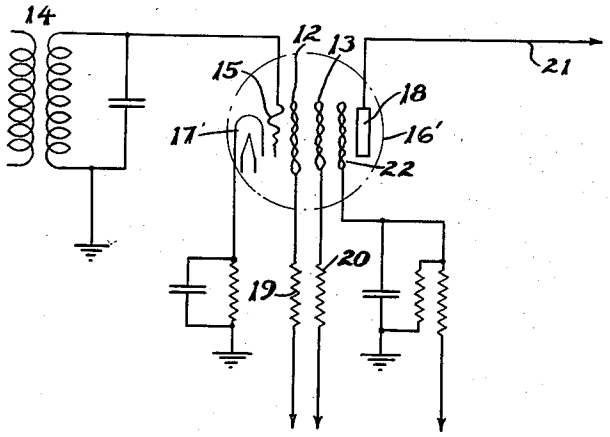


Fig. 4

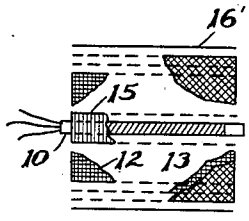
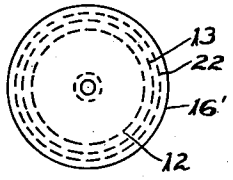


Fig. 4a



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Jan. 25, 1938. P. M. HAFFCKE 2,106,172

VACUUM TUBE

Filed July 30, 1936 4 Sheets-Sheet 3

Fig. 5

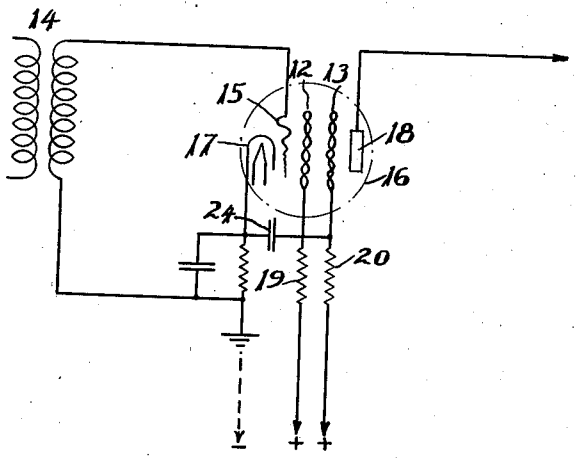
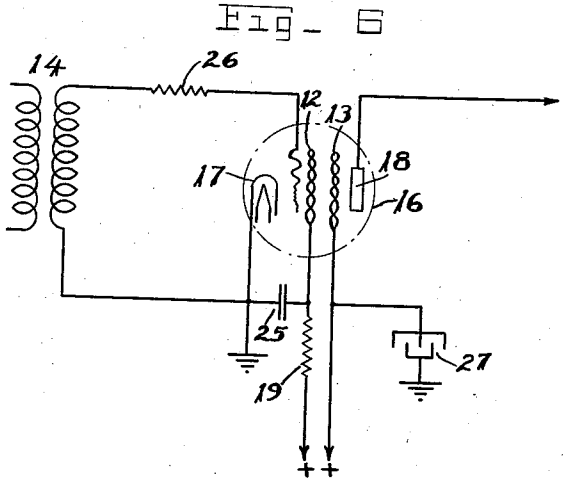


Fig. 6



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Jan. 25, 1938. P. M. HAFFCKE 2,106,172

VACUUM TUBE

Filed July 30, 1936 4 Sheets-Sheet 4

Fig. 7

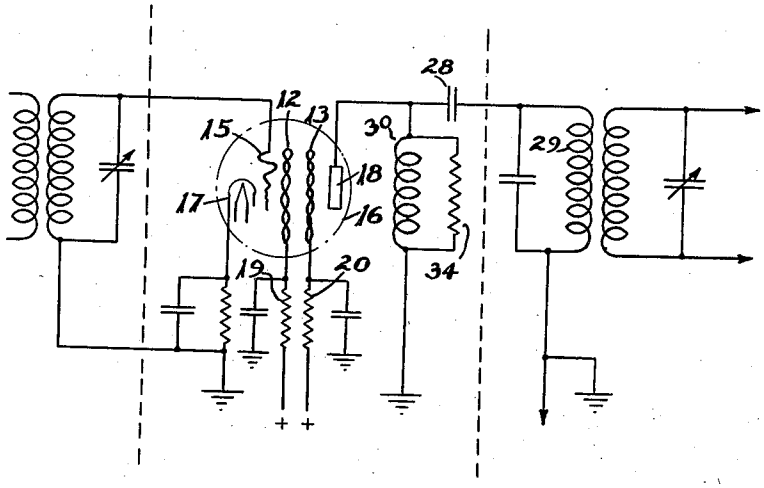
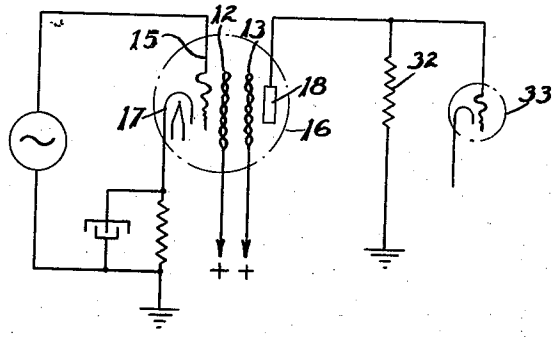


Fig. 8



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Patented Jan. 25, 1938 2,106,172

UNITED STATES PATENT OFFICE

2,106,172

VACUUM TUBE

Philip M. Haffcke, Washington, D. C.

Application July 30, 1936, Serial No. 93,464

27 Claims. (Cl. 250—27)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to a vacuum tube and the method of operating the same, and more particularly to a tube and method especially efficacious in suppressing the effects of static in a receiving system including such tube.

Among the several objects of this invention are:

To provide a tube that will function as an ordinary tube while the received energy has amplitudes within the normal operating range but will, in response to surges of static of greater than normal amplitude, exercise a control upon the electron stream within it to reduce the output of energy to a predetermined value;

To provide a tube that may be so operated that the output thereof will be reduced substantially to zero automatically when energy of excessive amplitudes is impressed thereon;

To provide a tube that will, under certain conditions of operation, generate harmonics that will be eliminated in the following tuned circuits for the duration of excessive amplitudes of received energy;

To provide in a vacuum tube means to absorb energy from the electron stream in the tube, which absorption is a function of the amplitude of the energy impressed upon the tube;

To provide a method of and means for automatically eliminating from a radio receiving system the effects of static.

In the drawings:

Fig. 1 is a side view, with parts broken away, of the electrode assembly of a tube according to my present invention;

Fig. 1*a* is an end elevation thereof;

Fig. 2 is a schematic diagram of a circuit that includes a tube having the electrode arrangement shown in Fig. 1;

Fig. 3 is a schematic diagram of a circuit having in it a tube like that in Fig. 1 modified by the addition of an electrostatic shielding electrode;

Figs. 4 and 4*a* are respectively a partially broken side view and an end elevation of the modified tube used in the circuit of Fig. 3;

Figs. 5 to 8 illustrate various circuit arrangements for utilizing the novel characteristics of my new tube.

The standard types of vacuum tubes are so constructed and operated that the major portion of the current flowing through the cathode is that of the anode or output circuit, whereas under the practice of the present invention the tube is so designed and connected in the circuit that the major portion of the current through the cathode is, under certain conditions, automatically derived from elements other than the anode for the duration of those conditions.

As disclosed in Figs. 1 and 1*a*, the signal input grid or control grid 9 is placed close to the cathode or electron emissive body 10 to exercise a high controlling factor upon the stream of electrons emitted from the cathode. Disposed between control grid 9 and plate 11, is a foraminous metallic interceptor grid 12, which may be of mesh or other construction, and a second like interceptor grid 13 is interposed between interceptor grid 12 and plate 11. As will hereinafter appear, the function of grids 12 and 13 is to intercept electrons from the electron stream to prevent their reaching plate 11, and the term "interceptor" is therefore applied to distinguish them from the control grid, electrostatic shielding grid and suppressor grid of the prior art.

Fig. 2 shows a tube and associated network incorporating my present invention. The inductive coupling 14 is connected to control grid 15 of tube 16 having the usual cathode 17 and anode 18 with interceptor grids 12 and 13 interposed between control 15 and plate 18. Interceptor grids 12 and 13 are connected through series resistances 19 and 20 to the same positive potential as is plate supply lead 21, these resistances having values of from 100,000 ohms up to several megohms, depending upon the use to which the tube 16 is put and the critical working limits desired.

The positive bias on grid 12 will attract electrons of the stream in the tube and a portion of them will be intercepted and absorbed while the remainder will pass through the mesh of the grid. Those that pass will be attracted by grid 13, where again a portion will be intercepted and those that pass through will reach the anode to furnish the output current. In the space between grids 12 and 13 there will be two forces acting upon the electrons—an accelerating force due to grid 13 and anode 18 and a decelerating force due to grid 12. The acceleration will ordinarily predominate but the deceleration will aid in the interception of electrons by grid 13 by detracting from the forces tending to move them to the plate. The same condition will obtain betweeen grid 13 and anode 18, and will tend to prevent secondary emission. The electrons intercepted by grids 12 and 13 will set up currrents through these grids and the cathode 17 and the potential drop due to these currents traversing resistances 19 and 20 will reduce by so much the

resultant voltage on the grids and thereby diminish the force acting to maintain the electron stream and also to decrease the absorption of electrons. It is apparent that there will arise a condition of equilibrium whereby the output of tube 16 will substantially follow the fluctuations of control grid 15 so long as the amplitudes are within the normal working range. However, as the voltage of grid 15 swings positive above the critical value the depression of the potentials on interceptor grids 12 and 13, by the flow of the increased currents through resistors 19 and 20, will cause the plate output to reach saturation quickly and the curve of plate current will level off and undergo no further increase of noteworthy magnitude even though the grid 15 is swung strongly positive, so that the E_g—I_p curve is very flat over a wide range. Moreover, by proper choice of resistor and voltage values this curve may be made to return to zero for strong positive swings of grid 15 due to static surges above normal amplitude, thereby substantially completely interrupting the output current. The resistances 19 and 20 are preferably of values comparable to the impedance in tube 16 between the respective grids 12 and 13 on the one hand and cathode 17 on the other, at no signal. Condensers should not be used in the circuits of the interceptor grids in order that the exterior circuits may be as nearly as possible replicas of those inside the tube and to avoid the introduction of time constants.

A receiving system that includes a stage using one of my novel tubes as above described gives very definitely improved performance over sets not having such a tube. For example, it has been used in the second detector position of a code receiver and gave a high percentage of readable copy from weak, distant stations, whereas a duplicate set having a standard screen grid tube in the second detector position was so blanketed by atmospherics that the signals were barely audible and the received signals were hopelessly unreadable by the operator. Tube 16 in the second detector position was followed by an audio tone filter to remove the harmonics generated thereby.

Where the internal capacity between plate 18 and interceptor grid 13 is detrimental, the modified tube 16' of Fig. 3 having an electrostatic shielding grid 22 is used. When this tube is in the radio frequency stages, grid 22 is grounded through bypass condenser 23.

Fig. 5 illustrates my novel tube serving as an output limiting device in a radio frequency stage. The grid 13 is grounded through condenser 24 and has the function of an electrostatic shielding grid. When so connected, grid 12 tends to offer a partial counterphase action in relation to the excitation from the input on control grid 15, when the input swing exceeds the critical value, and the change in the voltage on interceptor grid 12 resulting from the flow of current through resistor 19 compensates to a large degree for the change in potential on grid 15. This has a tendency to hold the response within fairly close limits.

Tube 16 may be employed as a delayed volume control, one method of which is shown in Fig. 6. The time values are determined by resistor 19 and condenser 25 and may be made of the order of 0.01 second if it precedes a "static suppressing" stage in broadcast reception. This will hold a program at substantially a constant amplitude and will aid the following "static suppressing" stage to operate most efficiently, the time constant being longer than the duration of the average crash of heavy static. As in Fig. 5, bias on the signal grid 15 may be used, but excellent results are also obtained on moderate to strong signals when a resistor 26 is connected between input 14 and grid 15. The resistor 26 shows a definite drop of voltage when excessive surges arrive and the grid current values are held down on the positive half of the cycle when the tube will rectify and pass considerable current in the grid input circuit. However, for most cases resistor 26 is not required as the impedance of the tube is much lowered during rectification and tends to load the input source heavily, a condition not detrimental to code reception, especially when the rectification does not occur while the grid is operating on the steep part of the E_g—I_p curve. Distortion in the output of the stage is harmonics, which are eliminated in the following tuned circuits. The condenser 27 is of relatively large capacity.

My novel tube may be successfully operated without applied plate voltage, the signal being induced upon the plate by the electrons that approach it with sufficient velocity to strike the plate and impart their charges thereto, and the energy thus transferred may be utilized for special purposes, such as high fidelity receivers.

A network so operating is shown in Fig. 7, the plate 18 being left floating without applied D. C. potential and the condenser 28 acting as a coupling between plate 18 and the following transformer primary 29. The momentum acquired by the electrons in the potential zones set up by grids 12 and 13 is sufficient to carry to the plate 18 those electrons that pass through both of the interceptor grids. In some cases, it is found advantageous to connect the radio frequency choke 30 between the plate 18 and ground, or a leak resistor 34 may be so connected as an alternative to using the choke 30.

Where direct connection to the grid of a following tube is used in high fidelity amplifiers, it is desirable to connect a leak resistor 32 to the lead between plate 18 and the following tube 33, as shown in Fig. 8. In this case the interceptor grids 12 and 13 are excited from a source of constant high potential without series resistors to give adequate acceleration to the electrons in order to progressively increase their velocity and effect a greater transfer of energy to plate 18. The resistor 32, which may be several megohms, prevents blocking of the tube, and may be replaced by either a tuned or an untuned impedance for special purposes.

In general, the higher the value of resistors 19 and 20, the lower the critical value of the input voltage swing that is required to cause the transconductance of the tube to fall to zero. Also, the lower the applied plate voltage, the closer the operating limits of signal input swing.

It is apparent from the foregoing that I have devised a vacuum tube whereby voltages may be applied to act upon the electron stream in a plurality of zones between the control grid and the output electrode which affords effective automatic control over the energy transmitted by the tube to prevent undesirable effects of static surges from appearing in the audible output of the receiver.

When distortion is of no importance and power output is desired, my novel tube may be built with a low mu grid and the geometry of the tube modi-

fied to correspond, and used in a transmitter to avoid overloading the following input circuits.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. A method of operating a vacuum tube, comprising applying a signal voltage to control an electron stream in said tube, intercepting from said stream at each of a plurality of spaced zones a portion of the electrons to set up a current through each zone separate from the current in the output signal channel, and utilizing the said currents to effect a decrease of potential in the respective zones, whereby increase of electron flow due to increase of signal voltage results in increase in said currents and greater decrease of potential in each said zone and a corresponding decrease in the proportion of the total stream passing all of said zones.

2. A method of operating a vacuum tube, comprising applying a signal voltage to control an electron stream in said tube, intercepting from said stream at each of a plurality of spaced zones a portion of the electrons to set up a current through each zone separate from the current in the output signal channel, and utilizing the said currents to effect a decrease of potential in the respective zones, whereby increase of electron flow due to increase of signal voltage results in increase in said currents and greater decrease of potential in each said zone and a corresponding decrease in the proportion of the total electron stream passing all of said zones until such condition is reached that increase in the signal voltage does not augment the stream passing all of said zones.

3. A method of operating a vacuum tube, comprising applying a signal voltage to control an electron stream in said tube, intercepting from said stream at each of a plurality of spaced zones a portion of the electrons to set up a current through each zone separate from the current in the output signal channel and utilizing the said currents to effect such decrease of potential in the respective zones that flow of electrons beyond said zones is prevented when said signal voltage is above a predetermined value.

4. A method of operating a vacuum tube having a cathode, an anode, a control grid, and a plurality of other electrode elements, which comprises so adjusting exterior circuit values affecting said tube that at least a major portion of the current through the cathode, deriving from the electron stream, passes through elements in said tube other than said anode when the input signal voltage is of greater than a predetermined value.

5. A method of operating a vacuum tube having at least one electrode element in addition to a cathode, an anode and a control grid, which comprises so adjusting exterior circuit values affecting said tube that at least a considerable portion of the current through the cathode, deriving from the electron stream, is diverted from the circuit that includes said anode when the input signal value exceeds a predetermined value.

6. A method of operating a vacuum tube having at least one electrode element in addition to a cathode, an anode and a control grid, which comprises so adjusting exterior circuit values affecting said tube that all of the current through the cathode, deriving from the electron stream, is diverted from the circuit that includes said anode when the input signal value exceeds a predetermined value.

7. An electron tube network, comprising a vacuum tube having a cathode, a control grid, an anode, and a plurality of mesh interceptor electrodes between said grid and said anode, an output circuit including said cathode and said anode, and means including an impedance connected to each of said interceptor electrodes to connect said interceptor electrodes into respective circuits with said cathode in parallel with said output circuit, said impedance and said anode being connected to a positive biasing potential.

8. An electron tube network, comprising a vacuum tube having a cathode, a control grid, an anode, and a plurality of interceptor electrodes between said grid and said anode, an output circuit including said cathode and said anode, and means including an impedance connected to each of said interceptor electrodes to connect said interceptor electrodes into respective circuits with said cathode in parallel with said output circuit, said impedance and said anode being connected to a positive biasing potential.

9. An electron tube network, comprising a vacuum tube having a cathode, a control grid, an anode, and a plurality of interceptor electrodes between said grid and said anode, an output circuit including said cathode and said anode, and means including an impedance comparable to the internal impedance of the tube at no signal connected to each of said interceptor electrodes to connect said interceptor electrodes into respective circuits with said cathode in parallel with said output circuit, said impedance and said anode being connected to a positive biasing potential.

10. An electron tube network, comprising a vacuum tube having a cathode, a control grid, an anode, and a plurality of interceptor electrodes between said grid and said anode, an output circuit including said cathode and said anode, means including an impedance comparable to the internal impedance of the tube at no signal connected to each of said interceptor electrodes to connect said interceptor electrodes into respective circuits with said cathode in parallel with said output circuit, said impedance and said anode being connected to a positive biasing potential, and an electrostatic shielding grid between said interceptor electrodes and said anode, said shielding grid having impressed thereon a constant potential.

11. An electron tube network, comprising a vacuum tube having a cathode, a control grid, an anode, and a plurality of interceptor electrodes between said grid and said anode, an output circuit including said cathode and said anode, means including an impedance comparable to the internal impedance of the tube at no signal connected to each of said interceptor electrodes to connect said interceptor electrodes into respective circuits with said cathode in parallel with said output circuit, said impedance and said anode being connected to a positive biasing potential, an electrostatic shielding grid between said interceptor electrodes and said anode, said shielding grid having impressed thereon a constant potential, and a condenser connecting said shielding grid to ground.

12. An electron tube network, comprising an electron tube having a cathode, a grid, an anode, an interceptor electrode, and an electrostatic shielding grid; an input circuit including said grid, said cathode, and means to limit the effect

upon said grid of a positive swing of energy in said input circuit, an impedance in series with said interceptor electrode, a condenser connected to said cathode and to a point between said interceptor electrode and said impedance, and a condenser connecting said shielding grid to ground; said electrode, said shielding grid, and said anode having positive potentials impressed thereon.

13. A method of operating a high vacuum electron discharge tube having a cathode, an anode, and a control grid between said cathode and said anode, which comprises applying accelerating forces in a plurality of zones between said grid and said anode to the electrons emitted by said cathode, the transfer of electrons to said anode being effected solely by the velocity of emission and the velocity imparted by said forces.

14. A method of operating an electron discharge device, which comprises controlling the electron stream therein by a signal input, and absorbing in a plurality of zones between the zone of said signal control and the output of the tube a considerable portion of the electrons in said stream, and applying in channels in parallel with the signal output channel, the currents derived from the absorbed electrons to effect further control of the electron stream.

15. A method of operating an electron discharge device, which comprises controlling the electron stream therein by a signal input, and absorbing in at least one zone between the zone of said signal control and the output of the tube a considerable portion of the electrons in said stream, and applying in channel in parallel with the signal output channel, the currents derived from the absorbed electrons to effect further control of the electron stream.

16. A method of operating an electron discharge device, which comprises controlling the electron stream therein by a signal input, and absorbing in at least one zone between the zone of said signal control and the output of the tube a considerable portion of the electrons in said stream, and applying the currents derived from the absorbed electrons to effect further control of the electron stream to reduce the output of the tube substantially to zero between certain predetermined values of the input signal.

17. A method of operating a high vacuum electron discharge tube, which comprises variably absorbing portions of the signal controlled electron stream in at least one zone to alter the velocity of the electrons in said stream, thereby maintaining the output energy of the tube substantially constant within predetermined limits, the said alteration of velocity being governed by the voltage momentarily applied where the absorption occurs, said momentarily applied voltage being a function of the number of electrons absorbed and the impedance offered to the flow of said electrons.

18. A method of operating an electron discharge tube, which comprises subjecting the signal controlled electron stream therein to combined accelerating and decelerating action in a plurality of zones between the zone of said signal control and the ouput of the tube with concomitant variable absorption of significant portions of the said stream in each of said plurality of zones, within predetermined limits of said signal control, said variable absorption and said acceleration and deceleration being functions of the respective currents through said zones due to the absorption and to the impedances through which said currents respectively pass, the currents due to such absorption being kept out of the signal output channel.

19. A vacuum tube comprising an envelope, a heated emitter, a grid having a controlling factor upon the electron stream, a signal output anode having higher internal impedance to the emitter than does any other electrode therein, and at least one electrode between said grid and said anode having a high factor of absorption for electrons approaching the same, the currents due to such absorption being kept out of the signal output channel.

20. A vacuum tube comprising an envelope, a heated emitter, a grid having a controlling factor upon the electron stream, an output anode having higher internal impedance to the emitter than does any other electrode therein, a first electrode between said grid and said anode having a high factor of absorption for electrons approaching it, and a second electrode between said first electrode, and said anode likewise having a high factor of absorption for electrons approaching it, the said electrodes mutually counteracting to a degree the action of each other upon the electron stream, the currents through said electrodes being kept out of the signal output channel.

21. A method of operating a vacuum tube having an emitter of electrons and an anode which comprises accelerating in a plurality of zones in said tube the electrons of the electron stream, and the potential on said anode being derived solely from the electron stream.

22. A method of operating a vacuum tube having an emitter of electrons and an anode which comprises accelerating in a plurality of zones in said tube the electrons of the electron stream, the electrons being carried to said anode solely by the momentum derived from said accelerating forces.

23. A method of operating a vacuum tube having an emitter of electrons, a control electrode and an anode, which comprises acting upon the electrons by drifting potentials in a plurality of zones between the control electrode and the anode, whereby the effect of the potential on the control grid and the effect of said drifting potentials are complementary when said signal control potential exceeds a predetermined value.

24. A method of operating a high vacuum electron discharge tube having a cathode, an anode, and a control grid between said cathode and said anode, which comprises applying automatically variable accelerating forces in a plurality of zones between said grid and said anode to the electrons emitted by said cathode, the transfer of electrons to said anode being effected solely by the velocity of emission and the velocity imparted by said forces.

25. A method of operating a high vacuum electron discharge tube having a cathode, an anode, and a control grid between said cathode and said anode, which comprises applying accelerating forces in a plurality of zones between said grid and said anode to the electrons emitted by said cathode, the transfer of electrons to said anode being effected principally by the velocity of emission and the velocity imparted by said forces.

26. A method of operating a high vacuum electron discharge tube having a cathode, an anode, and a control grid between said cathode and said anode, which comprises applying ac-

celerating forces in proportion to the input signal but without appreciable time lag in a plurality of zones between said grid and said anode to the electrons emitted by said cathode, the transfer of electrons to said anode being effected solely by the velocity of emission and the velocity imparted by said forces.

27. An electron tube network constituting a delayed volume control, comprising a tube having a cathode, a control grid, a first electrode, provided with spaces through which electrons may pass, a second electrode likewise provided with spaces, and an anode, in the order named, a resistive impedance connected in series with said control grid and said cathode in an input circuit, an impedance connected in series with the said first electrode, a condenser between said first electrode and said cathode, and a condenser of relatively large capacity connected between said second electrode and ground whereby an excessive positive swing of signal will cause a potential drop across said resistive impedance which drop is impressed on said grid and current is diverted through the input circuit by rectification, the time constant being fixed by said condenser and said impedance in series with said first electrode.

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