Jan. 30, 1934. G. HOLST ET AL 1,945,040

MEANS FOR AMPLIFYING ELECTRIC OSCILLATIONS

Filed Nov. 25, 1927

Fig. 1

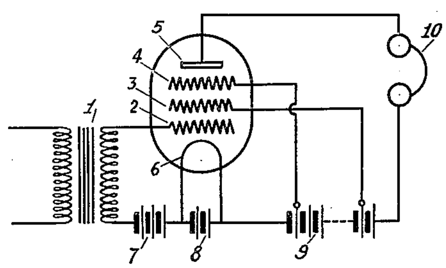


Fig. 2

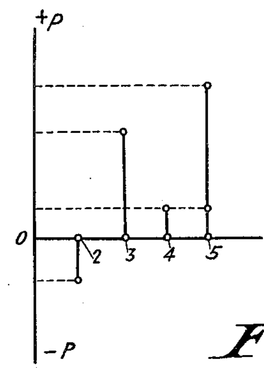


Fig. 3

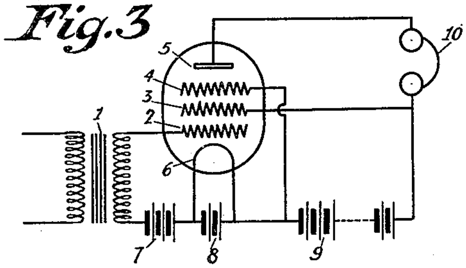


Fig. 4

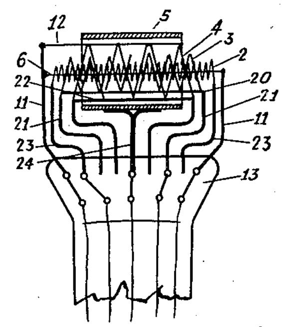


Fig. 5

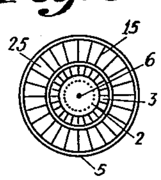


Fig. 6

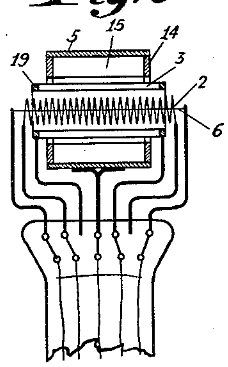


Fig. 7

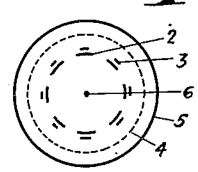


Fig. 8

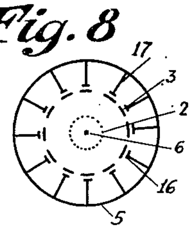
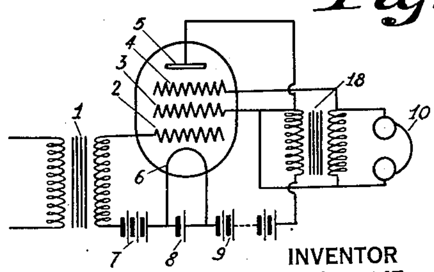


Fig. 9



INVENTOR
GILLES HOLST
B.D.H. TELLEGEN
BY Ira J. Adams
ATTORNEY

Patented Jan. 30, 1934 1,945,040

UNITED STATES PATENT OFFICE

1,945,040

MEANS FOR AMPLIFYING ELECTRIC OSCILLATIONS

Gilles Holst and Bernardus Dominicus Hubertus Tellegen, Eindhoven, Netherlands, assignors to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, a limited-liability company of the Netherlands

Application November 25, 1927, Serial No. 235,504, and in the Netherlands December 14, 1926

26 Claims. (Cl. 250—27)

This invention has reference to the amplification of electric oscillations by means of thermionic devices. It is known that when these devices are to be used for amplifying purposes it is desirable that the slope of the grid voltage-anode current characteristic should be steep. With the customary triodes the steepness of the static characteristic decreases to an appreciable extent when oscillations are impressed on the control grid because these oscillations are transferred to the anode amplified, but in opposite phase, so that when the grid potential increases the anode current will on the one hand increase under the influence of the said increasing potential but the current will on the other hand decrease under the influence of the falling anode potential caused by the increased current flow so that the resulting increase of the anode current is diminished. In order to obviate this disadvantage with the final amplifier a so-called screening grid may be used between the control grid and the anode, said screening grid being maintained at a constant and fairly high positive potential, whereby the possibility remains of applying an appreciable negative grid bias to the control grid, which is very desirable in connection with the comparatively large output energy of the final amplifier.

If, however, a so-called final valve is used in an amplifier the phenomenon occurs that when the anode potential decreases, the screening grid current increases at the expense of the anode current and that when this potential fall becomes so large that the anode potential is less than the potential of the screening grid, secondary electrons will pass from the anode to the screening grid while part of the primary electrons which reach a position between the screening grid and the anode will reverse their direction, and return to the screening grid. These phenomena result, some to a greater extent and others to a smaller extent, in the screening grid current increasing at the expense of the anode current so that the advantage incidental to the use of the screening grid is again largely lost.

The invention is based on the recognition of the just mentioned phenomena and consists therefore in providing means which ensure that when the anode potential falls the increase of the screening grid current at the expense of the anode current will be substantially avoided. At the present state of knowledge it is possible to suggest various means by which this object can be attained, said means being therefore also included in the invention. Some of these means, which on account of their simplicity and efficacious effect are particularly advisable, are the following:

1. The screening grid and the anode of the final amplifier have arranged between them an auxiliary grid kept at a constant potential which is not materially higher, preferably even lower, than the lowest instantaneous value of the anode potential.

2. On the said auxiliary grid are impressed potential variations which differ in phase by 180° from the variations of the anode potential.

3. A discharge tube, having at least two auxiliary electrodes between the cathode and the anode, is used as the final amplifier, the distance between the anode and the outermost auxiliary electrode being such that any electrons coming from the anode are prevented from passing to the said auxiliary electrode because of the space charge of the auxiliary electrode.

4. A discharge tube is used having at least three auxiliary electrodes between the cathode and the anode, the auxiliary electrode on the anode's side being electrically connected to the cathode. This electrical connection can be provided within the tube.

5. A discharge tube having at least two auxiliary electrodes between the cathode and the anode is used as the final amplifier, the anode comprising a number of partitions directed radially with respect to the cathode. The advantage of this construction will be more fully set out later.

In this construction of the discharge tube the auxiliary electrode nearest the anode is preferably made of a number of conductors positioned parallel to the cathode and so that each conductor is located in a plane with one of the anode partitions and the cathode.

6. A discharge tube, having at least two auxiliary electrodes between the cathode and the anode, is used as the final amplifier, and in which the auxiliary electrode nearest the cathode screens the next following auxiliary electrode against the electrons coming from the cathode. For this purpose the first-mentioned auxiliary electrode may be formed of a number of small flat ribbons. This construction will also be explained hereinafter.

7. A discharge tube having a screening grid, is used as the final amplifier, the said screening grid being in turn screened by an auxiliary grid in its proximity and nearer the anode, said auxiliary grid being electrically connected to the anode.

8. A final valve, having a screening grid,

should be used, the active elements of the said grid and those of the screening grid crossing each other at substantially right angles.

The invention will be more clearly understood by reference to the accompanying drawing in which some circuit arrangements and tube constructions according to the invention are diagrammatically illustrated by way of example. In the said drawing:

Figure 1 shows a circuit arrangement according to the invention in which the final amplifier is provided with an auxiliary grid between the screening grid and the plate, the said auxiliary grid being maintained at a constant positive potential.

Figure 2 is a diagram showing the potentials of the various electrodes of the final amplifier shown in Figure 1.

Figure 3 shows a circuit arrangement corresponding to that shown in Figure 1, the difference being inter alia that the auxiliary grid is electrically connected to the cathode.

Figures 4, 5, 6, 7 and 8 show diagrammatically various constructions of those discharge tubes which in accordance with the invention should be preferably used as the final amplifier.

Figure 9 shows a circuit arrangement in which the auxiliary grid has impressed on it alternating potentials which differ in phase by 180° from the potential variations at the anode.

Referring to Figure 1 the secondary of a transformer 1 has one end connected to the control grid 2 of the final valve and its other end is connected through a grid bias battery 7 to the negative end of the cathode 6. In addition the discharge tube comprises a screening grid 3 which is connected preferably through a path of negligible impedance to such a point of the high tension battery 9 that it is kept at a substantially constant high positive potential which, however, is slightly lower than the average potential of the anode 5. In the circuit of the anode 5 is included a reproducer 10 (telephone, loudspeaker, recording set or other load impedance). The cathode 6 is supplied from a battery 8 which may be connected across a variable resistor.

Between the screening grid 3 and the anode 5 is arranged an auxiliary grid 4 which is connected to such a point of the battery 9 that the potential of 4 is materially lower than that of the screening grid 3.

In the diagram shown in Figure 2, 3, 4 and 5 are graphically plotted so as to give a better idea of the distribution of the electric field within the discharge tube. The potential of the auxiliary grid 4 should be so little positive that it can be assumed with all reliability that the instantaneous anode tension never falls materially below the potential of 4, even not with maximum potential amplitudes on the control grid 2. Therefore any secondary electrons emitted by the anode are absolutely prevented from passing to the auxiliary grid 4 because the potential of 5 is so much greater than that of 4 that the strength of the field, due to the potentials, increases continuously and rapidly from grid 4 to anode 5.

The circuit arrangement may be slightly simplified by connecting the auxiliary grid 4 directly to one of the ends of the filamentary cathode 6, as shown in Figure 3. By said direct connection it is meant one that is non-inductive and having therefore negligible impedance. The auxiliary grid 4 consequently has a zero potential so that the same remarks made above in connection with the secondary electrons from the anode apply in this case. In addition it is possible to directly connect the grid 4 to the cathode within the valve as shown in Fig. 4, or, if desired, within the cap or base (not shown). Thus the number of the contact screws or pins to be fitted on the valve is decreased by one. A second difference between the structure of Figure 3 and that of Figure 1 is that the screening grid 3 is connected to the positive end of the battery 9 and thus receives the same direct current potential as the anode 5. The output of the final valve is thereby increased.

Figure 4 shows the principal elements of a tube constructed according to the invention in which the cathode and the anode have arranged between them three auxiliary electrodes, the outermost of which is electrically connected to the cathode within the tube envelope. In this construction the various electrodes are sealed in a well known manner, with some of the carriers serving also as leading-in wires, in the glass squeeze 13 of a stem only the uppermost part of which is shown. The glass bulb or envelope to which the stem is sealed is also omitted in the drawing.

The cathode 6 is formed by a taut wire or filament which is stretched between two carriers 11, the left hand one of which is lengthened upwardly and connected electrically at the top to a small metal beam 12 which in addition to the lower metal beam 22 serves to stiffen and support the outermost grid 4. This grid serves as an auxiliary grid in the sense of the invention and is arranged between the anode 5 and the screening grid 3. From Figure 4 of the drawing it will be observed that the turns of wire of the auxiliary grid 4 are more widely spaced than those of the screen grid 3; in other words, the former grid is of more open mesh than the latter grid. The latter or screening grid is supported in a well known manner by a small carrying beam 20 and by two carriers 21 sealed in the squeeze 13. The right hand carrier is led out through the squeeze. Finally the screening grid 3 and the cathode 6 have between them a control grid 2 which, similarly to the two grids 3 and 4, is shown as a helically wound wire attached on the lower side to a small carrying beam which is supported by means of two carriers 23 sealed in the squeeze or press 13. The control grid carrying beam which may be similar to those for the screen grid 3 and auxiliary grid 4 is not illustrated for the sake of simplicity. The left hand carrier of the two last mentioned carriers is led out through the squeeze or press. The anode 5 is supported in a well known manner by a stiff central carrier 24 which is sealed in the squeeze 13 and led out through this squeeze. There are therefore in the aggregate five leading-out wires, four of which may, for example, be connected to contact pins at the bottom of the cap or base, whereas the fifth one, for example the leading-out wire of the screening grid, may be led to a contact screw (not shown) on the cylindrical side wall of the same cap or base.

Figure 5 is a diagrammatical cross sectional view of the electrodes of a discharge tube of different construction. Again the cathode 6 is a stretched wire which is surrounded by a control grid 2 which may be of any construction. The control grid is surrounded by a screening grid 3 formed by a number of small metal ribbons parallel to the cathode 6 and arranged according to radial planes, said ribbons being united at their ends by metal rings. These rings are shown as members 19 in Figure 6, which shows a longitudinal section of such a tube construction. The anode 5 contains a number of radial partitions 15 which are in alignment with the ribbons 3 but which are much wider than the latter. These partitions are united at their ends by flat rings 14 to form a stiff aggregate. The intermediate space between the grid 3 and the anode 5 should preferably be small and also the intermediate spaces 25 between the partitions 15 are preferably kept small by choosing a large number of partitions. This arrangement has for its object to cause the electrons which have passed through the grid 3 and which show a tendency to return to the grid 3 instead of passing on to the anode, and which because of this tendency to return to grid 3, deviate laterally from their straight paths, to be intercepted by the partitions 15 and thereby reach the anode.

If in this construction the control grid 2 is formed by a helical coil or by a number of parallel rings, the elements of the grid 2 and 3 cross each other at substantially right angles. This will have a favourable effect since the electrons will consequently be less deviated from their straight paths than they would be in case the said elements were substantially parallel to each other.

Another construction which has also for its object to prevent the primary electrons which have traversed the screening grid from returning to the latter is shown in Figure 7. This figure is a diagrammatic cross-sectional view of the electrodes of a discharge tube according to the invention, the grid 2 of which is formed by a number of small flat ribbons parallel to the filament 6 and normal to the plane passing through their longitudinal axis and the cathode. On that side of the ribbons which is turned away from the cathode are the elements, for example wires, of the screening grid 3 which thus are almost completely screened by the ribbons 2. This has the effect that the electrons will deviate but little under the combined influence of the grids 2 and 3, and therefore the tendency to return to the grid 3 will be lessened. In addition, owing to the screening effect of the control grid 2 on the screening grid 3 there will be hardly any primary electrons that reach the screening grid directly. If in addition the screening grid 3 is surrounded by an auxiliary grid 4 which in the manner before described prevents the emission of secondary electrons from the plate 5 to the grid 3, all three prejudicial phenomena mentioned in the opening part of the present specification are consequently neutralized.

With the invention it is possible to use a final amplifier having a large power output and an internal resistance which is so large as compared with the impedance of the reproducer (loudspeaker or the like) that the current variations through the reproducer follow exactly the potential variations of the control grid of the final valve so that the reproduction is undistorted.

Referring to Figure 8 a third construction is shown in which the electrons are prevented from returning to the screening grid. For this purpose a grid 16 is provided immediately outside the screening grid and insulated therefrom and electrically connected to the anode 5 (this electrical connection is diagrammatically shown at 17) the elements of the said grid being in alignment with the elements of the screening grid. If now electrons change their direction of movement in the space between 16 and 5 the greater majority of these electrons will impinge on the outer surfaces of the element 16 and not on the grid 3.

Finally Figure 9 shows a circuit arrangement for a so-called "pentode" (five-electrode tube) in which the additional grid 4 arranged between the anode 5 and the screening grid 3 is connected to a point subjected to potential variations opposite in phase to those of the anode. For this purpose the plate circuit includes the primary of an output transformer 18, the secondary of which includes the reproducer 10. Now the auxiliary grid 4 is electrically connected to that end of the secondary the potential of which shows a phase difference of 180° with that of the anode. By a proper selection of the dimensions of the electrodes the ratio of transformation of transformer 18 the electrical field between the grid 3 and 4 will not be effected by potential fluctuations on the anode.

In summary, the invention therefore comprises means used either separately or in combination, with a final amplifier having a screening grid between the control grid and the anode by which the screening grid current is prevented entirely or partially from increasing at the expense of the anode current when the anode potential falls.

What we claim is:

1. An electron discharge device comprising an electron emitting cathode, an anode, a control grid and a screen grid interposed between cathode and anode, and means for producing a region of constant relatively low potential in the space between the screen grid and the anode for preventing the emission of secondary electrons from the anode.

2. An electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for maintaining the intermediate grid at a constant positive potential, and a direct non-inductive connection between the cathode and the grid nearest the anode.

3. An electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for maintaining the intermediate grid at a constant positive potential, and a direct connection between the cathode and the grid nearest the anode through a path of negligible impedance to signal frequencies.

4. An electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for maintaining the intermediate grid at a constant positive potential, said means including a connection through a path of negligible impedance to signal frequencies, and a direct connection between the cathode and the grid nearest the anode through a path of negligible impedance to signal frequencies.

5. An electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for connecting the intermediate grid to a source of constant positive potential of the same order of magnitude as that of said first mentioned source, means for impressing a negative potential on the grid nearest the cathode and a direct non-inductive connection between the grid nearest the anode and the cathode.

6. An electron discharge device having an elec-

tron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for connecting the intermediate grid to a source of constant positive potential of the same order of magnitude as that of said first mentioned source, means for impressing a negative potential on the grid nearest the cathode and a direct connection between the grid nearest the anode and the cathode through a path of negligible impedance to signal frequencies.

7. An electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for impressing on the intermediate grid through a path of negligible impedance to signal frequencies a constant positive potential of the same order of magnitude as that of said first mentioned source, means for impressing a negative potential on the grid nearest the cathode and a direct connection between the grid nearest the anode and the cathode.

8. An electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, means for connecting the anode to a source of positive potential, means for impressing on the intermediate grid through a path of negligible impedance to signal frequencies a constant positive potential of the same order of magnitude as that of said first mentioned source, means for impressing a negative potential on the grid nearest the cathode and a direct connection between the grid nearest the anode and the cathode, through a path of negligible impedance to signal frequencies.

9. An electron discharge device having an electron emitting cathode, an anode and three grids interposed between cathode and anode, means for connecting both the anode and the intermediate grid to a source of positive potential at points having substantially the same potential, and a direct connection within the device between one of the other of said grids and the cathode through a path of negligible impedance.

10. An electron discharge device having an electron emitting cathode, an anode, and control, screen and auxiliary electrodes interposed between cathode and anode in the order named, an input circuit connected to the control electrode, an output circuit including a source of potential having its positive terminal connected to the anode, a direct connection from a positive terminal of said potential source to said screen electrode and a direct connection within the device between the auxiliary electrode and the cathode.

11. The combination with an electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, of an input circuit connected to the grid nearest the cathode, an output circuit which includes a source of potential having its positive terminal connected to the anode through a load, a non-inductive connection from the grid nearest the anode to the cathode, and a non-inductive connection from a positive terminal of said source to the grid intermediate the first and second grids through a low impedance path.

12. The combination with an electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, of an input circuit connected to the grid nearest the cathode, an output circuit which includes a source of potential having its positive terminal connected to the anode through a load, a connection from the grid nearest the anode to the cathode through a low impedance path, and a non-inductive connection from a positive terminal of said source to the grid intermediate the first and second grids through a low impedance path.

13. The combination with an electron discharge device having an electron emitting cathode, an anode, and three grids interposed between cathode and anode, of an input circuit connected to the grid nearest the cathode, an output circuit which includes a source of potential having its positive terminal connected to the anode through a load, an electrical connection from the cathode to the grid nearest the anode, said connection including means for maintaining said grid positive with respect to the cathode, and a connection from a positive terminal of said source to the grid intermediate the first and second grids through a low impedance path.

14. An electron discharge device comprising an electron emitting cathode, an anode, a control grid and a screen grid interposed between cathode and anode, and means for effectively preventing the emission of secondary electrons comprising an auxiliary grid, maintained at a constant and relatively low potential, interposed in the space between the screen grid and the anode.

15. An electron discharge device comprising an electron emitting cathode, an anode, a control electrode and a screen electrode interposed between cathode and anode, and means for effectively suppressing the emission of secondary electrons from the anode, comprising a third electrode interposed in the space between the screen electrode and the anode and so connected to the cathode that a constant low potential is impressed on said third electrode.

16. An electron discharge device comprising an electron emitting cathode, an anode, a control grid and a screen grid interposed between cathode and anode, and means for effectively suppressing secondary electron emission between the screen grid and the anode comprising a third grid interposed in the space between screen grid and anode and provided with a potential lower than the potential corresponding to the potential that it would otherwise have at the point where said third grid is located.

17. An electron discharge device comprising an electron emitting cathode, an anode, a control grid and a screen grid interposed between cathode and anode, and means for effectively suppressing the emission of secondary electrons from the anode, comprising a third grid interposed in the space between the screen grid and the anode and so connected to the cathode within the device that a constant low potential is impressed on said third grid.

18. Electron discharge apparatus comprising a device having an electron emitting cathode, an anode, a control grid adjacent said cathode, a screen grid interposed between said control grid and said anode, a source of potential connected to the anode through a load impedance whereby said anode is subjected to varying potentials, and means for substantially preventing a flow of secondary electrons between said screen grid and said anode, comprising a grid interposed between said screen grid and said anode and having a

potential lower than the lowest instantaneous value of the anode potential.

19. Electron discharge apparatus comprising a device having an electron emitting cathode, an anode, a control grid adjacent said cathode, a screen grid interposed between said control grid and said anode, a source of potential connected to the anode through a load impedance whereby said anode is subjected to varying potentials, and means for substantially preventing a flow of secondary electrons between said screen grid and said anode, comprising an electrode positioned to produce between said anode and said screen grid a region having a fixed potential lower than the lowest potential reached by the anode during operation.

20. Electron discharge apparatus comprising a device having an electron emitting cathode, an anode, a control grid adjacent said cathode, a screen grid interposed between said control grid and said anode, a source of positive potential connected to the anode through a load impedance whereby said anode is subjected to varying potentials, said source of potential being connected also to the screen grid through a non-inductive path, and means for substantially preventing a flow of secondary electrons between said screen grid and said anode, comprising an electrode positioned to produce between said anode and said screen grid a region having a fixed potential lower than the lowest potential reached by the anode during operation.

21. A circuit arrangement for amplifying electric oscillations comprising an electron discharge tube having a cathode and an anode, a control grid adjacent said cathode, a screen grid adjacent the control grid, a source of relatively high potential connected to the anode through an impedance, means for keeping the screen grid at a constant relatively high potential, and means to substantially avoid an increase of screen grid current at the expense of the anode current when the anode potential falls below the potential of the screen grid as a result of the potential drop across the impedance connected to the anode, comprising an auxiliary grid adjacent the anode and means for keeping the auxiliary grid at a constant and relatively low potential.

22. The method of eliminating the effects of secondary electron emission between the screen grid and plate electrodes of a screen grid tube which consists in maintaining between said screen grid and said plate a region of constant space potential lower than the potential of either said screen grid or plate.

23. The method of eliminating the effects of secondary electron emission between the screen grid and plate electrodes of a screen grid tube which consists in maintaining between the screen grid and the plate a region of constant space potential lower than the potential corresponding to the potential that it would otherwise have at the point where said region is located.

24. The method of controlling a flow of electrons from an electron source to a cooperating anode which comprises varying the flow of electrons by impressing a variable potential upon a control electrode adjacent said electron source, accelerating the flow of electrons toward said anode by an accelerating electrode maintained at a positive potential and interposed between said electron source and said anode, and maintaining in the space between said accelerating electrode and said anode a region of positive potential sufficiently low so that the effects of secondary electron emission between said anode and said accelerating electrode are materially reduced.

25. The method of controlling a flow of electrons from an electron source to a cooperating anode which comprises varying the flow of electrons by impressing a variable potential upon a control electrode adjacent said electron source, accelerating the flow of electrons toward said anode by an accelerating electrode maintained at a positive potential and interposed between said electron source and said anode, and maintaining adjacent to and coextensive with said anode a space charge region at a fixed potential lower than the lowest instantaneous potential of the anode whereby the effects of secondary electron emission between anode and accelerating electrode are materially reduced.

26. An electron discharge device having an electron emitting cathode, an anode, and control, screen and auxiliary grids interposed between cathode and anode in the order named, means for impressing a positive potential upon said anode to permit the flow of electrons from cathode to anode, means directly connected to the screen grid for maintaining a region of constant high potential between control grid and anode, and a direct non-inductive connection between cathode and auxiliary grid for maintaining a region of constant low potential between the screen grid and anode.

GILLES HOLST.
BERNARDUS DOMINICUS HUBERTUS TELLEGEN.