

June 15, 1948.

P. W. STUTSMAN

2,443,205

GASEOUS DISCHARGE DEVICE

Filed May 3, 1945

3 Sheets-Sheet 1

FIG. 1.

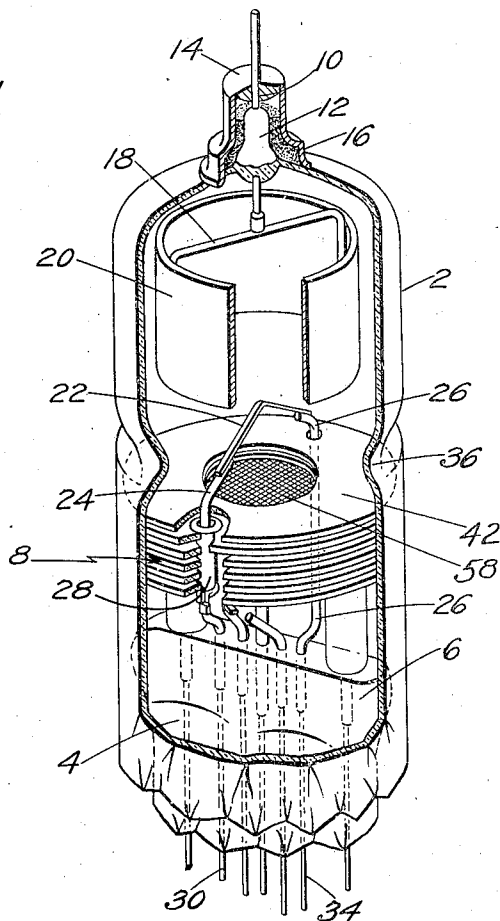
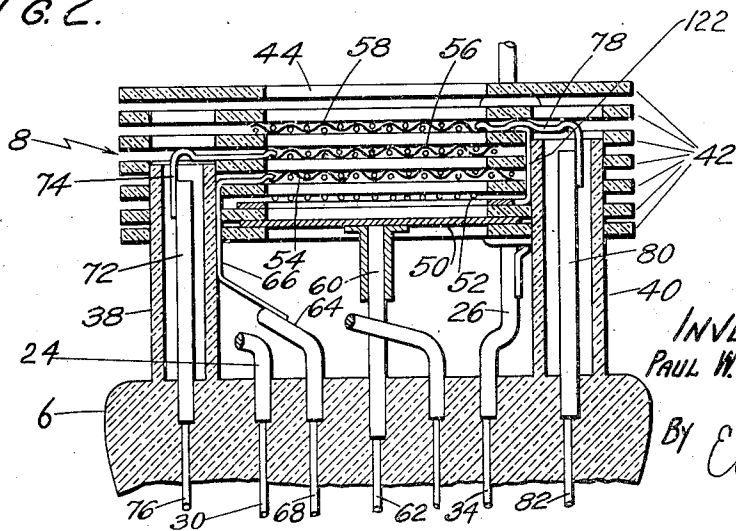


FIG. 2.



INVENTOR.
PAUL W. STUTSMAN,

By *Elmer J. Jones*
ATTY.

June 15, 1948.

P. W. STUTSMAN
GASEOUS DISCHARGE DEVICE

2,443,205

Filed May 3, 1945

3 Sheets-Sheet 2

FIG. 3.

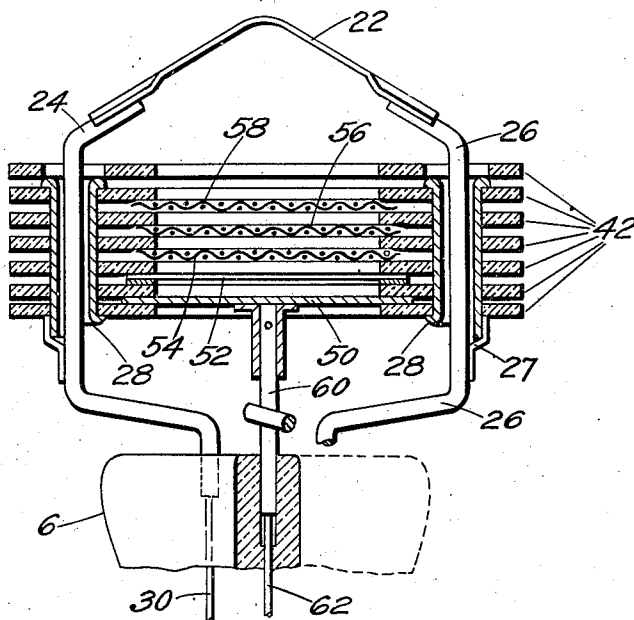
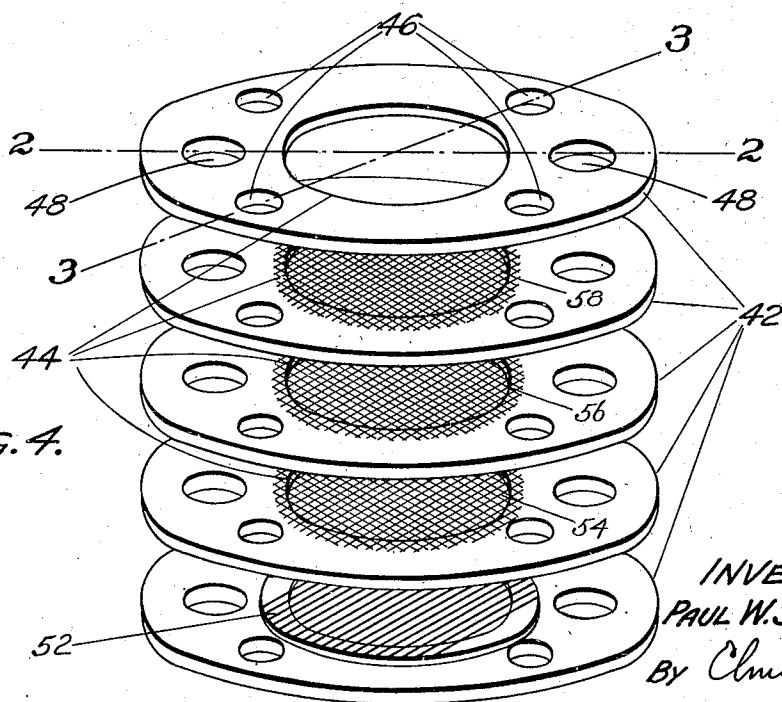


FIG. 4.



INVENTOR.
PAUL W. STUTSMAN,
BY *Chas. J. Jones*
ATTY.

June 15, 1948.

P. W. STUTSMAN

2,443,205

GASEOUS DISCHARGE DEVICE

Filed May 3, 1945

3 Sheets-Sheet 3

FIG. 5.

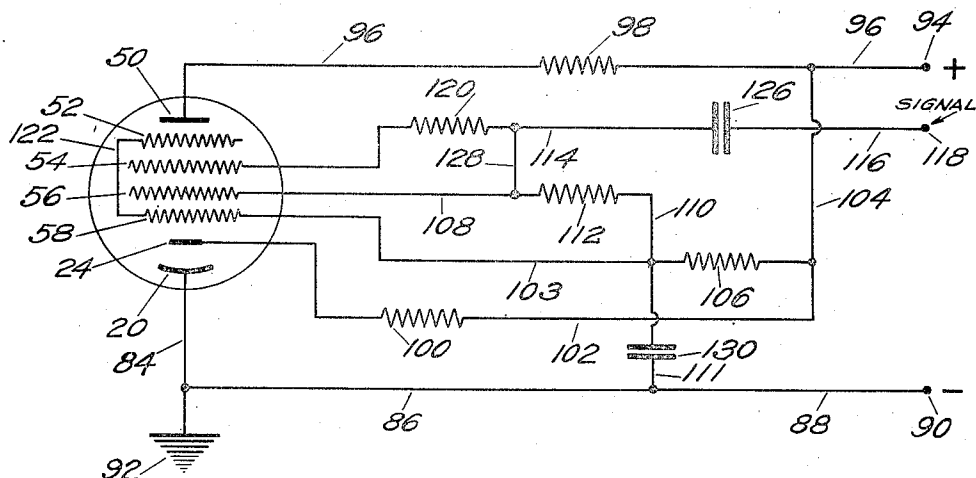
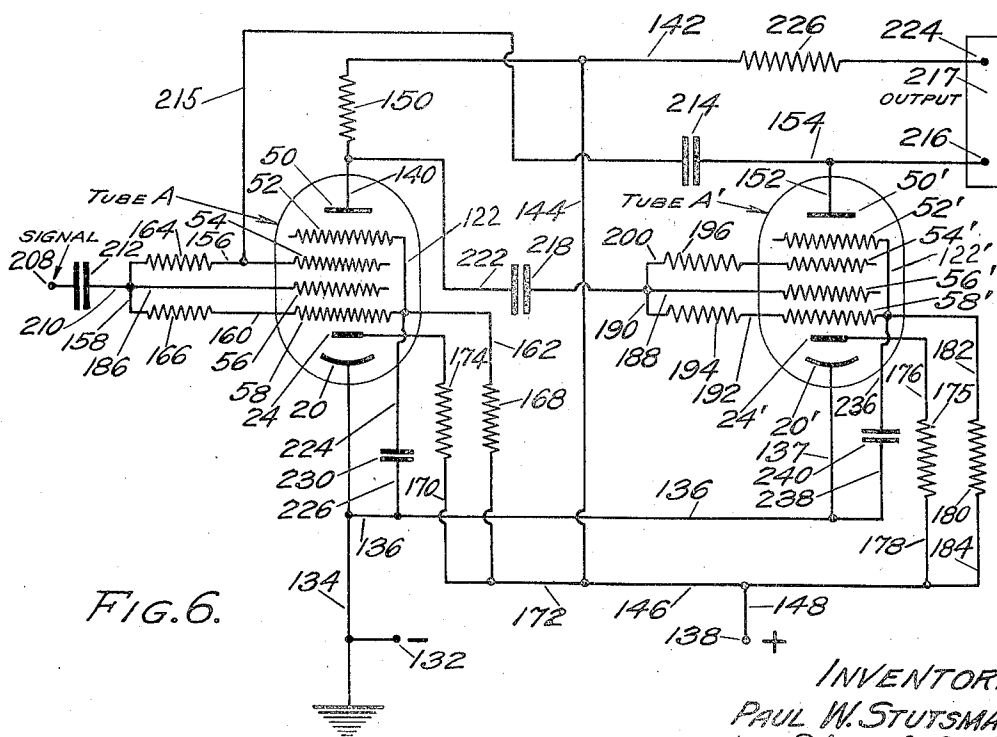


FIG. 6.

INVENTOR.
PAUL W. STUTSMAN
By *Clara J. Jones*
ATTY.

UNITED STATES PATENT OFFICE

2,443,205

GASEOUS DISCHARGE DEVICE

Paul W. Stutsman, Needham, Mass., assignor to
Raytheon Manufacturing Company, Newton,
Mass., a corporation of Delaware

Application May 3, 1945, Serial No. 591,778

13 Claims. (Cl. 250—27.5)

1

This invention relates to an electrical system utilizing a grid-controlled gaseous discharge tube and to a novel tube utilized in said system and to a circuit for said tube.

One of the objects of the present invention is to provide an improved system and tube of the type described.

Another object of the present invention is to provide a circuit for the improved tube of the type referred to.

A further object of the present invention is to provide a tube of the general type referred to in which the gain, that is to say the ratio of output to input, is greatly increased.

These and such other aims and objects of the present invention as may hereinafter appear will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawings, wherein:

Fig. 1 is a broken away perspective view of a tube incorporating an illustrative embodiment of the present invention;

Fig. 2 is a sectional view of the mount assembly illustrated in Fig. 1, taken on line 2—2 of Fig. 4;

Fig. 3 is a view similar to Fig. 2 taken on line 3—3 of Fig. 4;

Fig. 4 is an exploded perspective view of the mount assembly of Fig. 1;

Fig. 5 is a schematic diagram of an illustrative circuit including a tube of the type illustrated in Fig. 1; and

Fig. 6 is a schematic diagram of an illustrative circuit including two tubes of the type illustrated in Fig. 1, in cascade.

The tube incorporating the illustrative embodiment of the invention shown in Figs. 1 to 4 comprises an elongated envelope 2 provided with a reentrant stem 4 at the base thereof, the inner end of said stem being closed by a press 6 which carries the mount assembly 8. A conductor 10 (see Fig. 1) is sealed through a glass bead 12, hermetically secured in the top wall of said envelope 2, and is soldered to a metal contact cap 14 cemented exteriorly to the top of the envelope 2 at 16. The other end of said conductor 10 is connected to the middle of a conductor 18 having its ends welded to diametrically opposed points, upon the inner surface of a hollow cylindrical cathode 20 of the glow discharge type, which it supports. Said conductor 10 serves as a lead-in for the cathode 20, which is preferably open at both ends, it having been found that the cathode operates more efficiently if the opening through it is unobstructed. As clearly appears from the drawing, the area of the cylindrical walls

2

of the cathode, which are substantially parallel to the side walls of said envelope, is relatively large. The cathode is formed of sheet metal, preferably nickel, the nickel sheet being preferably stamped out and then bent into cylindrical form.

It has been found that the presence of thorium oxide, or other suitable non-gasifying radioactive substance, aids in producing the constant low starting voltage which is characteristic of the present tube. This action is believed to be due to the radio activity of these substances. Particles of the thorium oxide or other radioactive substance may be stamped into or otherwise imbedded in the surface of the cathode, but it is not necessary that said substance be on the cathode.

The cathode will preferably be oxidized to form thereon a coating of nickel oxide and is then coated with an alkaline earth metal or an alkali metal, hereinafter referred to as alkaline metals. I preferably use pure barium, which may be obtained by flashing a getter of the type known as "batalum" getter, within the tube.

Said getter (see Fig. 3) is shown at 22 and is conveniently connected at one end to the free end of an auxiliary electrode 24, serving as a stabilizing electrode, and at its other end to a conductor 26, extending through an electrically conductive eyelet 28, one of four which serve to hold the elements of the mount assembly together, said conductor being connected to a lead-in 34 (see Figs. 1 and 2) sealed through the press 6. Said stabilizing electrode 24 extends through a second eyelet of the aforesaid four eyelets 28, and is connected to a lead-in 30 sealed through said press 6.

Referring more particularly to Fig. 1, the top of said mount assembly 8 bears against a shoulder 36 formed in the side walls of the envelope 2, said shoulder thus imparting rigidity to the internal structure of the tube and cutting off any paths around the outside of said mount assembly, whereby the electron discharge is compelled to take place through openings provided in said mount assembly. Insulating sleeves 38 and 40 (see Fig. 2) fused in said press 6 support said mount assembly.

In accordance with the present invention said mount assembly 8 comprises a plurality of circular insulating washers 42, preferably of mica, each provided with a relatively large central opening 44 (see Fig. 4) for the passage of the electron discharge, in addition to four smaller openings 46 for the reception of the before mentioned four eyelets 28, and two suitable openings 48 for the reception of the upper portion of the previously mentioned insulating sleeves 38 and 40.

A flat disc-like anode 50 (see Fig. 2) is sandwiched between the two lower insulating washers, thus completely blocking the central openings 44 of said washers, but not the other openings in said washers. A suppressor or ion collector grid 52 of flat wire mesh rests upon the top washer of the two insulating washers between which the anode 50 is sandwiched, and above said suppressor grid are superposed in the order named, a screen grid 54, a control grid 56, and a cathanode grid 58, each of said grids being separated from the one above and the one below it by one of said insulating washers 42. Referring to Fig. 5 it will be noted that in accordance with the present invention the screen grid 54 is connected back to the control grid 56 through a suitable resistance. This increases the signal input impedance and enables the device to operate with a low power signal.

All of said grids completely cover the central openings 44 in said washers. The upper ends of the aforementioned eyelets 28 grip the insulating washer resting upon the cathanode grid 58, and the lower ends of said eyelets grip the bottom washer of said mount assembly so that the parts of the latter are securely clamped together. Two or more additional insulating washers, provided only with central openings for the passage of the electron-discharge, may be mounted loosely above the washer which rests upon the cathanode grid 58, and are held with their central openings in alignment with those of the other washers by the stabilizing electrode 24 and conductor 26 which pass through perforations in said additional washers. The stabilizing electrode 24 is mounted adjacent the cathode in the ionization space and serves to maintain an ionizing discharge to the cathode and thus to maintain ionization in the cathode-cathanode space. This prevents the occurrence of objectionable relaxation oscillations in the cathanode circuit by bringing the ignition potential of the cathanode close to the cathode drop. The suppressor or ion collector grid 52 has a negative potential, so that it tends to attract positive ions in their passage and prevent them from showering the control grid 56. The suppressor grid 52 consists of parallel wire strands, twenty wire strands to the square inch, the wire being preferably of tungsten and .0007 inch in diameter. The screen grid 54 will preferably be made of wire of a diameter of .005 inch and a mesh of 30 x 30 (900) openings to the square inch. This grid in picking up positive ions tends to be driven positive in proportion to the number of ions which in turn is proportional to the number of electrons flowing. This tends to amplify the plate swing and thus increase the amplification of the tube. The control grid which controls the electron flow from the cathode to the anode responsive to the input signal and the cathanode grid which draws an electronic discharge from the cathode and directs it toward the anode are preferably woven from wire of less than .005 inch and preferably .003 inch in diameter and have a mesh of 60 x 60 (3600) openings per square inch. It is also preferable that the openings of these two last-named grids coincide.

The anode 50 is connected to a rigid conductor 60 sealed in the press 6 and connected to a lead-in 62 (see Figs. 2 and 3). The suppressor grid 52 is connected to the cathanode 58 by a ribbon conductor 122. The screen grid 54 is connected to a conductor 64 by a ribbon 66, said conductor being sealed in said press 6 and connected to a

lead-in 68 also sealed in said press. The control grid 56 (see Fig. 2) is connected to a rigid conductor 72 by a ribbon 74, said conductor being sealed in said press 6 and connected to a lead-in 76 also sealed in said press. The cathanode 58 is connected by a ribbon 78 to a conductor 80 sealed in said press and connected to a lead-in 82 also sealed in the latter.

After the tube has been exhausted, a current is passed through the getter 22 from the lead-ins 34 and 30 (see Fig. 1), and heats the getter to a point at which barium is liberated to clean up residual gases and also to deposit on the surface of the cathode 20 for the purpose described above. Thereupon an inert ionizable gaseous atmosphere is introduced, said gaseous atmosphere preferably consisting of a rare gas, such as argon or krypton, but preferably xenon at a suitable pressure. The pressure is critical. I have found that a critical pressure region of about 300 to 1500 microns exists within which the tube will operate satisfactorily for the purposes herein indicated.

If the pressure is lower than 300 microns, the cathode drop tends to increase, and if the pressure is above 1500 microns, the mean free path of the electrons is too short to keep control of them in the embodiment described.

Referring to Fig. 5 and the circuit therein delineated, the cathode 20 is connected by conductors 84, 86, and 88 to the negative terminal 90 of a source of direct current which is grounded at 92, while the anode 50 is connected to the positive terminal 94 of said source by a conductor 96 through a load resistance 98 of 10 megohms. The stabilizing electrode 24 for maintaining an ionizing discharge to said cathode is adjacent said cathode and connected to said positive terminal 94 through a resistance 100 of 30 megohms by conductors 102, 104, and 96. The foraminous cathanode 58 is mounted adjacent said ionizing space and is connected by conductors 103, 104, and 96 through a series resistance 106 of 10 megohms with said positive terminal 94. The control grid 56 is located within the control section upon the opposite side of said cathanode from said ionizing space, and is connected through conductors 108, 128, 114, condenser 126 and conductor 116 to a signal input terminal 118. It is also connected to the cathanode 58 through conductors 108 and 110, resistance 112 of 20 megohms, and conductor 103. The cathanode 58 is connected back to the cathode 20 through conductor 103, condenser 130, and conductors 111, 86, and 84.

Said condenser 130 may have a value of 0.002 microfarad and functions as a cathanode bypass condenser to bypass any variable voltages between the cathode and the cathanode. The stabilizing electrode 24, by maintaining a continuous discharge to the cathode, eliminates any objectionable oscillations that might otherwise occur in this circuit due to the presence of said condenser 130. The screen grid 54 is connected through resistance 120 and conductors 128 and 108 to the control grid 56 which as already pointed out above increases the input impedance of the control grid. Condenser 126 functions as a grid coupling condenser, and may have a value of 0.002 microfarad. The suppressor grid 52 is adjacent the anode and connected back to the cathanode 58 by the conductor 122 as described above.

Two tubes constituted as herein described in accordance with my invention and connected in

cascade will materially increase the gain. Fig. 6 shows schematically two tubes A and A' in accordance with the present invention in cascade, and an illustrative circuit therefor. Referring to said Fig. 6, the cathode 20 of tube A is connected to the negative terminal 132 of a source of direct current by a conductor 134, the cathode 20' of tube A' being connected to said terminal by said conductor 134, conductor 136, and conductor 137. The anode 50 of tube A is connected to the positive terminal 138 of said source by conductors 140, 142, 144, 146, and 148 through a load resistance 150 of 10 megohms, and to the output terminal 224 by conductor 140, resistance 150, conductor 142, and a resistance 226 of 10 megohms. The anode 50' of tube A' is connected by conductors 152 and 154 with terminal 216 of the output device 217; thence through said output device to the other terminal 224 of said output device; and thence through the resistance 226 and conductors 142, 144, 146, and 148 to said positive terminal 138.

The stabilizing electrode 24 of tube A, for maintaining a discharge to the cathode of said tube, is connected to the positive terminal 138 of said source of direct current by conductors 170, 172, 146, and 148 through a resistance 174 of 30 megohms, and the stabilizing grid 24' of tube A', for maintaining a discharge to the cathode of tube A', is connected to said positive terminal 138 of said source by conductors 176, 178, 146, and 148 through a resistance 175 of 30 megohms.

The cathanode 58 of tube A, which draws a discharge from the cathode of said tube, is connected to said positive terminal 138 of said source of direct current through conductors 162, 172, 146 and 148, through a resistance 168 of 10 megohms; and the cathanode 58' of tube A' is connected to said terminal 138 through a resistance 180 of 10 megohms, similar to the aforesaid resistance 168, and conductors 182, 184, 146, and 148.

The control grid 56 of tube A is connected to the cathanode 58 of said tube by conductors 186, 158, and 160 through a resistance 166. Said control grid is also connected to the signal input terminal 208 through conductors 186, 210 and condenser 212. The cathanode is connected back to the cathode by conductor 224, condenser 230, and conductors 226, 136, and 134. The condenser 230, inserted between the conductors 224 and 226, is a bypass condenser to bypass any variable voltages between the cathode and the cathanode. Similarly the control grid 56' of tube A' is connected by conductors 188, 190, and 192 through a resistance 194 similar to the resistance 166 of tube A, to the cathanode 58' of said tube A'. said control grid 56' is supplied with the amplified output of tube A by conductor 222 connected to the anode lead 140 and thence through condenser 218 and conductor 188 to said control grid. The cathanode 58' is connected back to the cathode 20' by conductor 236, condenser 240, and conductors 238 and 137. The condenser 240 is a cathanode bypass condenser having the same function as the aforesaid condenser 230 and of the same capacity as the latter.

The screen grid 54 of tube A is connected to the control grid 56 of said tube through a resistance 164 of 10 megohms and the conductors 156 and 186, and similarly the screen grid 54' of tube A' is connected to the control grid 56' of said tube A' through resistance 196 of 10 megohms and conductors 200 and 188.

The suppressor grid 52 of tube A is connected

back to the cathanode 58 by conductor 122, and the suppressor grid 52' of tube A' is connected back to the cathanode 58' by conductor 122'. The above connections of suppressor grids markedly lower the signal input power required to operate the system.

All of the above-mentioned resistances have been selected of predetermined values to give the optimum results in tubes as herein constituted in accordance with the present invention.

The signal input is indicated at 208 and is led in directly to the control grid 56 of tube A by conductors 210 and 186 through a coupling condenser 212, which may be of the order of 0.002 microfarad, to arrest any direct current, while allowing alternating current to pass. After being amplified in tube A, voltage is led from said tube A through conductors 140, 222, and 188 directly to the control grid 56' of tube A', and said voltage is thus still further amplified by said tube A'. A coupling condenser 218 between conductors 22 and 188 exercises the same function as the aforesaid condenser 212 of tube A and may be of 0.002 microfarad.

After being thus twice amplified, first in tube A and then in tube A', a portion of the output is reconducted from tube A' back to tube A through conductors 152, 154, condenser 214, and conductor 215 to the screen grid 54 of tube A. Thus the signal is still further amplified and led back to tube A' through the connections previously described. The coupling condenser 214 functions similarly to the coupling condenser 218, and may be about 0.00005 microfarad.

It will thus be seen that the output is regeneratively amplified, which accounts in part for the remarkable gain obtained with the system of my invention. Two tubes in cascade as above described will produce a voltage gain of 20 at 1000 cycles and one of 50 at 100 cycles and at 180 volts.

I am aware that the present invention can be embodied in other specific forms without departing from the spirit or essential attributes thereof, and I therefore desire the present description to be considered in all respects as illustrative and not restrictive, reference being had to the appended claims rather than to the aforesaid description to indicate the scope of the invention.

What is claimed is:

1. An electrical-discharge tube containing an inert ionizable gas, a glow discharge cathode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode, and an anode adjacent said suppressor grid.

2. An electrical discharge tube containing xenon gas, a glow discharge cathode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode, and an anode adjacent said suppressor grid.

3. An electrical-discharge tube containing an inert ionizable gas, a glow discharge cathode, an

auxiliary electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected back to said control grid, and an anode adjacent said suppressor grid.

4. An electron-discharge tube containing an inert ionizable gas, a glow discharge cathode, an anode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, and four additional electrodes comprising a suppressor grid adjacent said anode, a screen grid, a control grid adjacent said screen grid, and a foraminous cathanode adjacent the space in which said ionizing discharge occurs, said control grid being on the opposite side of said cathanode from said ionizing discharge space, and a plurality of insulating washers, said anode and said four additional electrodes being superposed in the order named and separated one from another by at least one of said insulating washers, each of said washers being provided with a central opening, said openings being aligned with each other and with said anode and said four additional electrodes.

5. An electron-discharge tube containing an inert ionizable gas, a glow discharge cathode, an anode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, and four additional electrodes comprising a suppressor grid adjacent said anode, a screen grid, a control grid adjacent said screen grid and a foraminous cathanode adjacent the space in which said ionizing discharge occurs, said control grid being on the opposite side of said cathanode from said ionizing discharge space, said screen grid, control grid and cathanode consisting of a wire mesh and said suppressor grid consisting of parallel wire strands, and a plurality of insulating washers, said anode and said four additional electrodes being superposed in the order named and separated one from another by at least one of said insulating washers, each of said washers being provided with a central opening, said openings being aligned with each other and with said anode and said four additional electrodes.

6. An electron-discharge tube containing an inert ionizable gas, a glow discharge cathode, an anode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, and four additional electrodes comprising a suppressor grid adjacent said anode, a screen grid, a control grid adjacent said screen grid, and a foraminous cathanode adjacent the space in which said ionizing discharge occurs, said control grid being on the opposite side of said cathanode from said ionizing discharge space, and a plurality of insulating washers, said anode and said four additional electrodes being superposed in the order named and separated one from another by at least one of said insulating washers, each of said insulating washers being provided with a central opening, said openings being aligned with each other and with said anode and said additional electrodes, and clamping means to clamp said anode and said four additional electrodes and the intervening washers together to form there- of a unit.

7. An electron-discharge tube comprising an envelope provided with a press and containing an inert ionizable gas, a glow discharge cathode, a relatively flat anode, an auxiliary electrode for maintaining an ionizing discharge to said cath-

ode, and a mount assembly comprising a plurality of insulating washers and superposed upon one another in the order named, said relatively flat anode, and four additional electrodes, namely a suppressor grid, a screen grid, a control grid and a foraminous cathanode, each one sandwiched between two of said insulating washers, each of said washers being provided with a central opening, the openings in said washers being covered by said anode and said additional electrodes between them, extending through said mount assembly and headed upon the exterior surfaces of the two end washers of said mount assembly, and supporting means for said mount assembly, anchored in said press and in said mount assembly.

8. An electron-discharge tube, comprising an envelope provided with a press and containing an inert ionizable gas, a glow discharge cathode, a relatively flat anode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, and a mount assembly comprising a plurality of insulating washers and superposed upon one another in the order named, said relatively flat anode, and four additional electrodes, namely a suppressor grid, a screen grid, a control grid, and a foraminous cathanode, each one sandwiched between two of said insulating washers, each of said washers being provided with a central opening, said openings in said washers being covered by said anode and said additional electrodes between them, means for fastening said mount assembly together to form thereof a unit, and supports for said mount assembly anchored in said press and in said mount assembly.

9. An electrical-discharge tube comprising an inert ionizable gas, a glow discharge cathode, an auxiliary electrode for maintaining an ionizing discharge to said cathode adjacent the latter, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid in the opposite side of said cathanode from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode and back through a resistance to said control grid, and an anode adjacent said screen grid.

10. An electrical-discharge tube containing an inert ionizable gas under a pressure of from 300 to 1500 microns, a glow discharge cathode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode, and an anode adjacent said suppressor grid.

11. An electrical-discharge tube containing xenon gas under a pressure of from 300 to 1500 microns, a glow discharge cathode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode, and an anode adjacent said suppressor grid.

12. An electrical-discharge tube containing an inert ionizable gas under a pressure of 550 microns, a glow discharge cathode, an auxiliary

electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode from said ionizing discharge 5 space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode, and an anode adjacent said suppressor grid.

13. An electrical-discharge tube containing 10 xenon gas under a pressure of 550 microns, a glow discharge cathode, an auxiliary electrode for maintaining an ionizing discharge to said cathode, a foraminous cathanode adjacent the space in which said ionizing discharge occurs, a control grid on the opposite side of said cathanode 15 from said ionizing discharge space, a screen grid adjacent said control grid, a suppressor grid adjacent said screen grid and connected to said cathanode, and an anode adjacent said suppressor grid.

PAUL W. STUTSMAN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,145,735	Ainsworth	July 6, 1915
1,629,009	Snook	May 17, 1927
1,878,341	Spencer	Sept. 20, 1932
2,051,609	Langmuir	Aug. 18, 1936
2,097,157	Jameson	Oct. 26, 1937
2,106,847	Kniepkamp	Feb. 1, 1938
2,229,138	Schwartz	Jan. 21, 1941
2,238,595	McNall	Apr. 15, 1941
2,243,121	Preisman	May 27, 1941
2,275,023	White	Mar. 3, 1942

FOREIGN PATENTS

Number	Country	Date
413,302	Great Britain	July 9, 1934