June 4, 1940. B. BERGHAUS ET AL 2,203,452

ELECTRONIC DISCHARGE TUBE

Filed Dec. 17, 1938 6 Sheets-Sheet 1

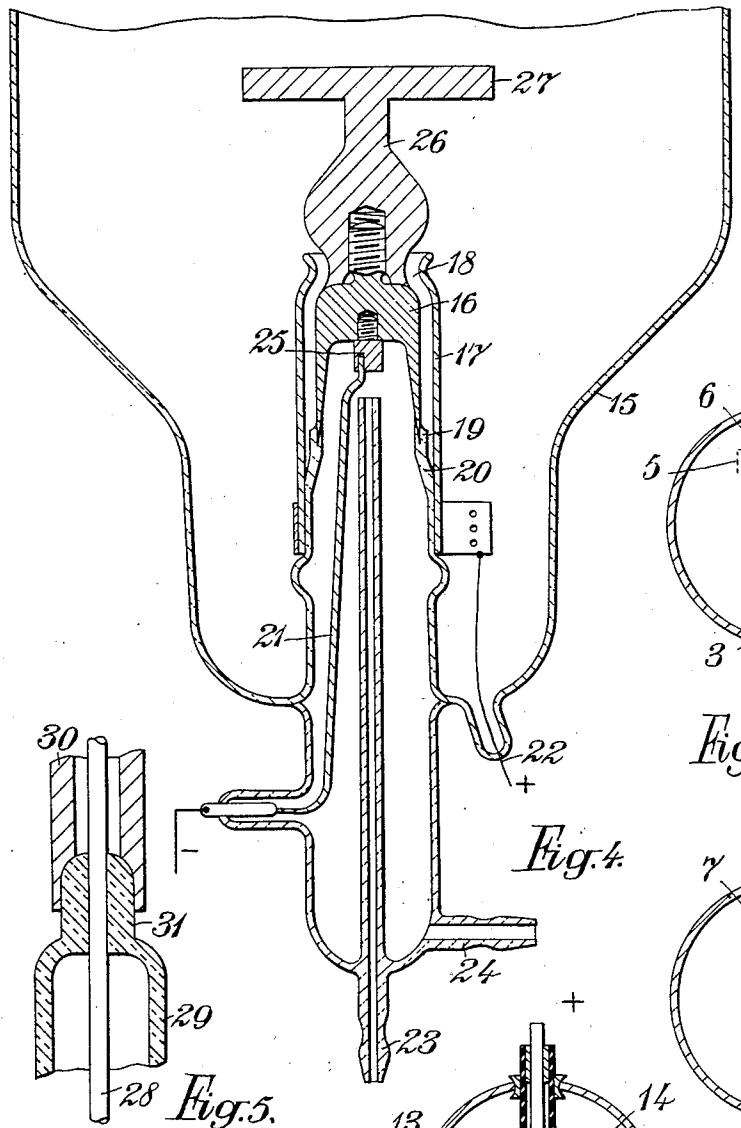


Fig. 4.

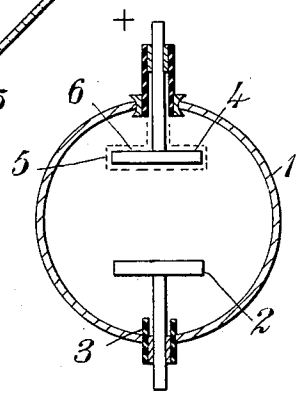


Fig. 1.

Fig. 5.

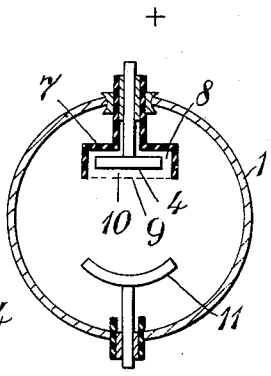


Fig. 2.

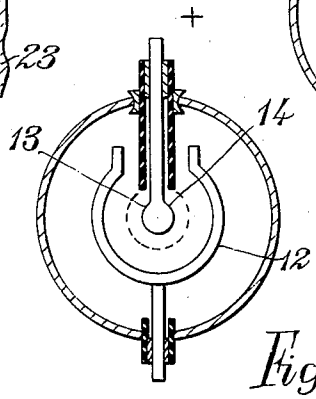


Fig. 3.

B. Berghaus
W. Burkhardt
Inventors

By: Glascock Downing & Seebold
Attys.

June 4, 1940. B. BERGHAUS ET AL 2,203,452

ELECTRONIC DISCHARGE TUBE

Filed Dec. 17, 1938 6 Sheets-Sheet 2

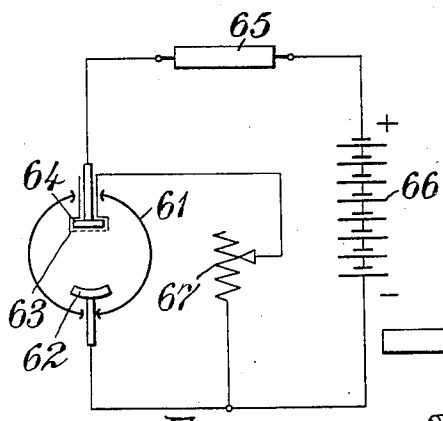


Fig. 8.

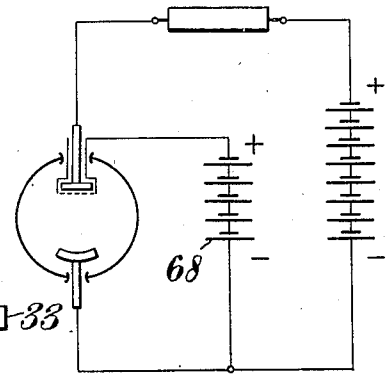


Fig. 9.

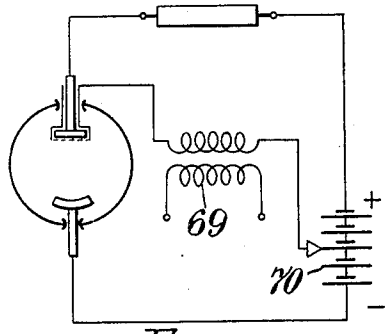


Fig. 10.

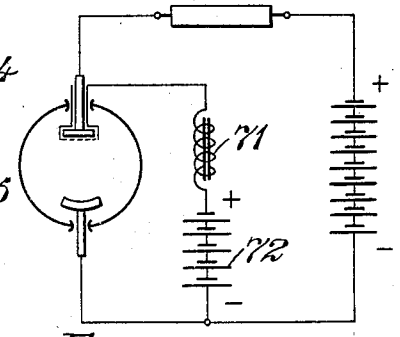


Fig. 11.

Fig. 6.

Inventors,
B. Berghaus,
W. Burkhardt

By: Glascock Downing & Seebold
Attys.

June 4, 1940. B. BERGHAUS ET AL 2,203,452

ELECTRONIC DISCHARGE TUBE

Filed Dec. 17, 1938 6 Sheets-Sheet 3

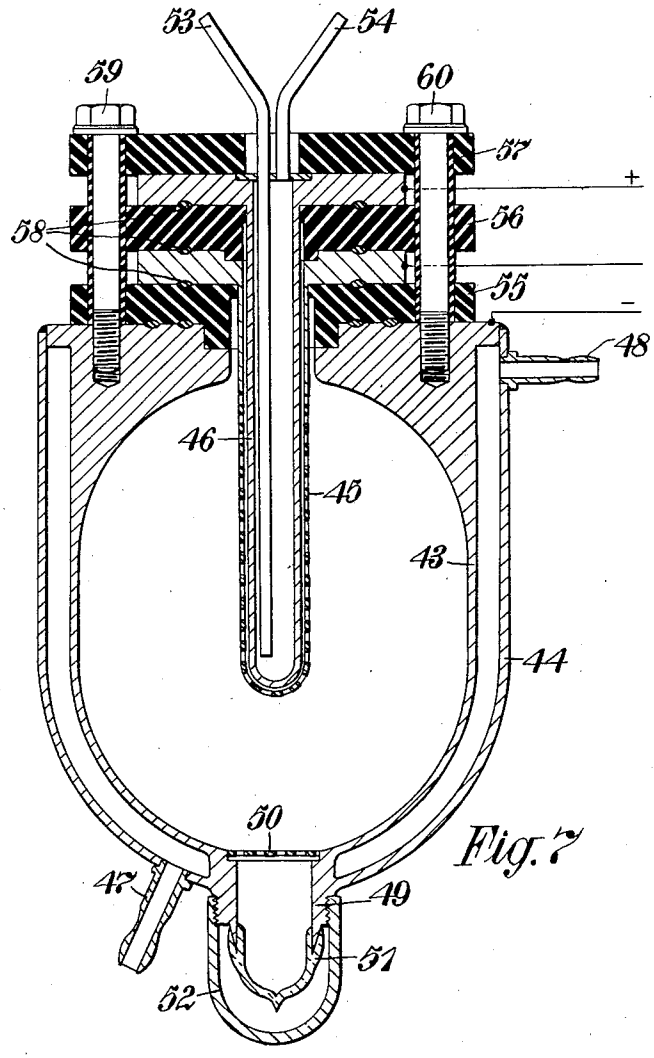


Fig. 7

Inventors,
B. Berghaus
W. Burkhardt

By: Glascock Downing & Seebold
Attys.

June 4, 1940. B. BERGHAUS ET AL 2,203,452

ELECTRONIC DISCHARGE TUBE

Filed Dec. 17, 1938 6 Sheets-Sheet 4

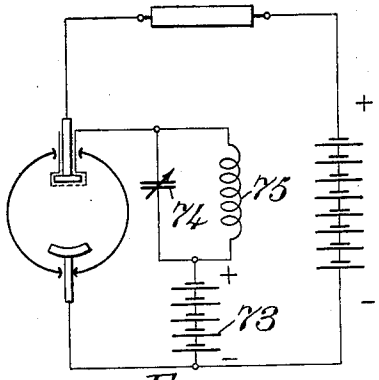


Fig. 12.

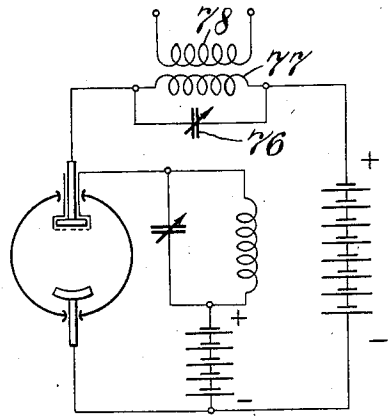


Fig. 13.

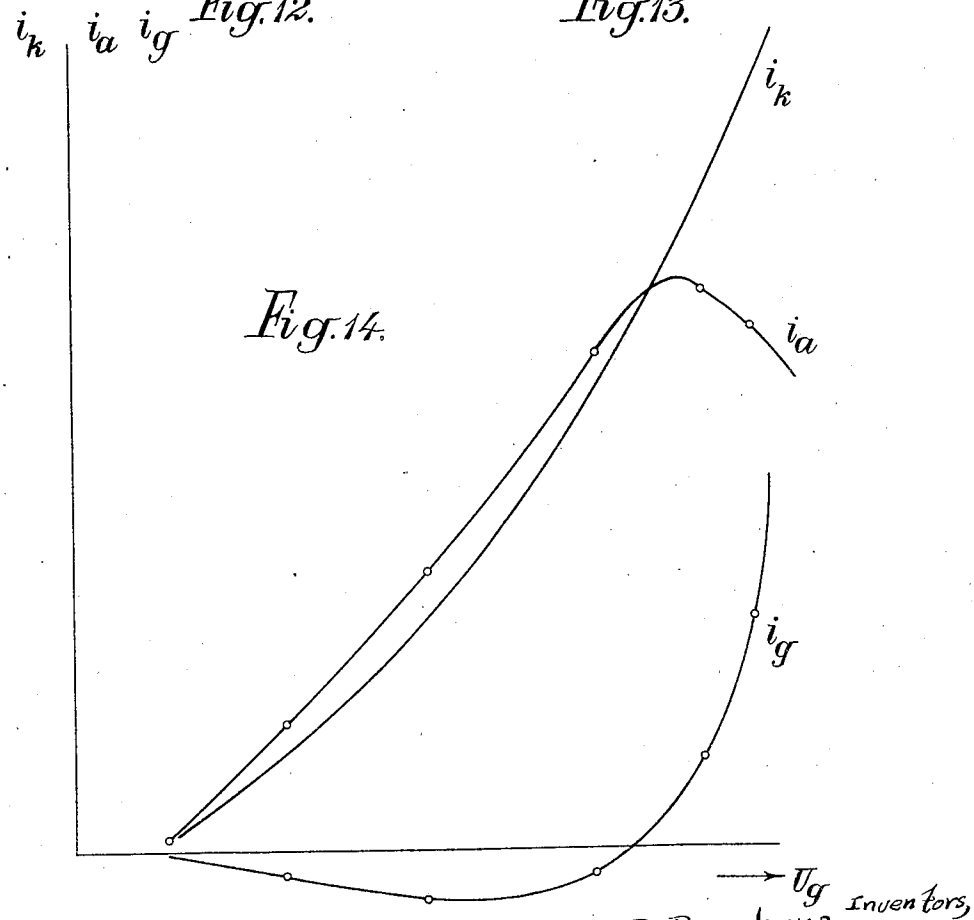


Fig. 14.

Inventors,
B. Berghaus
W. Burkhardt
By: Glascock Downing & Seibold
Attys.

June 4, 1940. B. BERGHAUS ET AL 2,203,452

ELECTRONIC DISCHARGE TUBE

Filed Dec. 17, 1938 6 Sheets-Sheet 5

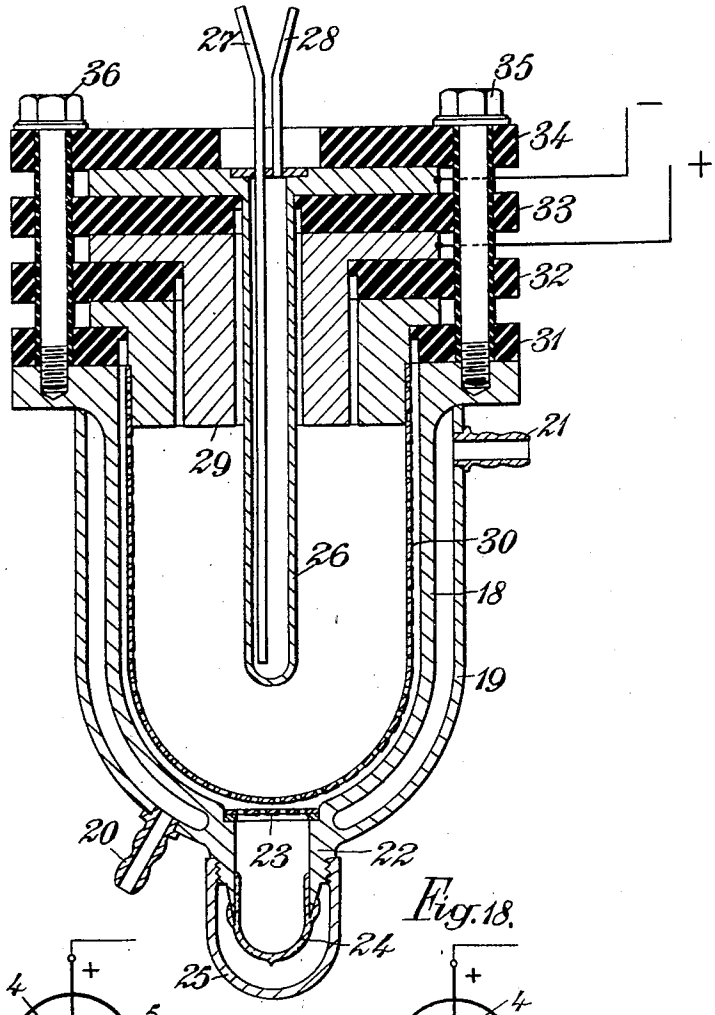


Fig. 18.

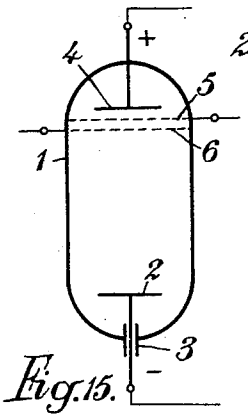


Fig. 15.

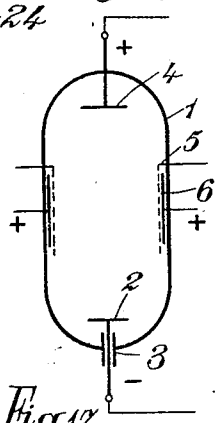


Fig. 17.

Inventors,
B. Berghaus
W. Burkhardt

By: Glascock Downing & Seibold
Attys.

June 4, 1940. B. BERGHAUS ET AL 2,203,452

ELECTRONIC DISCHARGE TUBE

Filed Dec. 17, 1938 6 Sheets-Sheet 6

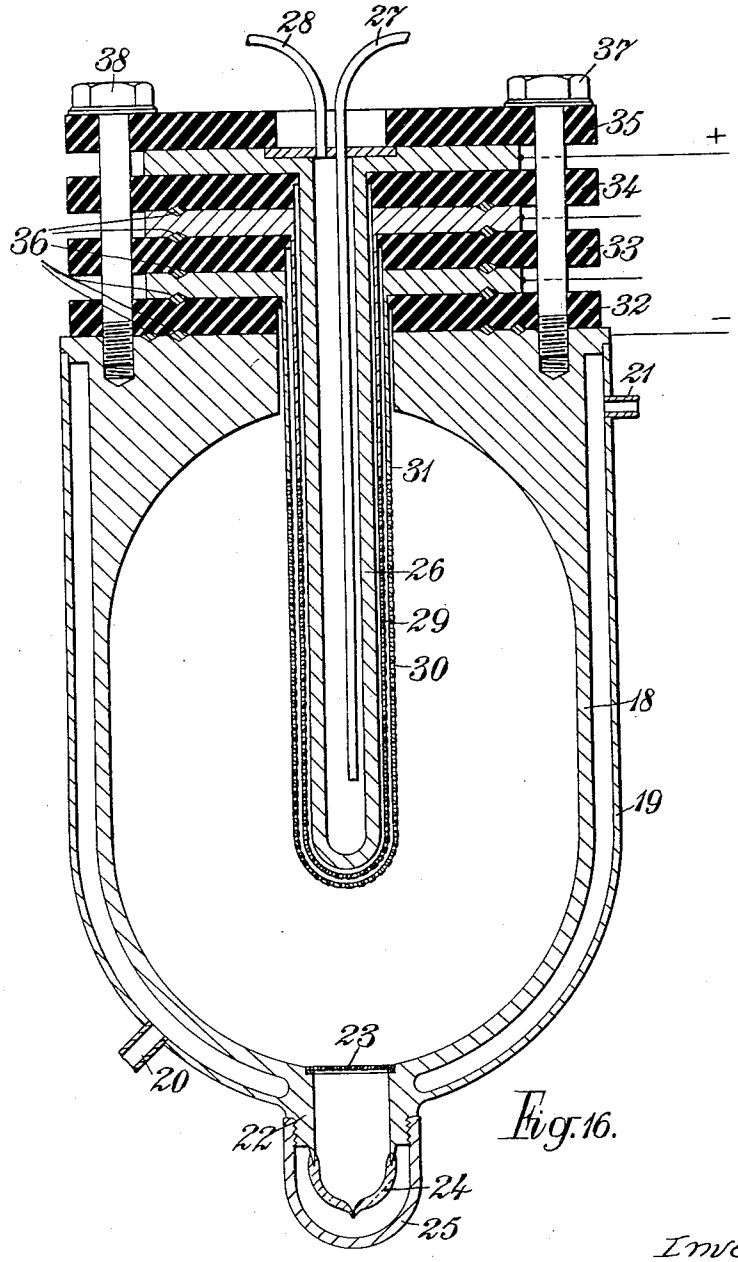


Fig. 16.

Inventors,
B. Berghaus
W. Burkhardt

By: Glascock Downing & Seebold
Attys.

Patented June 4, 1940

2,203,452

UNITED STATES PATENT OFFICE

2,203,452

ELECTRONIC DISCHARGE TUBE

Bernhard Berghaus, Berlin-Lankwitz, and Wilhelm Burkhardt, Berlin-Grunewald, Germany; said Burkhardt assignor to said Berghaus

Application December 17, 1938, Serial No. 246,432
In Germany December 24, 1937

4 Claims. (Cl. 250—27.5)

The invention relates to a gas-filled electronic tube with a cathode and anode and a grid and it consists in this that the current lead-in of the cathode is provided with means which prevent a glow discharge at the insulation parts. The cathode is preferably introduced into the metallic or non-metallic discharge vessel in a screened manner and the current lead-in of the cathode is provided with a metallic covering, at such a short distance that no gas discharge (glow discharge) can take place in the space between the covering and the current lead-in.

The invention also relates to a method of operating a gas-filled electronic tube with a cathode, an anode and a controlling grid, which is characterized by this, that the discharge current of the glow discharge itself is continuously regulated for the purpose of control by changing the potential on a control grid, which grid divides up the discharge space between the cathode and anode in such a manner that in the space between the grid and anode no automatic discharge can take place. The grid potential may be varied by an adjustable source of voltage in the grid circuit. However, a change in the grid potential may also be effected by varying a resistance arranged in the grid-cathode circuit. The adjustable resistance may be an ohmic resistance or an alternating current resistance (choke, oscillatory circuit, etc.).

The loading of the cathode per unit of surface is preferably beyond the normal value, so that the control of the glow current takes place in the region of the abnormal glow discharge.

The invention further relates to apparatus for carrying out the method described, by using a gas-filled electronic tube with an anode, a cathode and a grid, the characteristic feature of which is that the discharge tube is so divided into two spaces by a grid electrode between the cathode and anode that no ionization takes place in the space between the grid and anode with the anode voltage which is applied and the existing pressure. The apparatus is further characterized by this, that the grid completely surrounds the anode at such a short distance that, in the space between the grid and the anode, no proper gas discharge (glow discharge) can be produced. The grid has such a small mesh that the electric control field of the grid is not broken down by the space charges which are caused by the carriers of the glow discharge. The free openings of the grid are preferably chosen smaller than 1 square millimeter. The grid may consist of perforated metal sheets or wire nettings

The grid dividing the tube into two spaces may be partly replaced by a closed metallic or non-metallic wall, which surrounds the anode at such a short distance that in the space between the metallic or non-metallic wall and the anode no proper gas discharge (glow discharge) can take place.

The cathode is preferably inserted in a screened manner into the metallic or non-metallic discharge vessel, for instance of glass, quartz glass, iron, steel, aluminum "Elektron," or the like. The current lead-in conductors are preferably provided with metallic coverings at such a short distance that, in the space between the coverings and the current lead-in, no gas discharge (glow discharge) can be formed, so that the transition from the conductor to the insulator is protected against attack by the gas discharge.

The filling gas for the tube may be a rare gas or a rare gas mixture. Especially suitable is a filling with helium which, as is well known, does not result in any substantial disintegration of the cathode, but also the other rare gases, such as argon, neon, krypton, xenon, may be used. In the tube there is maintained a gas pressure between 5 and 0.001 and preferably about 1 to 0.1 millimeters of mercury. When the cathode is highly loaded, the same is preferably made of a metal having a high melting point, such as tungsten, molybdenum and tantalum. With smaller load of the cathode use may be made for the latter of metals which melt at a lower temperature, such as light metals, aluminium, magnesium or copper, iron. The cathode may, however, be also made of a metal alloy, for instance chromium and iron. The grid is preferably made of a material which is a good heat conductor, such as silver, copper, aluminium, or the like. The anode may be made of the same metals as the cathode or the grid. Further the electrodes of the tubes may be so constructed as to be capable of being cooled. The cathode may be provided in a known manner with an emission paste, an alkali metal or the like in order to increase the emission of the electrons.

The gas-filled electronic tube according to the invention does not consume any heating current. It has no mutual conductance (the anode current does not change with the anode voltage), whereby a maximum of current control is obtained. It can also be very easily excited at low frequencies. It is also capable of delivering high outputs with a simple metal construction.

Experiments have shown that a third electrode introduced in an insulated manner assumes ap-

proximately the potential of the anode in a gas discharge, irrespective of the place where it is arranged. By applying a definite potential to this third electrode, however, no substantial control of the existing gas discharge can be obtained. However, if the anode of the gas discharge is completely surrounded by an electrode with small openings at such a distance that no gas discharge can be produced in the remaining intervening space at full operative voltage between grid and anode, then the grid also assumes a positive potential, but by the application of a variable voltage it influences the gas discharge in the space between cathode and grid in such a manner as if this electrode was the anode of the gas discharge without, however, taking over the total current of the discharge. Presumably there is formed in the space between the grid and the anode, by the entry of charge carriers from the discharge in the space cathode-grid, a discharge which reacts on the first one. This coupling between discharges seems to determine the capability of control of the discharge tube. The current flowing between the anode and the cathode changes with the application of a constant voltage thereon according to the voltage variation on the grid electrode. A current characteristic dependent on the voltage on the grid electrode between anode and the cathode can be obtained in which the voltage on the grid electrode is varied, preferably between the potential of the anode and the cathode. The main current flows to the anode and a fraction thereof to the grid electrode. The steepness of the characteristic is dependent on the pressure and upon the distance of the electrodes from one another. The current which is supplied to the grid electrode is changed in a way similar to the current to the anode but with a much smaller steepness of the characteristic. By inserting a variable resistance in the circuit of the grid electrode and cathode, a characteristic of the current to the anode can be similarly obtained. By applying an alternating current voltage in the circuit "grid electrode and cathode" a corresponding alternating current voltage is produced across a working resistance in an anode circuit. The current fluctuations in the anode circuit correspond approximately to those of the static characteristic. Thus there is only a small reaction of the anode on the gas discharge. The discharge tube is self-excited and imparts an alternating current voltage to a working resistance when an alternating current resistance, for instance a choke, is inserted in the circuit "grid electrode and cathode," the frequency of the alternating current voltage on the working resistance approximately corresponding to the natural frequency of the choke. If an oscillatory circuit consisting of self-inductance and capacity is inserted in the circuit "grid electrode and cathode," an alternating current voltage is produced on the working resistance in the anode circuit, the frequency of which is approximately the same as the resonance frequency of the circuit. In order to use the required large values of current in the abnormal region of the gas discharge without disturbing the same, the current lead-in conductors provided with insulations for the electrodes are protected against the gas discharge by screens. For this purpose the current lead-in conductors are provided with metallic coverings at such a distance that no gas discharge can be produced between them and the current lead-in conductor. The electrodes may be introduced in a screened manner into a glass or metal vessel. The filling with gas may be effected once, or in the case of larger types of tubes may be continuously renewed by a connection to a vacuum pump. The gas-filled electronic tube is suitable for relays used in the weak and heavy current industry for amplifiers of high and low frequency, as alternating current generator for all frequencies, for instance, for the generation of high frequency oscillations for transmitters and high frequency furnaces.

The invention further relates to a gas filled "head" current electronic tube with a cathode and an anode, a cathanode and a grid lying between the anode and the cathanode, the characteristic feature of which is that the cathode is introduced in a screened manner into the metallic or non-metallic discharge vessel.

The invention also relates to a gas-filled "wall" current electronic tube with a cathode and an anode and a "wall" electrode covered by a grid, the characteristic feature of which is that the cathode is introduced into the metallic or non-metallic discharge vessel in a screened manner. As material for the discharge vessel, use may be made of glass, porcelain, as well as of any desired metals or alloys such as iron, steel and light metals. The current lead-in of the cathode is preferably provided with a metallic covering at such a short distance and of such a length that in the space between the covering and the current lead-in no gas discharge (glow discharge) can take place. In this way the insulation of the current lead-in is protected against destruction by the charge carriers from the gas discharge, and the advantage is attained that the cathode can be loaded to a substantially larger extent than hitherto.

Preferably the cathode is loaded so highly per unit of surface that the generation of the electrons takes place in the range of the abnormal glow discharge. The electronic current depends upon the nature of the gas, the cathode material, and gas pressure and, in addition thereto, substantially upon the applied voltage and the size of the cathode. Owing to the lead-in to the cathode according to the invention the latter can be loaded almost to any desired extent. The loading of the cathode may reach glow temperature and, according to the material, even the fusing temperature of the same. In the case of loads which result in a glow temperature or higher temperatures of the cathode the lead-in or even the whole of the cathode may be cooled. The gas-filled "head" current or "wall" current electronic tube is suitable for relays, amplifiers and the generation of oscillations. The gas discharge to be operated as desired in the abnormal range by the screened cathode lead-in may be correspondingly modulated, for instance, by telegraphic or telephonic signs and an oscillation produced in the controlling system.

The invention is illustrated by way of example, in connection with different forms of construction.

Fig. 1 is a gas-filled electronic tube with an anode, a cathode which is not heated and a grid completely surrounding the anode at such a short distance that no proper gas discharge (glow discharge) takes place in the space between the grid and the anode;

Fig. 2 is another gas-filled electronic tube in which the grid is replaced partially by a closed metallic or non-metallic wall, which surrounds the anode at such a short distance that no proper gas discharge (glow discharge) can take place in

the space between the metallic or non-metallic wall and the anode;

Fig. 3 is a gas-filled electronic tube in which the cathode surrounds the grid which encloses the anode at a short distance;

Fig. 4 shows a cathode introduced in a screened manner into a glass tube and provided with a cooling device;

Fig. 5 shows another form of construction of such a current lead-in provided with a screen;

Fig. 6 shows a cathode introduced in a screened manner into a metal tube;

Fig. 7 shows another gas-filled electronic tube;

Figs. 8 to 13 show different diagrams of connections for controlling the electronic tube; and

Fig. 14 shows a characteristic of the gas-filled electronic tube;

Fig. 15 is a section through a gas-filled "head" current electronic tube with a cathode and an anode, a cathanode and a grid lying between the anode and cathode, the cathode being introduced in a screened manner into the metallic or non-metallic discharge vessel;

Fig. 16 is a section through a "head" current amplifier in which the cathode is screened by a grid support.

Fig. 17 is a section through a gas-filled "wall" current electronic tube with a cathode and an anode and a "wall" electrode covered by a grid, wherein the cathode is introduced in a screened manner into the metallic or non-metallic discharge vessel;

Fig. 18 is a section through a "wall" current amplifier in which the one anode screens the cathode.

Fig. 1 shows a section through a gas-filled electronic tube having a wall 1, which may be made of metallic or non-metallic material and which may instead of being spherical may be made oval or cylindrical. The cathode 2 is introduced into the tube by means of the lead-in 3 in a screened and insulated manner; the anode 4, which is similarly introduced in an insulated and screened manner, is surrounded completely by a grid 5, at such a short distance that no proper gas discharge (glow discharge) can be formed in the space 6 between the grid and the anode.

The gas-filled electronic tube according to Fig. 2 differs from the arrangement according to Fig. 1 in this, that the grid surrounding the anode 4 is replaced partially by a closed metallic or non-metallic wall 7 which surrounds the anode at such a short distance that no proper gas discharge (glow discharge) can take place in the space 8 between the metallic or non-metallic wall and the anode. The grid 9 is again arranged at such a short distance from the anode that no proper gas discharge (glow discharge) can take place in the space 10 between the grid and the anode. In this case the cathode 11 is, for instance, constructed as a hollow cathode but it may have another form. The distance of the cathode from the anode, the size of the cathode in proportion to the anode, the size of the surface of the grid in proportion to the size of the screened anode surface, as well as the size of the mesh of the grid or the width of the hole of the grid sieve, depend upon the load on the tube, the gas pressure in the tube and the nature of the filling gas.

The gas-filled electronic tube according to Fig. 3 is characterised by this that the cathode 12 surrounds the anode 13 and the grid 14.

In Fig. 4 which illustrates a cathode with cooling device introduced into the tube in a screened manner, 15 is the wall of the electronic tube with the fused-in current lead-in 16 and the metallic screening sleeve 17, the distance between which is such that no glow discharge can take place in the space between the two. The space may in that case form a labyrinth 18, so that no charge carrier or disintegrated metal can reach the point of connection 19 with the glass wall 20. The screening sleeve 17 covers the point of connection 19 completely. 21 is the current lead-in for the cathode and 22 is a lead-in conductor for a positive voltage, which may be applied to the screening sleeve 17 if necessary. However, the conductor 22 may also be dispensed with. The current lead-in is constructed so that it can be cooled and the cooling means may be supplied through the pipe 23 and be discharged through the pipe 24. 25 is a screw for securing the current conductor 21 to the current lead-in 16. 26 is the screwed-in cathode holder with the cathode 27. The built-in cooling device is mainly used when the cathode is loaded with a very large current. In the case of a smaller loading of the cathode the cooling device may be dispensed with, whereby the construction is simplified.

Fig. 5 differs from the device according to Fig. 4 mainly in this, that the rod-like current conductor 28 is fused directly into the glass 29 and that the protecting sleeve 30 is slid over the sealing point 31.

In Fig. 6, which shows a cathode introduced in a screened manner into a metal tube, 32 is the metallic wall of the electronic tube with the cathode 33, which is arranged in a support 34 screened by a metallic screen 35 arranged at a short distance. The distance of the screen 35 is so small that no glow discharge can take place in the intervening space between the two. The support 34 may, for instance, be made hollow and be cooled. The cooling means is supplied through the pipe 36 and is discharged through the pipe 37. The insulating ring 38 serves to insulate the support 34 from the screen. 39 are sealing means and 40 is an insulating and clamping ring, which is pressed on by means of the screws 41 and 42.

Fig. 7 shows a further example of construction of a gas-filled electronic tube according to the invention. The large surface cathode 43 which is provided with a cooling jacket 44 surrounds the grid 45 and the anode 46 all around. A cooling means may be supplied through the pipe connection 47 and be discharged through the pipe connection 48. The metallic cathode has at the lower end a pipe connection 49 for the pump with a sieve 50 which may be closed, for instance by a glass seal 51. The metal cap 52 protects the glass seal. The anode 46, which is surrounded by the grid 45 at such a short distance that no glow discharge can take place in the intervening space, is made hollow and capable of being cooled, and the cooling means is supplied through the pipe 53 and discharged through the pipe connection 54. 55, 56 and 57 are insulating rings and 58 sealing rings. 59 and 60 are fixing screws.

Fig. 8 shows a diagram of connections for the gas-filled electronic tube 61 with a cathode 62, the grid 63 and anode 64, which is connected to the source 66 of the anode current over the consuming device 65. In this case the grid is controlled only by the adjustable resistance 67 lying between the grid and the cathode.

The diagram of connections according to Fig. 9 differs from the diagram of connections according to Fig. 8 merely in this, that a source of current 68 is provided in the grid circuit instead of the resistance.

In the diagram of connections according to Fig. 10 the grid circuit contains the secondary coil of a transformer 69, one end of which taps the source 70 of anode current.

In the diagram of connections according to Fig. 11 the grid circuit contains a self-inductance or choke 71 and a source of current 72.

In the diagram of connections according to Fig. 12 the grid circuit contains in addition to the source of current 73 an oscillatory circuit consisting of an adjustable capacity 74 and a self-inductance 75. The source of current 73 may be dispensed with.

The diagram of connections according to Fig. 13 differs from the one shown in Fig. 12 merely by this, that instead of the consuming device use is made of an oscillatory circuit consisting of an adjustable condenser 76 and a self-inductance 77 coupled to a coil 78.

Fig. 14 shows a characteristic of the gas-filled electronic tube, namely the anode current i_a, the cathode current i_k and the grid current i_g in dependence upon the grid voltage U_g.

In Fig. 15 the cathode 2 is arranged in a "head" current amplifying electronic tube 1, which cathode is introduced, screened by a screen 3 and insulated. The screen 3 is similar to the screen shown in Figure 6. The anode 4 is arranged opposite the cathode, whilst the grid 5 and the auxiliary grid anode 6 are arranged in the proximity of the anode.

In Fig. 16 showing a section through a "head" current electronic tube the large surfaced cathode 18 is provided with a cooling jacket 19, to which a cooling means is supplied by the pipe connection 20, and discharged by the pipe connection 21. The metallic cathode has at a lower end a pipe connection 22 for the pump with a sieve 23 which may be closed, for instance by a portion 24 of fused glass. The metal cap 25 protects the part of fused glass. The anode 26 is hollow and constructed so as to be capable of being cooled, a cooling means being introduced through the pipe 27 and discharged through the pipe connection 28. The grid 29 surrounds the anode 26 at such a short distance that no glow discharge can take place in the intervening space. The grid is surrounded by an auxiliary grid anode 30, the solid supporting part 31 of which screens the cathode. 32, 33, 34, 35 are insulating rings and 36 are sealing rings; 37 and 38 are fixing screws.

In the Fig. 17 the cathode 2 is arranged in the "wall" current electronic tube 1, which cathode is screened by a screen 3 and introduced in an insulated manner. The screen 3 is constructed in the same way as in Figure 6. The main anode 4 is arranged opposite the cathode, whilst the grid 5 surrounds the "wall" anode 6.

In the Fig. 18, which shows a section through a "wall" current amplifying electronic tube, the anode 18 is provided with a cooling jacket 19, to which a cooling means is supplied through the pipe connection 20, being discharged through the pipe connection 21. The metallic anode 18 is provided at the lower end with a pipe connection 22 for the pump, which pipe connection has a sieve 23 which may be closed up by a fused glass portion 24. The metal cap 25 protects the portion of fused glass. The cathode 26 is hollow and adapted to be cooled, the cooling means being supplied through the pipe 27 and discharged through the pipe connection 28. The main anode 29 surrounds the cathode at a short distance and in this way it screens the cathode. The grid 30 surrounds the anode at such a short distance that no glow discharge can take place in the intervening space. 31, 32, 33, 34, are insulating and sealing rings, and 35 and 36 are clamping screws.

What we claim is:

1. An electronic discharge tube comprising, a housing providing one electrode for the tube and containing an ionizable gaseous medium, a hollow electrode arranged within said housing and extending therefrom, means for sealing said hollow electrode with respect to said housing, means for supplying a cooling medium to said electrodes, and a control grid mounted within the housing covering one of said electrodes and spaced therefrom at such a small distance as to prevent ionization of the gaseous medium in the space between the control grid and the electrode covered thereby.

2. An electronic discharge tube comprising, a housing providing a cathode for the tube and containing an ionizable gaseous medium, a hollow anode arranged within said housing and extending therefrom through an opening in the housing, means for sealing said anode with respect to said housing, means for cooling said anode, a jacket surrounding said housing for receiving a cooling medium, and a control grid mounted within the housing covering said anode and spaced therefrom at such a small distance as to prevent ionization of the gaseous medium in the space between the control grid and the anode.

3. An electronic discharge tube comprising, a housing providing an anode for the tube and containing an ionizable gaseous medium, a hollow cathode arranged within said housing, means for supplying a cooling medium to said cathode, a jacket surrounding said anode for receiving a cooling medium, and a control grid arranged within the housing covering said anode and spaced therefrom at such a small distance as to prevent ionization of the gaseous medium in the space between the control grid and the housing.

4. An electronic discharge tube comprising, a housing providing an anode for the tube and containing an ionizable gaseous medium, a hollow cathode arranged within said housing and extending therefrom through an opening in the housing, means for sealing said cathode with respect to said housing, means for insulating the cathode with respect to the housing, means surrounding said cathode and spaced therefrom at such a small distance as to prevent ionization of the gaseous medium between the cathode and said last mentioned means so as to prevent ionization of the gas adjacent the insulating means, and a control grid arranged within the housing covering said anode and spaced therefrom at such a small distance as to prevent ionization of the gaseous medium in the space between the control grid and the housing.

BERNHARD BERGHAUS.
WILHELM BURKHARDT.