Oct. 17, 1933. U. DOERING 1,931,254

ELECTRONIC TUBE

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Fig. 1.

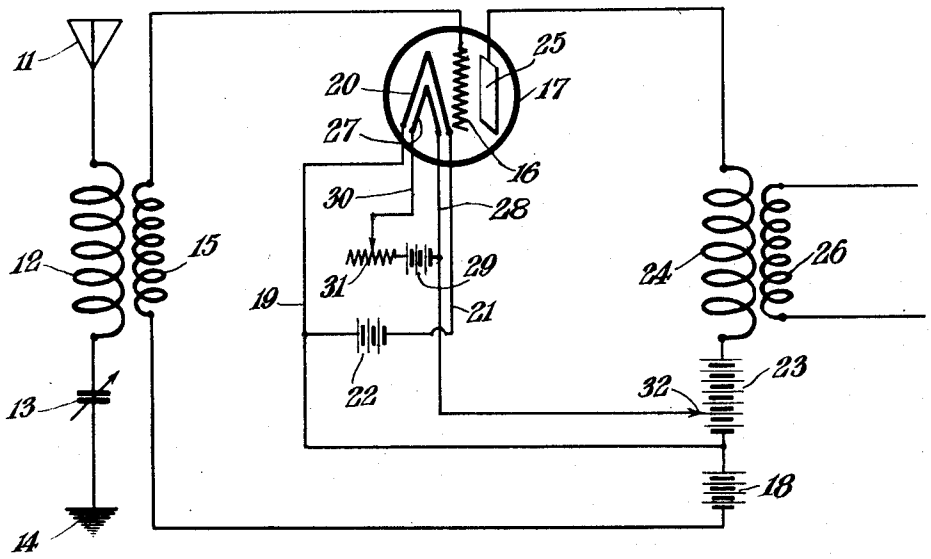


Fig. 2.

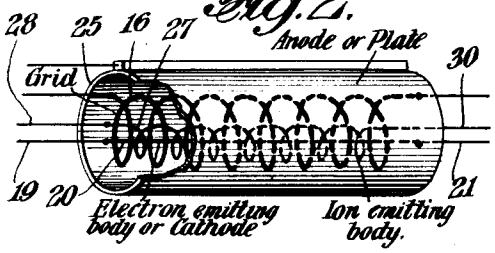


Fig. 4.

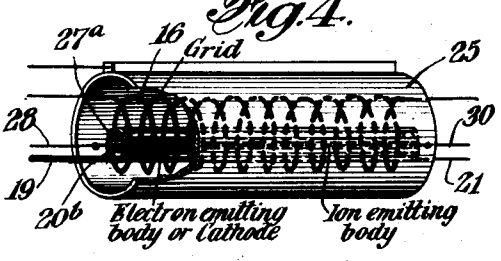


Fig. 3.

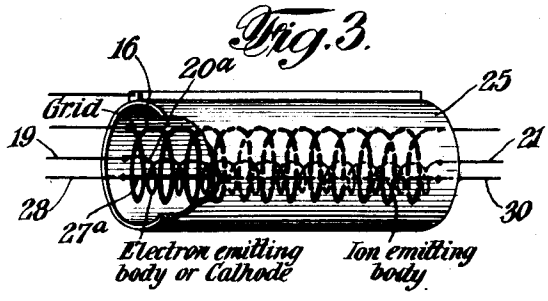
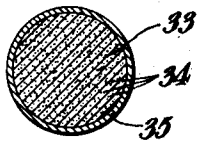


Fig. 5.



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Fig. 6.

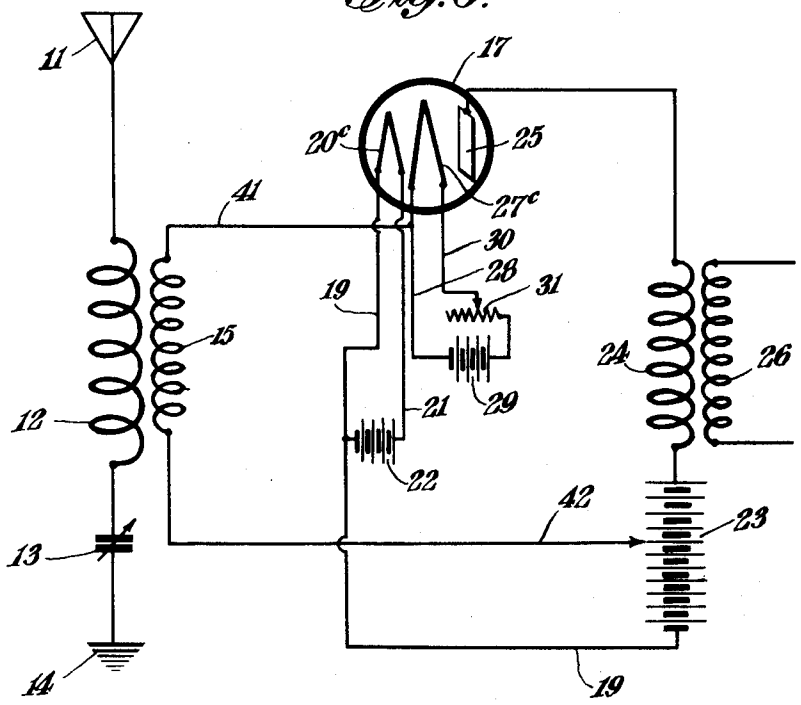
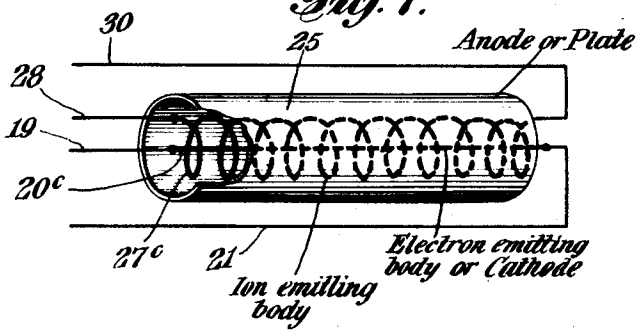


Fig. 7.



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Fig. 8.

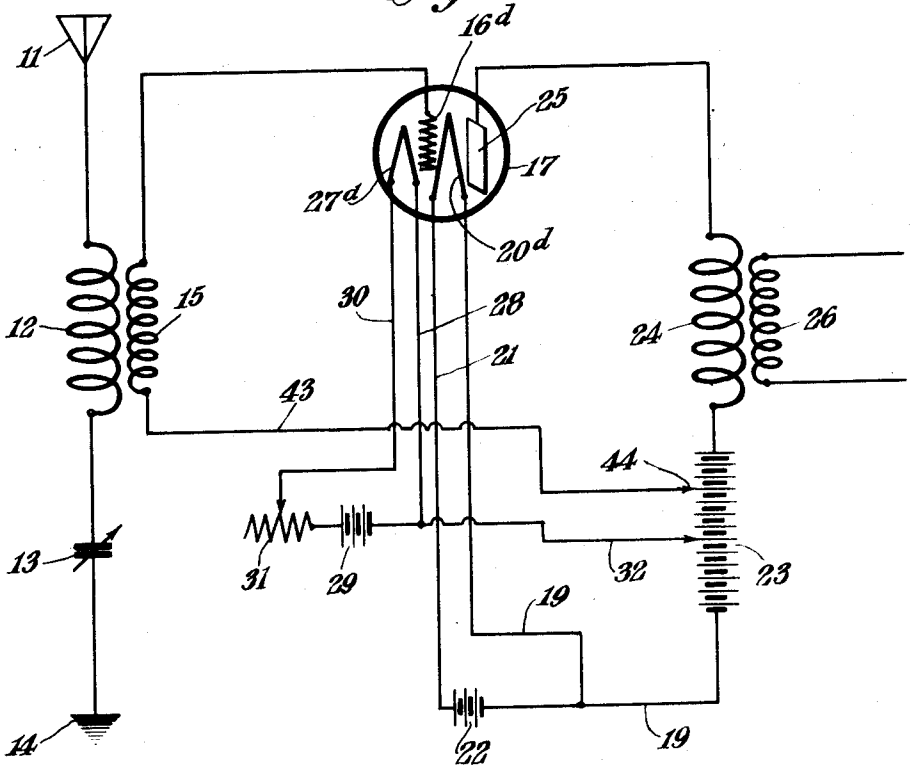
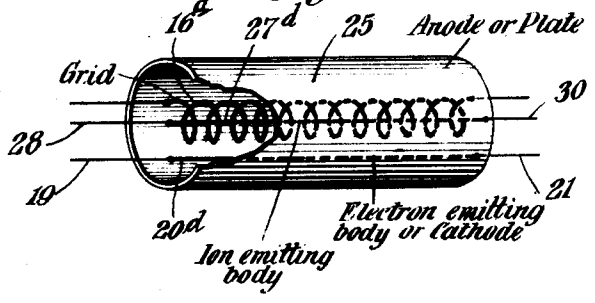


Fig. 9.



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UNITED STATES PATENT OFFICE

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ELECTRONIC TUBE

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Application February 16, 1929, Serial No. 340,510, and in Germany February 28, 1928

6 Claims. (Cl. 250—27.5)

This invention relates to electronic tubes and has for one of its objects the neutralization of the effect of the negative space charge due to the cloud of electrons around the cathode. It has been suggested that positively charged ions be used for neutralizing the effect of the space charge but the practical carrying out of such an idea involves the overcoming of a number of difficulties.

Electronic tubes operate at a very high vacuum and the permissible variation in pressure within the tube is very small. The introduction of positive ions for the purpose of neutralizing the space charge is likely to also introduce uncontrollable variations in the gas pressure. Another disadvantage inherent in certain of the methods heretofore suggested is the change which takes place during the life of the tube in the rate of generating positive ions and therefore in the amount of neutralization effected. Still another disadvantage is the effect of certain chemicals in decreasing or completely stopping the emission of electrons from the cathode.

Among the objects of the present invention is the controlling of the rate of positive ions formation and the maintenance of a uniformly high vacuum without impairing or decreasing the emissivity of the cathode and also to maintain such conditions throughout the life of the tube. More specifically these objects are attained by the materials employed for the ion emitting body and in the form given thereto.

In order to more clearly explain the invention reference is made to the following description of different embodiments thereof taken in connection with the accompanying drawings, in which

Fig. 1 is a connection diagram of a radio receiving circuit showing an improved form of electronic amplifying tube in diagrammatic form;

Fig. 2 is an enlarged perspective view showing the detailed construction of a set of electrodes suitable for use in the tube shown in Fig. 1;

Fig. 3 is a perspective view of another form of electrode construction;

Fig. 4 is a perspective view showing still another form of electrode construction;

Fig. 5 is a greatly enlarged cross-sectional view of the ion emitting body or filament of the previous figures;

Fig. 6 is a connection diagram of a radio receiving circuit in which another form of improved electronic tube is employed in a somewhat different manner;

Fig. 7 is an enlarged perspective view showing the detailed construction of the electrodes of the tube of Fig. 6;

Fig. 8 is a connection diagram of another radio receiving circuit in which is employed still another form of tube; and

Fig. 9 is an enlarged perspective view showing the detailed construction of the electrodes of the tube shown in Fig. 8.

In Fig. 1 is shown a conventional aerial 11 connected in series with an inductance 12 and a variable condenser 13 to the ground 14. Coupled to the inductance 12 is another inductance 15, one terminal of which is connected to a conductor leading to a grid 16 of an electronic tube 17. The other terminal of the inductance 15 is connected to the negative terminal of a battery 18, usually called the C battery, the positive terminal of which is connected to a conductor 19 which is connected to one terminal of an electron emitting cathode 20 which is usually spoken of as the "filament". The other terminal of the cathode 20 is connected by means of a conductor 21 to one terminal of a battery 22. The other terminal of the battery 22 is connected to the conductor 19. The battery shown at 22 is commonly called the A battery. A battery 23, usually called the B battery, has its negative terminal connected to the conductor 19 and its positive terminal connected through the primary coil 24 of a step-up transformer to an anode 25, or plate as it is commonly called. The secondary coil 26 of the amplifying transformer may be connected in any suitable manner to a detector circuit or to other amplifying units. The foregoing connections as well as the corresponding tube construction are similar to that of the ordinary electronic tube which is used in large quantities in radio receiving sets for amplification.

In addition to the foregoing structural elements the tube may also be provided with a positive ion emitting body 27. Suitable provision may be made for heating the positive ion emitting body as for example by making the positive ion emitting body itself in the form of a filament which is the construction shown in the drawings. One terminal of the filament 27 is connected through a conductor 28 to a battery 29. The other terminal of the filament 27 may be connected by means of a conductor 30 to a variable resistance 31 which in turn is connected to the remaining terminal of the battery 29. By adjusting the resistance 31 the current passing through the ion emitting body 27, and therefore its temperature, may be controlled. Pro-

vision may also be made for imposing upon the ion emitting body 27 a positive electrical potential bias with respect to the cathode 20. This may be conveniently done by means of an adjustable connection 32 between the conductor 28 and the battery 23.

One form of the detailed construction of the electrodes is shown in Fig. 2 in which the plate or anode 25 is a hollow cylinder open at both ends. The electron emitting cathode or filament 20 is shown as a straight piece of wire disposed within the anode 25 in a direction generally parallel to the axis of the cylinder. The positive ion emitting body 27 is also shown as a filament and is disposed around the cathode 20 in the form of a helix. The grid 16 is shown in the form of a wire surrounding both the cathode and the ion emitting body as a helix of a still larger diameter.

Fig. 3 shows another structural form of the electrodes similar to the form shown in Fig. 2 except that the positive ion emitting electrode and the cathode are interchanged in position and in form, the cathode 20*a* being in the form of a helix with the positive ion emitting body 27*a* as the axis of the helix. In this form the grid control is not directly affected by the potential given to the ion emitting body 27*a;* that is, the field of the grid is not modified by the field of the body 27*a*.

The form shown in Fig. 4 is similar to that of Fig. 3 with the exception that the wires of the cathode 20*b*. instead of extending circumferentially around the ion emitting body, comprises a plurality of longitudinally extending wires parallel to the body 27*a*.

In obtaining a satisfactory ion emitting body there are three important factors involved. A great many substances have a marked deleterious effect on the electron emitting body or cathode whereby the emissivity is greatly decreased or destroyed altogether. This is sometimes called "poisoning" of the cathode. It is therefore of prime importance that any substance used for the positive ions should be such as to permit full electronic emission from the cathode. Another characteristic that the substance used for generating ions should have is a low vaporizing temperature. And also the substance should preferably have a high atomic weight as heavier ions move more slowly through the field and therefore are longer effective in neutralizing the negative space charge. Such materials as hydrogen, helium, nitrogen or one of the rare gases are sometimes used for the generation of positive ions although they do not possess the third characteristic of high atomic weight. There are other materials such as caesium, barium, rubidium, mercury or cadmium which also have a high atomic weight and are especially desirable for use as silicates, borates, phosphates, etc. Caesium and rubidium are particularly adapted for such use as, in addition to their other desirable characteristics, they not only do not "poison" the cathode but actuate it to a certain extent. They may be placed on a metallic core or wire as a thin covering or layer and when heated give off the positive ions or anions. Instead of the layer or coating on the outside of the core a solid solution or alloy of caesium, rubidium or other alkali or alkali earth metal may be employed using for the core a metal such as nickel, copper or iron. The foregoing metals also have the advantage that they condense on the cathode or if they do not reach the cathode they will eventually be deposited on the other portions of the tube, which results in a more stable gaseous pressure within the tube than is the case with certain gases. They also have a low ionization pressure. It is also desirable that the recombining of the positive ions with the electrons should take place to only a relatively small extent so that the atoms of material may exist as ions as long as possible and exercise their neutralizing effect as long as possible.

Fig. 5 shows in greatly enlarged section the filament of one form of positive ion emitting body having a core 33 of a metal such as nickel having embedded therein an emissive material such as caesium indicated by the scattered dots 34. It sometimes happens that as the caesium or other material works out to the surface and passes into the surrounding space as positive ions, the core becomes somewhat impoverished near the outer surface and is not so effective until it has had opportunity to recuperate. In Fig. 5 the core 33 is shown enclosed by a layer 35 of material such as cobalt which affords more resistance to the passage therethrough of the caesium than does the nickel core so that the caesium when it reaches the layer of cobalt is retarded sufficiently to prevent undue exhaustion of the outer core portion.

In operation the apparatus in Fig. 1 functions in much the same way as in the ordinary amplifying tube, the hot filament of the electron emitting cathode and the anode or plate 25 carrying current therebetween, the rate of flow being governed by the potential imposed on the grid which current flow varies with the variation of the potential on the grid derived from the inductance 15. The electron stream passing from the cathode is very dense near the surface of the cathode and this electron cloud ordinarily tends to repel the electrons passing out of the cathode and thus to reduce the electron flow and the plate filament current. The ion emitting body 27 counteracts or neutralizes this repelling tendency. The total positive ions and negative electrons in a given space should be substantially equal to give a completely neutralized region. But as the ions move much more slowly than the electrons they are more effective and the amount of ions required are less than the electrons, the electron current varying from 1/20th in the case of hydrogen to 2/1000th in the case of argon or caesium. The amount of metal necessary to have in reserve to correspond with the average life of a tube would therefore vary from one milligram to over 100 milligrams of the substance in question. The amount of positive ions required can be controlled by varying the heating of the ion emitting body. If one of the rare gases is used or nitrogen or hydrogen, the latter in the form of a solid solution in the metal, the gas may also be maintained at a suitable value in the tube, the pressure being that at which the ionized vapor in the tube and the same substance in the emitting body are equal, the latter being determined by its concentration, the manner in which it is held in the metal, and also the temperature, which latter factor can be regulated.

In Fig. 6 those parts of the circuit which are the same as in Fig. 1 are given the same reference characters. It will be noted that the grid shown in Fig. 1 is omitted in Fig. 6. One terminal of the inductance coils 15 is connected through a conductor 41 to the conductor 28 of the ion emitting body, and the other terminal

of the inductance coil 15 is connected by means of a conductor 42 to the B battery 23 in such manner that it can be adjusted along the battery 23 and its voltage varied. The structural details of the electrodes are shown in Fig. 7. The electron emitting cathode may be longitudinally disposed in the axis of the cylinder or plate 25. The ion emitting body 27*c* is disposed around the cathode 20*c* in the form of a helically wound coil.

In operation the positive ions which pass from the ion emitting body 27*c* to the region of the cathode 20*c* depend on the voltage existing between these two electrodes. The oscillating potentials derived from the coil 15 are impressed on these electrodes with the result that the positive ions emitted vary in accordance therewith, and also the neutralization of the space charge of the electrons around the cathode varies in like manner. In accordance with the neutralization of the space charge around the cathode the stream of electrons from the cathode to the anode 25 changes. Therefore the current in the plate circuit is indirectly controlled by the potential and ion emission of the body 27*c* through the neutralization by positive ions of the space charge and control of the electronic flow around the cathode. It is not essential that the ion emitting body surround the cathode as the effect of the positive ions in neutralizing the electronic space charge also exists when the body is merely positioned adjacent to the cathode.

Fig. 8 shows another method of connecting a tube in a receiving circuit and Fig. 9 shows structural details of the electrodes for the tube used in Fig. 8. It will be noted that in Fig. 9 the grid 16*d* surrounds an ion emitting body 27*d* and is in the form of a spiral. An electron emitting body or cathode 20*d* is positioned between the anode or plate 25 and the positive ion emitting body and its grid or spiral. The external connections are different from Fig. 1 in that the inductance has one terminal connected to the grid and the other terminal thereof adjustably connected through a conductor 43 to the battery 23 at a point 44 such that the potential of the grid 16 is positive with respect to the ion emitting body.

In operation the rate of emission of the positive ions from the ion emitting body 27*d* depends both on the temperature of the body and also on the potential of the grid 16*d*, the higher the potential of the grid, the more the positive ions are repelled and prevented from leaving the body 27*d* and passing to the region of the cathode 20*d* and its negative space charge. Therefore the variation of the potential from the coil 15 changes the positive ion flow toward the cathode and indirectly the electron flow from the cathode and the current in the plate circuit.

The above described embodiments of the invention are shown in connection with amplifying tubes, but it is to be understood that the invention may also be employed in connection with detector tubes or otherwise and that the foregoing description is for the purpose of illustration only and various changes may be made in the specific forms shown without departing from the spirit and scope of the invention as defined in the subjoined claims.

I claim:—

1. An electronic tube comprising an anode, a heatable electron emitting electrode, and a heatable positive ion emitting body adjacent said electrode comprising a metal core having embodied therein ionizable material and a layer of another metal on said core to effect a controllable resistance to the diffusion of said material therethrough.

2. An electrode for an electronic discharge tube comprising a metal core and an ionizable substance embodied therein, said core being permeable to vapors derived from said substance when heated, and a coating of metal on said core which is less permeable to said vapors at operating temperatures than said core.

3. An electrode for a high vacuum tube and adapted to be heated, comprising a metallic core porous to diffusion of highly electropositive metal vapor, a highly electropositive metal embodied in said core, and a coating on said core which retards the rate of diffusion of the vapor of said metal into the vacuous space surrounding it.

4. An electrode comprising a core of nickel having caesium distributed therein, and an outer coating of cobalt on said core.

5. An evacuated vessel having disposed therein an electron emissive cathode in the form of a cage comprising a plurality of parallel wires which are adapted to be heated, a heatable filament disposed within said cage substantially at the center thereof, said filament being adapted to emit positive ions when bombarded by electrons from said cathode, a grid electrode surrounding said cathode and an anode surrounding said grid electrode.

6. An electrode for an electron discharge device, comprising a core of nickel having distributed therein a substance which yields caesium vapor when heated, and an outer coating on said core of metal which is less permeable to caesium vapor than the nickel core.

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