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VACUUM TUBE AND ASSOCIATED ELEMENT

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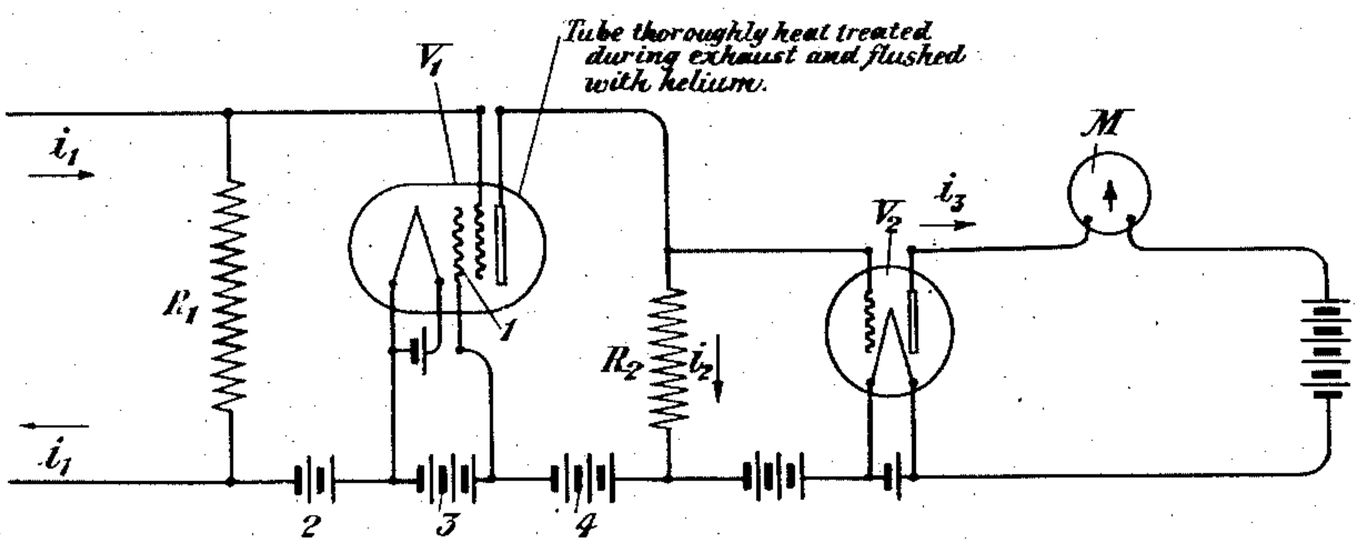

indicates poling of all batteries.

Sum of voltages from sources 2, 3 and 4 is less than resonance voltage of helium.

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VACUUM TUBE AND ASSOCIATED ELEMENT.

Original application filed June 1, 1926, Serial No. 113,020. Divided and this application filed April 26, 1927. Serial No. 186,784.

My invention relates to the amplification of electric currents, and more particularly to the amplification of very small direct currents.

This application is a division of my co-pending application, Serial No. 113,020, filed June 1, 1926, and entitled Amplification of small direct currents.

In certain work in the electrical field, it is necessary or desirable to amplify minute direct currents in order that electrodynamic rather than electrostatic measuring instruments may be employed. Examples of such work are work with photo-electric cells and measurement work relating to radio activity. Serious difficulties are encountered in connection with efforts to produce these vary small direct currents. These difficulties are due to the fact that in the ordinary vacuum tube amplifier, even one having the best commercial vacuum, there is a minute positive ion current flowing to the grid, which current results from the ionization of the residual gas in the tube by the electrons constituting the space current. This current is ordinarily of a value from 10^{-6} to 10^{-3} amperes. If direct currents of this magnitude or smaller are to be amplified, or if input resistances of 10^{6} to 10^{8} megohms are employed, the positive ion current to the grid may cause difficulty by masking the direct current to be amplified. This positive ion current to the grid may also alter the grid bias and, in addition, the character of the current is, in all probability, unsteady.

For a discussion of ionization in vacuum tubes, reference may be had to Van der Bijl, "Thermionic Vacuum Tube," Chapter II. It is sufficient to state here a few points directly connected with the invention. When a vacuum tube is used as an amplifier, most of the ionization of the gas (of which there is always a residuum) takes place between the grid and the anode or plate. Since the grid is negative with respect to the plate, the positive ions formed by collision ionization in this region are attracted to the grid. The ionization energy of any gas or vapor is the smallest energy with which an electron must collide with an atom of that gas or vapor in order completely to detach an electron therefrom. This amount of energy is usually expressed in terms of the voltage through which the electron drops before it collides with the atom and is then referred to as the "ionization voltage," which expression will be used hereinafter.

From the above dicsussion, it will be understood that in order to have available in a vacuum tube electrons of sufficient energy to produce ionization, the plate voltage supplied to the tube must be above a certain amount. Accordingly, it has been proposed to eliminate the source of the difficulty discussed above in amplifying minute direct currents by reducing the plate voltage below this certain amount. This step alone, however, is probably insufficient. Electrons having energies sufficient to excite resonance radiation from the atoms of the residual gas may give rise to grid current. The production of soft X-rays occurring when the electrons strike the plate may also result in grid current. This grid current is due to the emission of photo-electrons from the grid material as a result of the resonance or soft X-ray radiation to which the material is exposed. In other words, the residual gas in a vacuum tube has not only an ionization voltage, which will give rise to grid current unless the plate voltage supplied is very low, but also a resonance voltage somewhat lower than the ionization voltage, which may result in grid current, as explained above. The following table gives the approximate ionization and resonance voltages of mercury vapor and hydrogen:

Substance	Ionization voltage	Resonance voltage
Mercury vapor	10.4	4.9
Hydrogen	13.6	9

Accordingly, if the ordinary type of three-electrode vacuum tube is used for the amplification of small direct currents, say, of 10^{-10} amperes, the plate voltage supplied to the tube must be reduced to a vlue from 7 to 9 volts in order to obtain a sufficiently close approximation to the elimination of grid current. With this forced reduction of plate voltage, it becomes desirable to employ the type of vacuum tube having two grids—the ordinary controlling grid and an additional grid called a space charge grid, which is placed between the control grid and the filament and is positively biased. By means of the addition of this space charge grid, a material increase in gain from the tube may be obtained.

It is the purpose of this invention to pro-

vide means for permitting the use of a materially higher plate voltage in a vacuum tube amplifying system without the production of ionization or resonance radiation difficulties.

I accomplish this object by employing in the amplifying system a vacuum tube treated in a novel and highly advantageous manner, the method being described below.

The nature and purpose of my invention will be more clearly understood when the following detailed description of the circuit, including a description of the preparation of my special tube, is read with reference to the accompanying drawing, which shows the circuits of the amplifying system in diagrammatic form.

The tubes V_1 and V_2 are connected in cascade. The tube V_1 is a double grid tube, while the tube V_2 is of the ordinary three-electrode type. The biasing voltage for the control grid of the tube V_1 is supplied from the source 2, and the voltage for the space charge grid 1 is supplied from the source 3, this grid being biased positively with respect to the control grid. The source 4 supplies the plate voltage for tube V_1. The usual resistance R_1 and R_2 are included. Let it be assumed that a very small direct current i_1 is supplied to the input of the system and that it is desired to amplify this current in order to produce a satisfactory operation of the meter M, which is connected in the plate circuit of the tube V_2. A current i_3, considerably larger than the current i_1, must be produced in the plate circuit of tube V_2, and, in order to obtain the proper value for this current, there must be produced in the plate circuit of the tube V_1 a current i_2, which, of course, must represent a large amplification of the input current i_1.

The tube V_1, which is the double grid tube, is, according to my invention, specially prepared to be suitable as an amplifier of the very small current i_1. It is known that helium has a relatively large ionization voltage and a correspondingly large resonance voltage, these being perhaps larger than the corresponding voltages of any other known gas or vapor. More specifically, the ionization voltage of helium is 29 volts, and its resonance voltage approaches 20 volts. In accordance with my invention, I subject the tube V_1 to the well known exhaust and heat treatment. By this treatment, during the exhaust, or, in other words, while the tube is on the molecular pump, a large current is passed through the filament in order to produce a temperature materially higher than that at which the tube is to operate in service. It is readily understood that the result of this heating of the filament is a severe electron bombardment of the anode and the grids. In accordance with my invention, upon the completion of the exhaust and heat treatment, helium is admitted to the tube. After a brief period of time, the exhaust and heat treatment is repeated. In other words, the tube is flushed with helium. It may be desirable to repeat the whole process several times. The result of this treatment of the vacuum tube is that the residual gases ordinarily present in an evacuated bulb, which gases have relatively low ionization and resonance voltages, are replaced or, at least, substantially replaced by helium, which has relatively high ionization and resonance potentials. In addition, helium has the advantage that it offers very little impedance to the passage through it of a stream of electrons at velocities below its resonance voltage. Relatively high pressures of helium may therefore be left in the tube without disadvantage.

In order to secure the best operation of my amplifying system, the sum of the voltages from the sources 2, 3 and 4 should be less than the resonance voltage of the residual gas in the tube V_1, that is, less than approximately 20 volts, or the resonance voltage of helium. The scope of my invention is defined in the appended claims.

I claim:

1. In a system for amplifying electric currents, a vacuum tube and sources of anode and grid potentials therefor, said tube being flushed with a gas of a high resonance voltage, and the sum of the voltages from said sources being less than the resonance voltage of said gas.

2. In a system for amplifying electric currents, a vacuum tube having a cathode, an anode, a controlling grid, and a space charge grid, and a source of potential for each of said electrodes, said tube being flushed with a gas of a high resonance voltage, and the sum of the voltages from the anode, controlling grid, and space charge grid sources being less than the resonance voltage of said gas.

3. In a system for amplifying electric currents, a vacuum tube and sources of anode and grid potentials therefor, said tube having a gaseous residuum composed exclusively of a gas of a high resonance voltage, and the sum of the voltages from said sources being less than the resonance voltage of said gas.

4. In a system for amplifying electric currents, a vacuum tube having a cathode, an anode, a controlling grid, and a space charge grid, and a source of potential for each of said electrodes, said tube having a gaseous residuum composed exclusively of a gas of a high resonance voltage, and the sum of the voltages from the anode, controlling grid, and space charge grid sources being less than the resonance voltage of said gas.

5. A vacuum tube and sources of anode and grid potentials therefor, said tube having a gaseous residuum composed exclusively of a gas of a high resonance voltage, and the sum

of the voltages from said sources being less than the resonance voltage of said gas.

6. A vacuum tube having a cathode, an anode, a controlling grid, and a space charge grid, and a source of potential for each of said electrodes, said tube having a gaseous residuum composed exclusively of a gas of a high resonance voltage, and the sum of the voltages from the anode, controlling grid, and space charge grid sources being less than the resonance voltage of said gas.

In testimony whereof, I have signed my name to this specification this 23rd day of April, 1927.

WILLIAM H. T. HOLDEN.