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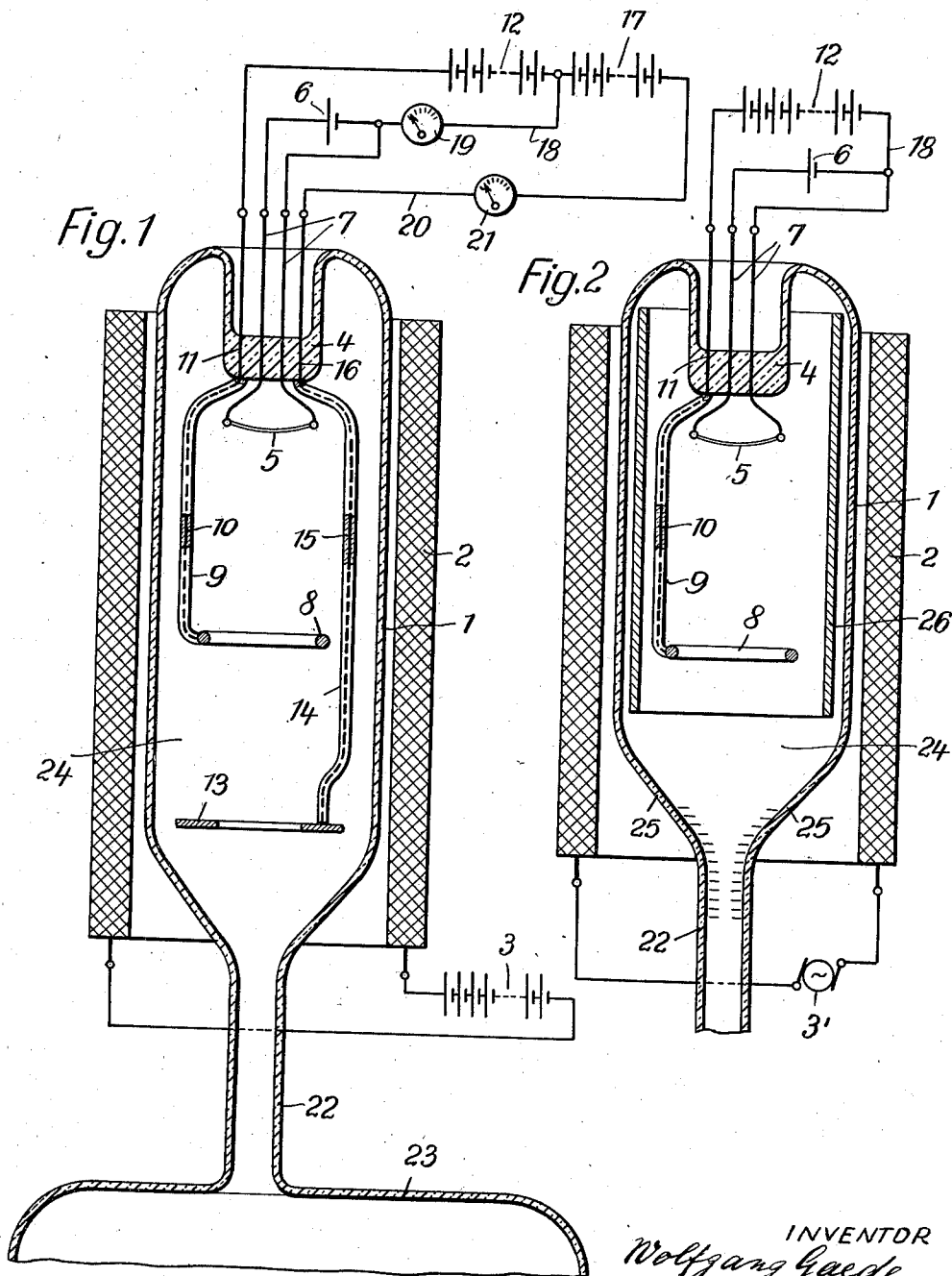
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2,081,429

ELECTRON TUBE AND METHOD OF OPERATING THE SAME

Filed June 1, 1934

5 Sheets-Sheet 1



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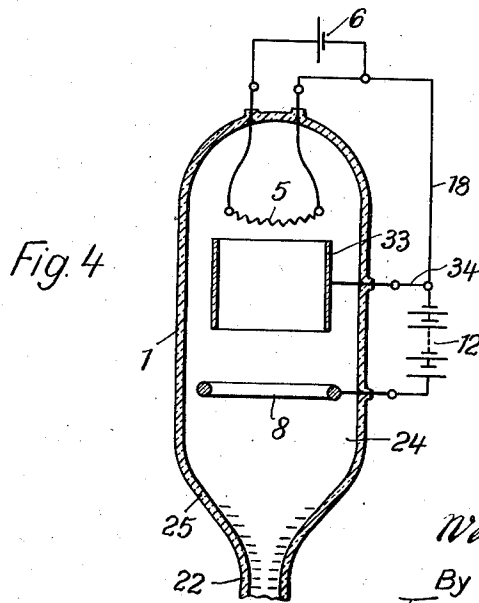
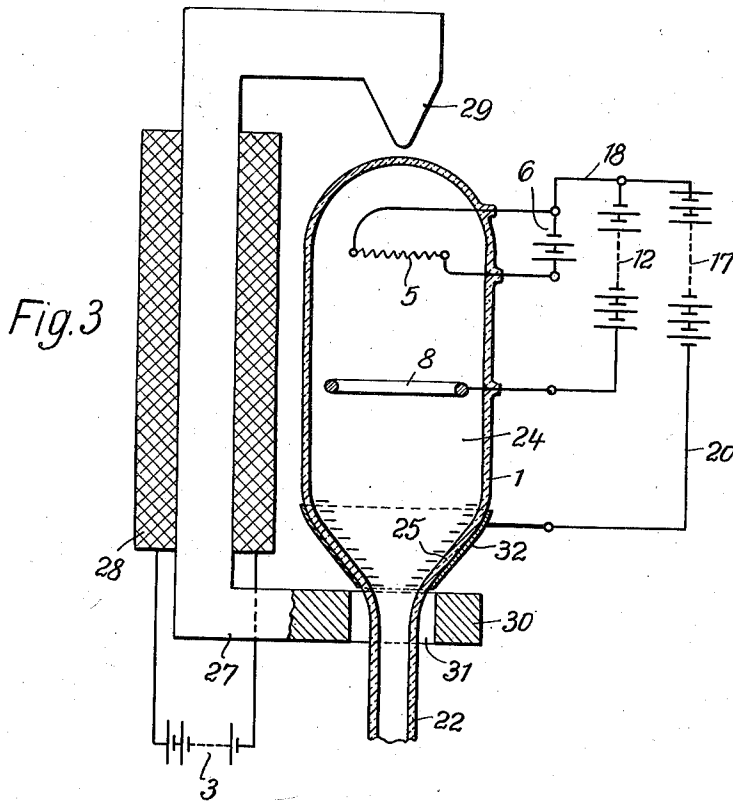
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5 Sheets-Sheet 2



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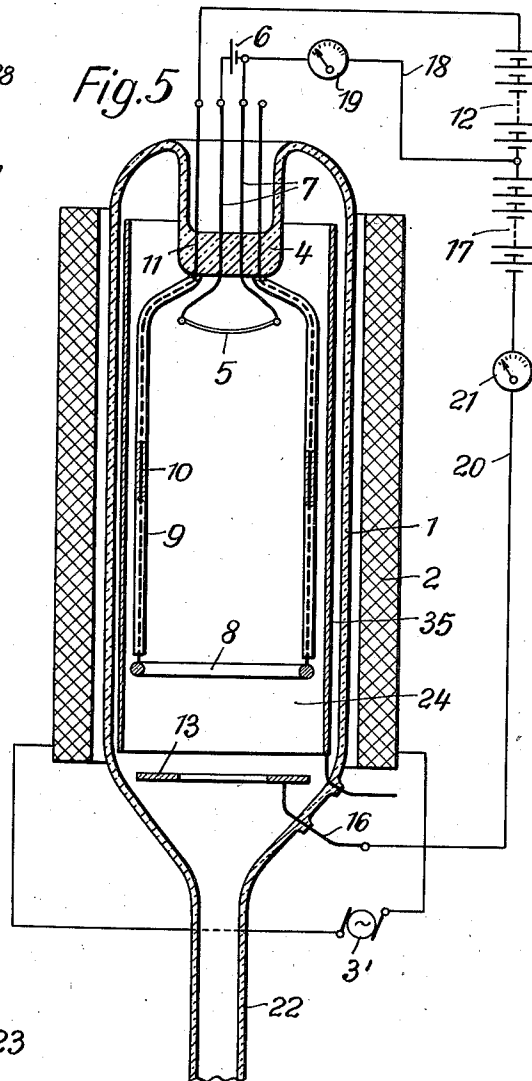
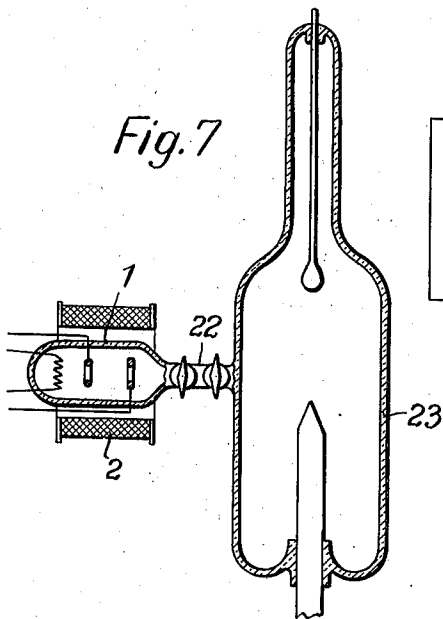
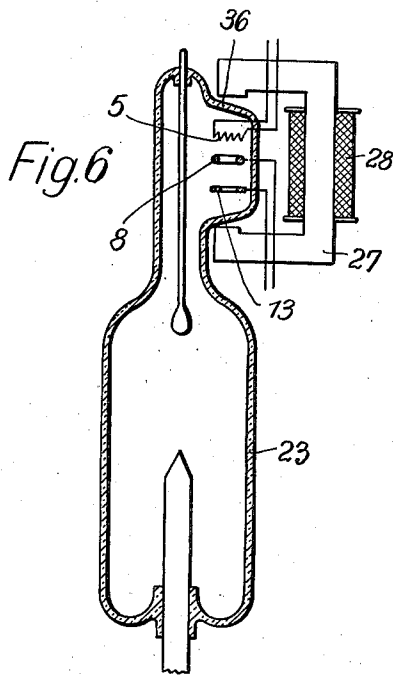
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ELECTRON TUBE AND METHOD OF OPERATING THE SAME

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5 Sheets-Sheet 3



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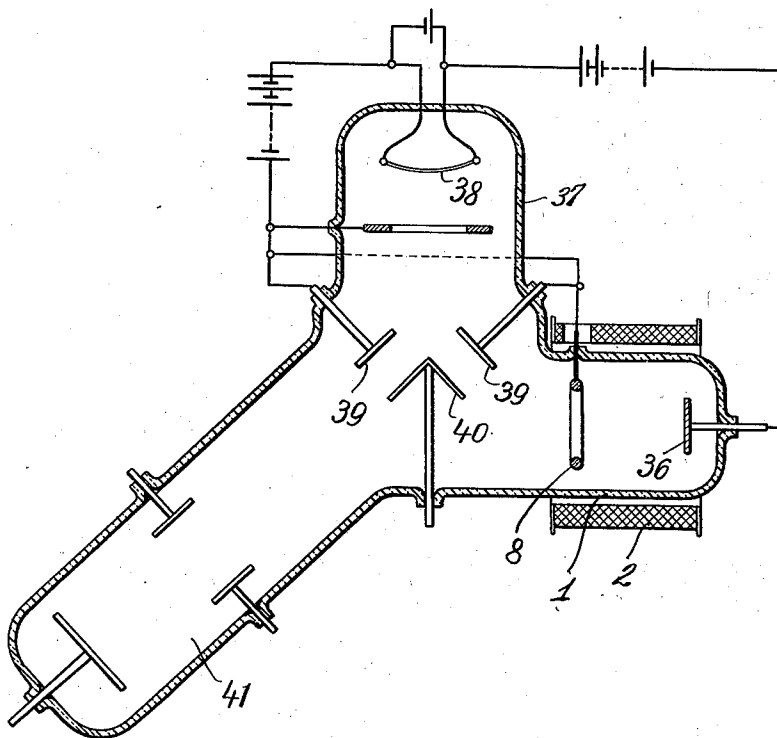
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ELECTRON TUBE AND METHOD OF OPERATING THE SAME

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Fig. 8



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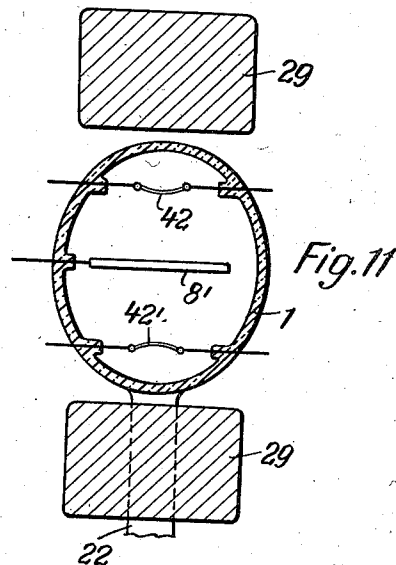
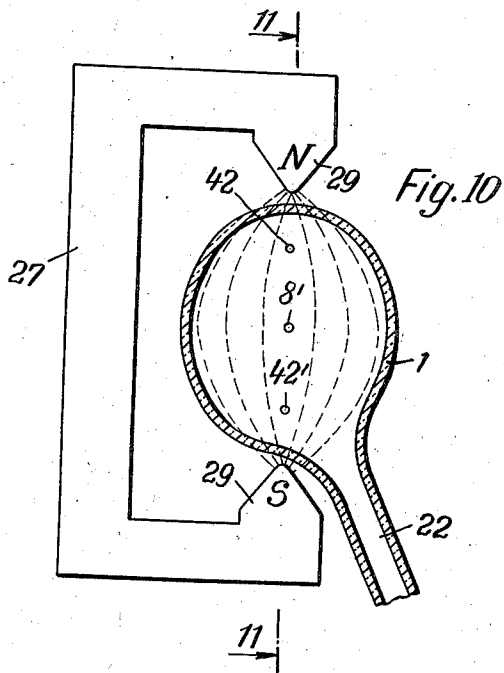
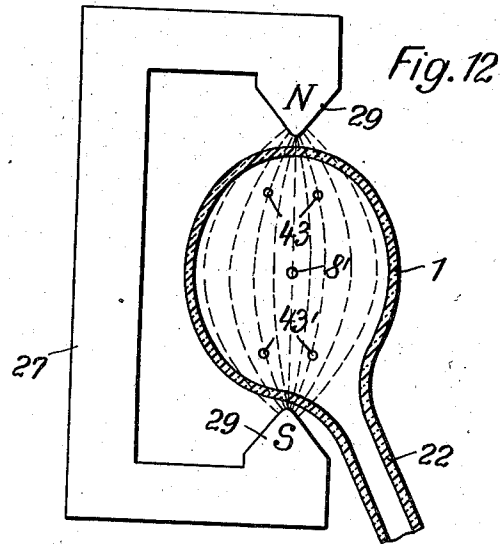
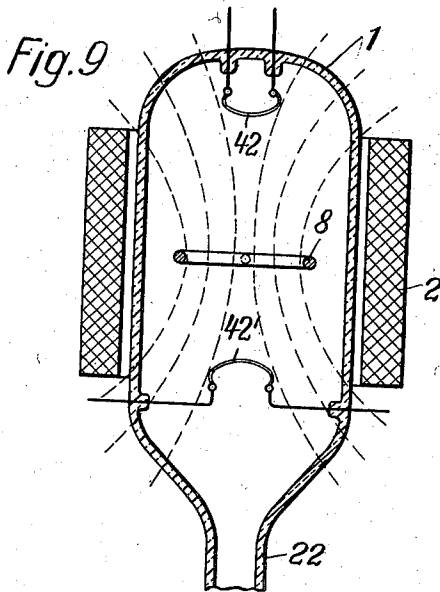
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ELECTRON TUBE AND METHOD OF OPERATING THE SAME

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5 Sheets-Sheet 5



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UNITED STATES PATENT OFFICE

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ELECTRON TUBE AND METHOD OF OPER-
ATING THE SAME

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Application June 1, 1934, Serial No. 728,565
In Germany June 3, 1933

12 Claims. (Cl. 250—27)

My invention relates to improvements in electron tubes and in the method of operating the same, and more particularly in electron tubes in which a flow of electrons is produced between a glowing cathode and a positive anode. One of the objects of the improvements is to provide an electron tube and a method of operating the same by which the vacuum in the tube or in a high vacuum container connected therewith is reduced. With this object in view my invention consists in causing the electrons emitted from the cathode to perform oscillating movements, so that said electrons are not directly transmitted from the cathode to the anode, the said electrons flowing past the anode and having the direction of their flow once or several times reversed so as to be transmitted to the anode after one or more oscillating movements. Such oscillating movement may be imparted to the electrons by means of suitably arranged magnetic or electric fields.

My invention is based on the fact that the electrons emitted from the cathode impinge upon gas molecules contained within the receptacle and transform the same by ionization into ions. These ions are thrown against the glass wall of the tube or against another suitable body and are absorbed in such wall or other body. If the gas pressure within the receptacle is small the number of the ionizations is likewise small, and the probability of an electron meeting a gas molecule is proportional to the number of the gas molecules within the receptacle and therefore to the gas pressure. The length of the way of an electron, with which the probability of a gas molecule being met is 1, is described as the free length of way of the electrons. The value of the free length of way is inversely proportional to the gas pressure.

By causing oscillating movement of the electrons the length of the way thereof between the cathode and the anode is increased, and thereby in the operation of the tube the number of the ionizations is accordingly increased. If therefore, instead of passing in direct path from cathode to anode, the electrons are made to oscillate within the receptacle, the gas occupying the free space within the tube may by absorption of the gas molecules on the walls of the receptacle within a short period of time be reduced to a fraction of the initial quantity.

In order to prevent the electrons moving past the anode from impinging upon the wall of the receptacle and transforming their kinetic energy into heat or radiation, as in a Braun tube, a negative charge is provided at the side of the anode remote from the cathode, for example by providing an electrode having a negative potential, or by imparting a negative charge to the part of the wall of the receptacle remote from the cathode, or by shaping the said wall so that it is initially impinged upon by electrons emitted from

the glowing cathode and moving past the anode. When the wall of the receptacle, consisting of glass or of another non-conductive medium, has received a negative charge from the said electrons, it acts in the same way as an electrode of negative potential, so as to reverse the direction of the flow of the electrons moving past the anode. In my improved system the vacuum within the receptacle or within a container communicating therewith may be measured in a simple and exact way. The current which is delivered from an electrode located between the cathode and the anode and having a potential intermediate the potentials of the cathode and the anode may be used for measuring the vacuum. In the same way the current delivered from an electrode located at the side of the anode remote from the cathode, and having a potential which is negative as compared to that of the cathode, may be used for measuring the vacuum. This is based on the fact that the gas pressure is inversely proportional to the free length of way of the electrons, and on the further fact that a constant fraction of the ions caused by ionization of the molecules by the electrons collect upon the electrode of median potential (or upon the electrode located beyond the anode and having a negative potential relatively to the cathode). The current delivered from the electrode is in either case proportional in value to the number of the ionized gas molecules that collect upon it; and accordingly, the value of this current is indicative of the free length of way of the electrons and of the gas pressure.

As the number of the ionizations is multiplied by my improved method, the intensity of the current delivered from the third electrode is likewise multiplied, and as, for measuring the pressure, the current must be compared with the current supplied to the cathode, the measurement is made more exact, because the difference between the values of the said currents is considerably reduced.

For the purpose of explaining the invention several examples embodying the same have been shown in the accompanying drawings in which the same reference characters have been used in all the views to indicate corresponding parts. In said drawings,

Fig. 1 is a sectional elevation showing an electron tube and its electrical connections which may be used either for measuring a vacuum or for improving the said vacuum,

Fig. 2 is a similar sectional elevation showing an electron tube constructed for having the vacuum improved,

Figs. 3 to 5 are similar sectional elevations showing modifications,

Figs. 6 and 7 are diagrammatical views showing my improved apparatus connected with an X-ray tube, for measuring or improving the vacuum thereof,

Fig. 8 is a sectional elevation showing a Braun tube connected with my improved system,

Figs. 9 and 10 are sectional elevations showing modifications,

Fig. 11 is a sectional elevation taken on the line 11—11 of Fig. 10, and

Fig. 12 is a sectional elevation showing another modification.

In the example shown in Fig. 1 the electron tube comprises an elongated receptacle 1 of insulating material such as glass, and an electromagnetic coil 2 connected with a supply of direct current such as a storage battery 3 and generating a magnetic field extending substantially through the inner parts of the receptacle 1. The receptacle 1 is formed with a press 4 for the passage of the leads of the electrodes therethrough. In the top part of the receptacle there is a glowing cathode 5 to which electric current is supplied from a source 6 through leads 7. In the median part of the receptacle 1 there is an electrode, viz. the anode 8, which as shown is annular in form, and which is connected with a lead 10 insulated by a suitable insulating medium 9 and a lead 11 passed through the press 4 and connected with the positive pole of a battery 12. In the bottom part of the receptacle 1 there is a third electrode 13 which as shown takes the form of an annular disk. The lead 15 of the said electrode is likewise insulated with an insulating medium 14, and it is passed at 16 through the press 4 and connected by a lead 20 with the negative terminal of a battery 17. The positive terminal of the said battery is connected with the negative terminal of a battery 12. To the said joint between the batteries 17 and 12 the glowing cathode 5 is connected through a lead 18 including a milliamperemeter 19. The lead 20 connecting the electrode 13 with the battery 17 includes a second milliamperemeter 21. The sources of electric energy, 6, 12, and 17, are adequate to effect the ends described.

The receptacle 1 ends in a reduced elongated neck 22 which communicates with a container 23, for example the receptacle of an X-ray tube, a Braun tube or the like, the vacuum of which is to be improved or measured.

The operation of the tube shown in Fig. 1 is as follows:

The electrons emitted from the glowing cathode 5 flow in a direction towards the anode 8. By the magnetic field generated by the coil 2 they are prevented from directly impinging upon the anode, a large part of the said electrons being made to flow by the action of the field through the free space provided by the annular shape of the anode 8. The said electrons get into the portion 24 of the receptacle, where by the negative potential of the electrode 13 they are arrested in their courses, the direction of their flow is reversed, and they now flow towards the anode, and a part thereof through the annular space provided thereby, whereupon the reversal in direction of flow is repeated. Thus the electrons have oscillating movements, and the number of the oscillations performed by the electrons before they impinge upon the anode may be controlled by the potentials imparted to the electrodes and the shape thereof and particularly by the shape of the anode.

The electrons oscillating between the said three electrodes impinge upon the gas molecules within the container 1 and cause ionization thereof. Thereby the said molecules are thrown on the wall of the receptacle 1, a large part of the said

molecules getting into the microscopic pores of the wall. I have found that the molecules adsorbed by the glass wall have the tendency to pass into the said capillary pores of the wall, where they are absorbed, so that they may be removed from the wall only by heating the same.

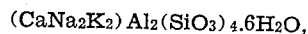
By the considerable increase of the number of the ionizations caused by the oscillation of the electrons, a considerable part of the molecules is made to be absorbed by the glass wall; and thus the vacuum within the receptacle 1 and within the container 23 communicating therewith is improved.

Gas ions produced by the ionization collect also upon the negative electrode, and therefore a current is emitted from the said electrode which is proportional to the number of the ionizations and, accordingly, to the free length of way of the electrons, and to the gas pressure. If this current is compared with the current supplied to the cathode 5, the value of the vacuum within the receptacle may be ascertained by calculation. Both currents are read from the milliamperemeters 19 and 21. Since the number of the ionizations is very high, the current read from the instrument 21 is large, as compared to the current of a system in which the electrons are not made to oscillate. I have observed that the intensity of the current may be increased to the 10^3 fold of the ordinary current. While in a system in which no oscillating movement of the electrons is caused, the currents read from the instruments 21 and 19 are at a ratio of 1:5000000, the ratio of the said currents in the system in which oscillating movement of the electrons is caused is 1:1000.

The system shown in Fig. 1 may be used for improving the vacuum, or for measuring the vacuum, or simultaneously to improve the vacuum and to measure the vacuum.

In the modification shown in Fig. 2 the negative electrode 13 has been omitted. Most of the other parts are similar in construction and arrangement to the corresponding parts shown in Fig. 1, and the same letters of reference have been used to indicate corresponding parts. The electrons emitted from the cathode 5 and flowing through the space left by the anode 8 impinge, at the beginning of the operation, upon the portion 25 of the receptacle 1 located at the rear of the anode 8. Thus a negative charge is imparted to the said portion 25 of the wall of the receptacle, as is indicated in the figure by the minus signs. The said negative charge has the function of the electrode 13 shown in Fig. 1. Therefore, after the portion 25 has been charged, the electrons getting into the space 24 do not impinge any more on the wall of the receptacle, but they are arrested and thrown backwardly through the anode 8.

In the example shown in Fig. 2 a cylinder 26 is located within the receptacle 1, which cylinder surrounds the electrodes. This cylinder is made from a material of high absorbing property, such for example as a body presenting a large surface, such as meerschaum, chabazite,



silica gel and the like. Silicates such as chabazite and silica gel are particularly suitable by reason of their uniform composition. Similar cylinders may be provided in all the examples in which it is desired to improve the vacuum and not merely to measure the same. In the construction shown in Fig. 2 the coil 2 is energized by a source 3' of alter-

nating current, because the direction of the magnetic flux is immaterial.

In the modification shown in Fig. 3 the magnetic field is generated by means of an electromagnet which consists of an iron core 27, a coil 28 and two pole shoes, the upper shoe 29 preferably tapering inwardly and towards the inner part of the receptacle 1 for the purpose of concentrating the magnetic flux, while the lower shoe 30 is provided with a hole 31 for the passage of the neck 22 therethrough.

In the construction shown in Fig. 3 the negative charge of the portion 25 of the receptacle 1 is produced not only by the electrons impinging thereon at the beginning of the operation, but in addition by an outer metallic coating 32 connected with the negative pole of the battery 17. Otherwise, the construction is similar to the one illustrated in Fig. 1.

In Fig. 4 I have shown a modification in which oscillation of the electrons is produced by an electric field. As shown in the said figure, between the anode 8 and the glowing cathode 5 a metal cylinder 33 is provided around the flow of the electrons, which cylinder is connected by a lead 34 with the negative pole of the battery 12, and which therefore has the potential of the cathode 5. Otherwise, the construction is similar to the one illustrated in Fig. 2.

Since by the intense gas ionization caused by the oscillation of the electrons the gas is consumed, the vacuum is varied while measuring. In cases in which such reduction of the vacuum is not desired, means may be provided for preventing the consumption of gas.

Suitable means are shown in the system illustrated in Fig. 5. Within the receptacle 1 there is a metal cylinder, for example a platinum cylinder 35, which surrounds the electrodes. I have found that the absorption of the molecules by the metallic body is considerably less than that by bodies of insulating material such as glass, silicates etc. Therefore in the system shown in Fig. 5 the consumption of gas is considerably reduced, so that the vacuum may be measured without being simultaneously reduced in a considerable degree. Such metal cylinders may also be used for regulating the intensity of the absorption of gas, if such regulation is desired.

In Figs. 6 and 7 I have illustrated the use of the system in connection with an X-ray tube. As is shown in Fig. 6 the receptacle 23 of the said X-ray tube is formed with a subsidiary chamber 36 in which the glowing cathode 5, the anode 8 and the negative electrode 13 are located. The magnetic field is generated by means of an electromagnet comprising a core 27 and a coil 28. In this construction the system may be used either for increasing the vacuum within the X-ray tube or for measuring the said vacuum.

The construction shown in Fig. 7 is distinguished from the one illustrated in Fig. 6 by having the electrodes 5, 8, and 13 disposed within a separate container 1 located within an electromagnetic coil 2, the construction of the said receptacle being similar to the one illustrated in Fig. 1. The neck 22 communicates with the X-ray tube 23 through the side wall thereof, and if desired it contains one or more cocks for connecting the receptacle with the X-ray tube or disconnecting the same therefrom.

In Fig. 8 I have shown a modification in which a glowing cathode 38, which cooperates with other elements to provide for example a Braun tube, is used for generating the flow of electrons for

consumption of gas or measuring of pressure. The receptacle 1 contains an annular anode 8 and an electrode 36 having a negative potential, and is surrounded by a coil 2 for generating a magnetic field. The receptacle is connected with the Braun tube 37 containing the glowing cathode 38. By means of metal screens 39 of positive potential and a screen 40, the flow of electrons emitted from the glowing cathode 38 is divided into two branches, one flowing into the elongated portion 41 of the Braun tube and the other into the receptacle 1. The electrical connections are similar to those shown in Fig. 1.

Instead of providing an electrode having a negative charge on the side of the anode remote from the glowing cathode, the said third electrode may take the form of a glowing cathode having a negative potential. In this case the glowing cathodes disposed at opposite sides of the anode emit electrons which flow past the anode, the flow of the said electrons being reversed by the glowing cathodes. This modification has been shown in Fig. 9. Within the receptacle 1 two glowing cathodes 42 and 42' are disposed at opposite sides of the annular anode 8. The said glowing cathodes emit electrons, and simultaneously they have the function of the electrode 13 in so far, as they reverse the flow of the electrons.

In Fig. 9 the distribution of the magnetic field produced by the coil 2 has been indicated. If a coil is used for producing the magnetic field the said field is concentrated around the axis of the receptacle, and therefore an annular anode is suitable, the said annular anode being preferably located substantially at the middle of the coil.

In the examples so far described annular anodes have been used. But I wish it to be understood that the invention is not limited to this feature, and that anodes of other shapes may be used.

For example, in Figs. 10 and 11 I may provide an anode or anodes in the form of a rod. In this case either by the shape of the anode or by a suitable distribution of the magnetic field care must be taken that the lines of force of the field are located laterally of the anode.

In the construction shown in Figs. 10 and 11 a magnetic core 27 of iron or steel and comprising pole shoes 29 is provided, in which case the lines of force are expanded between the poles of the core in the manner shown in the figure. In this case an anode 8' in the form of a rod is suitable, so that the electrons following the lines of force move past the said anode.

In the construction shown in Figs. 10 and 11 two glowing cathodes 42 and 42' are provided at opposite sides of the anode 8'. The yoke 27 may be provided with an exciting coil, or it may be a permanent magnet.

In the modification shown in Fig. 12 an anode 8' in the form of a rod is provided at the middle between the pole shoes 29. Instead of a single glowing wire two parallel glowing wires 43 and 43' are provided at either side of the anode. Therefore there are no lines of force which intersect both the glowing cathode and the anode, and therefore the probability that none of the electrons emitted from the cathodes directly meets the anode 8' is further increased.

If the receptacles containing the glowing cathode and the anode for improving the vacuum are connected with a container, the vacuum of which is to be improved or measured, it is preferred to

provide the neck 22 connecting the receptacle with the container so that it is substantially located in the direction of the flow of the electrons.

Of the magnetic field it will be observed that in each case the lines of force are symmetrical with respect to an axis, and that the cathode and anode are so situated with respect to that axis that the electrons emitted from the cathode and tending to travel to the anode are by the presence of the magnetic field subject to a diverting influence, with the consequence and effect that they oscillate to and fro relatively to the anode.

I claim:

1. An electron tube comprising a receptacle, a body of gas within the receptacle attenuated to a degree affording free length of way for electrons, a cathode and an anode arranged within the receptacle, means for diverting from otherwise normal paths electrons emitted by the cathode and causing them in increased numbers to pass by without impinging upon the anode, and means for effecting reversal in the direction of electrons so passing by the anode.

2. An electron tube comprising a receptacle, a cathode and an anode within said receptacle, means to cause ionizing emission of electrons from said cathode, means for diverting from their otherwise normal paths of travel electrons emitted by the cathode and causing them in increased numbers to pass by the anode without impingement thereon, and means including an electrode of negative potential relatively to the cathode arranged within the tube on the opposite side of the anode from the cathode and adapted to produce an electric field within said receptacle having direction and intensity such as to repel electrons so emitted by the cathode and passing by the anode and to cause them to advance toward said cathode again.

3. An electron tube comprising a receptacle, a body of gas within the receptacle attenuated to a degree affording free length of way for electrons, a cathode and an annular anode arranged within said receptacle, means to cause ionizing emission of a stream of electrons from said cathode toward said anode, means for producing a magnetic field spatially concentric with respect to said annular anode, whereby the electrons advancing in such stream are diverted and caused in increased numbers to pass by without impinging upon the anode, and means including an electrode of negative potential relatively to the cathode arranged within the receptacle on the side of the anode opposite to the cathode, whereby the electrons so passing by the anode are checked and impelled in opposite direction.

4. An electron tube comprising a receptacle, a body of gas within the receptacle attenuated to a degree affording free length of way for electrons, a cathode and an anode within said receptacle, means to cause ionizing emission of electrons from said cathode, said anode being spaced from the wall of said receptacle remote from said cathode, and such wall of the receptacle remote from the cathode being disposed transversely to the direction of travel of electrons proceeding from the cathode, means for diverting from their otherwise normal paths of travel electrons emitted by the cathode and causing them in increased numbers to pass by the anode and to impinge upon such end wall of the receptacle remote from

the cathode, and an outer conductive coating upon such end wall of the receptacle.

5. An electron tube, comprising, an elongate receptacle, an anode and a cathode within said receptacle, said anode being located at a point intermediate the ends of said receptacle and leaving a space for the passage of electrons, means to cause ionizing emission of electrons from said cathode, means counteracting direct transmission of the ionizing electrons to said anode, a conductive body located within the said receptacle at the side of the anode remote from the cathode, and a circuit including a source of electric potential difference and connected with said cathode, anode and body and adapted to impart a negative potential to said body, a positive potential to said anode, and a potential intermediate the said potentials to the cathode, and means to measure the relation between the currents flowing from said source through the said body and through the cathode.

6. An electron tube as claimed in claim 5, in which in addition means are provided for preventing the gas molecules impinged upon by the ionizing electrons from being taken up by the wall of said receptacle.

7. An electron tube as claimed in claim 1, in which in addition a body of high gas absorbing property is provided within said receptacle.

8. An electron tube as claimed in claim 1, and a high vacuum container, the receptacle of the tube and the said container being in open communication one with the other and being filled in common with such body of attenuated gas.

9. The method herein described of improving the vacuum in an electron tube filled with a body of gas attenuated to a degree affording free length of way for electrons and containing an anode and a cathode, which consists in setting up a stream of electrons from the cathode toward the anode and subjecting the stream of electrons to a course-diverting impulse, causing them to pass by without impingement upon the anode, whereby the length of the course of travel of the electrons is increased.

10. An electron tube as claimed in claim 1, in which the magnetic field is produced between two magnetic poles located at opposite ends of the receptacle, and in which the anode takes the form of a rod and is disposed between the said poles transversely of the lines of force.

11. An electron tube as claimed in claim 1, in which the magnetic field is produced by magnetic poles located at either end of the receptacle, in which the anode takes the form of a rod disposed transversely of the lines of force, and in which the glowing cathode comprises two rod-shaped wires disposed one beside the other and substantially parallel to the anode.

12. An electron tube comprising a receptacle, a body of gas within the receptacle attenuated to a degree affording free length of way for electrons, a cathode and an anode within said receptacle, means to cause ionizing emission of a stream of electrons from said cathode toward said anode, means for producing a magnetic field coaxial with such stream whereby the electrons advancing in such stream are diverted and caused in increased numbers to pass by without impinging upon the anode, and means for producing within the receptacle and on the side of the anode opposite to the cathode an electrical field adapted to effect reversal in the direction of travel of electrons so passing by the anode.

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