Dec. 10, 1929. A. MUTSCHELLER 1,738,960

VACUUM DISCHARGE DEVICE AND METHOD OF USING THE SAME

Filed March 30, 1926 2 Sheets-Sheet 1

FIGURE 1

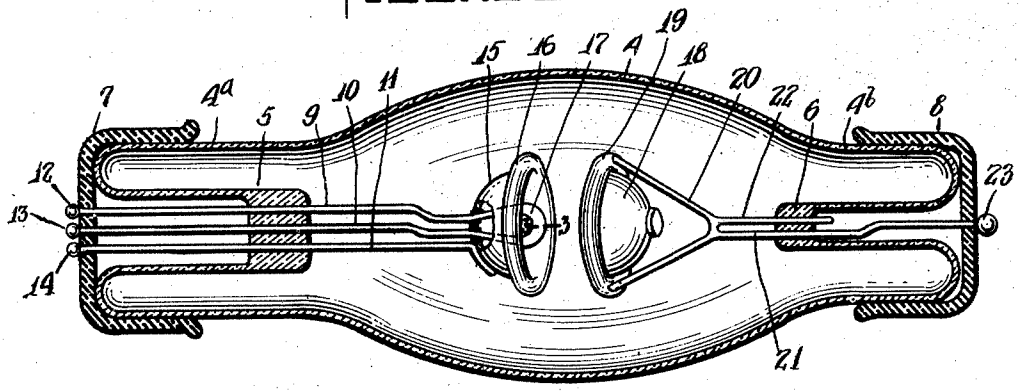


FIGURE 2

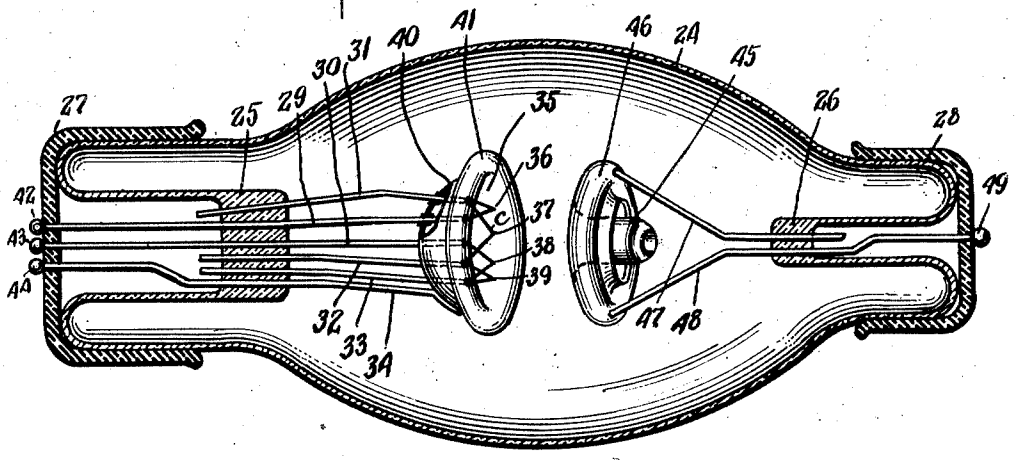


FIGURE 3



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Filed March 30, 1926 2 Sheets-Sheet 2

FIGURE 4

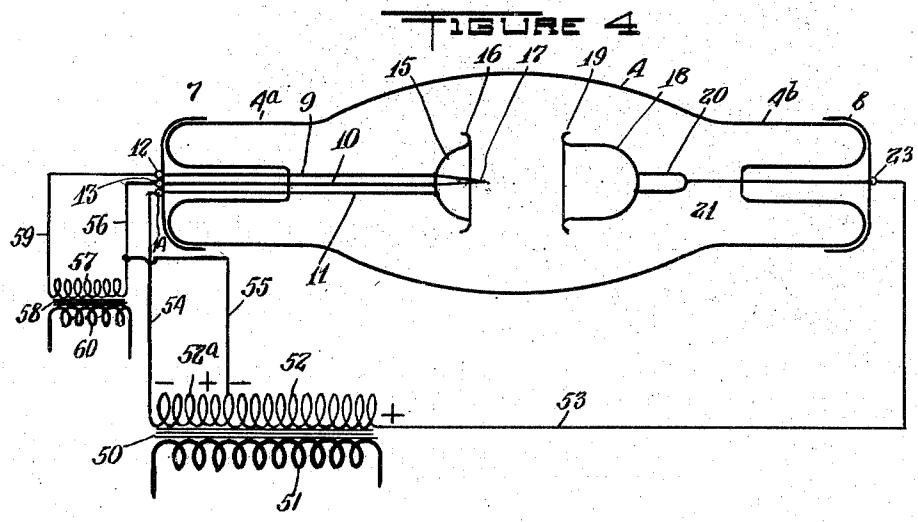
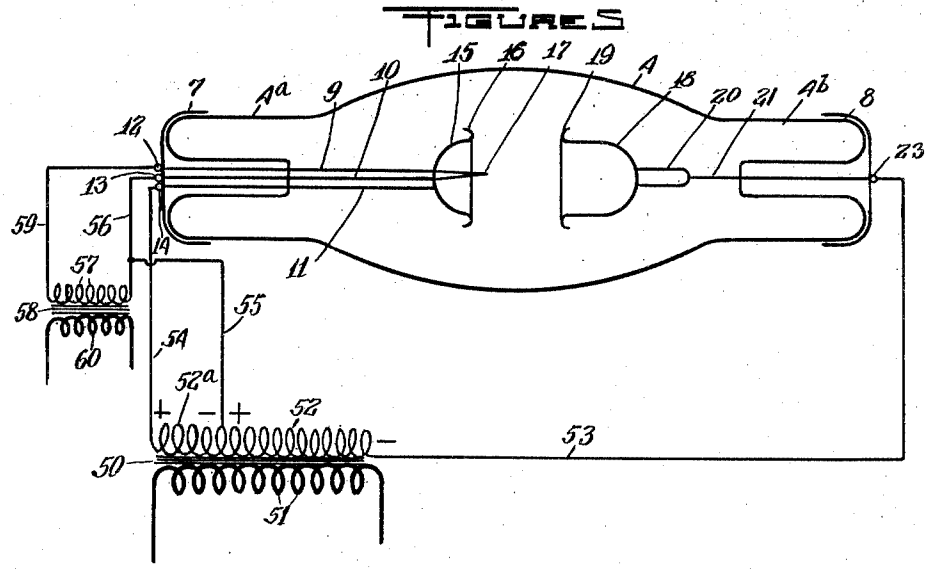


FIGURE 5



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UNITED STATES PATENT OFFICE

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VACUUM DISCHARGE DEVICE AND METHOD OF USING THE SAME

Application filed March 30, 1926. Serial No. 98,457.

The vacuum discharge device contemplated by this invention is essentially a vacuum tube in which the passage of current from one electrode to the other is effected by the passage of electrons, generated at the cathode, in the manner outlined generally in my pending application, Serial No. 560,545, filed May 15, 1922.

By means of my invention it is possible to fix and to control the emission of electrons from a heated cathode, dependent upon the voltage applied to the terminals of the tube; and this cannot be done with any of the devices hitherto known in this art.

Furthermore, through my invention I am able to vary, theoretically without limit, those characteristics and constants which have heretofore been universally regarded as invariable and fixed, and which were claimed and used to define such conditions as degree of vacuum and absence or presence of positive ionization, etc., as described and defined in the prior art. These new results therefore make up convincing proof that the principle underlying my invention has not been previously known to those skilled in the art, and that many new effects are obtainable through the application of my invention in the vacuum discharge technique.

In order to visualize my invention in a general way, let us assume that we have before us a heated cathode facing toward the anode. Then if the edge is blunt and approaches a plane perpendicular to an imaginary line connecting the anode with the cathode, the current emitted obeys, in the voltage region below saturation, the Lilienfeld-Langmuir equation, and in the saturation region obeys the Richardson equation. If, however, by one of the methods indicated, an electrostatic field is concentrated upon the edge facing toward the anode and this edge is made increasingly sharper or is brought nearer to the anode, or rendered sharper and also brought nearer the anode, then the current will increase above the respective values called for by the foregoing equations.

Again, let us assume that we place to the rear of the heated cathode a shield, electrically connected therewith, and so shaped as to concentrate an electrostatic field upon the heated portion of the cathode, then the current passing between the cathode and the anode will still further increase above the values corresponding to those expressed in the equations above discussed.

Furthermore, by insulating the shield from the heated cathode and impressing an adequate difference of negative potential between the shield and the cathode, there is then an increase in the amount of current passing through the tube above the corresponding values in the aforesaid equation, provided the potential applied to the shield is negative relatively to the cathode. If the potential applied to the shield is positive relatively to the cathode, the value of the current passing through the tube is decreased. It follows, therefore, that a much larger discharge current can be obtained in instances where the potential of the shield is negative instead of positive relatively to the cathode. Thus in one case, when the anode of the tube is positive, the cathode is negative and the shield is negative with respect to the cathode, then the resistance through the tube is greatly decreased and a considerably larger current than that corresponding to the aforementioned equations of the prior art will pass through the tube. If, however, the polarity at the electrodes of the tube and the potential between the shield and the cathode are reversed, then the resistance of the tube is considerably greater than otherwise with the ordinary kinds of flat cathodes and therefore, under otherwise like conditions, with my device there is a greater and more pronounced valve action than with the valve tubes of the prior art.

These features are particularly prominent and useful when high voltage alternating currents are to be rectified. This is due to the fact that if any impulse in the desired direction tends to pass, the valve tube offers less resistance, and if an impulse in the undesired direction tends to pass, the valve tube offers more resistance than the usual type of valve tubes would offer. This constitutes a materially improved and highly valuable increased valve effect.

This applies to both cases of the discharge tube operating below saturation as a valve tube, or above saturation as an X-ray tube. In a X-ray tube the feature of my invention enables the obtaining of a larger self-rectifying action of the tube if it is energized with alternating current. But with the aid of a properly functioning device and by regulating the voltage on the shield with respect to the cathode, it is possible to select the passage of any desired portion of the current implse, and on the other hand, to prevent a certain undesirable portion of the current impulse from passing through the X-ray tube. Such devices for regulating the voltage on the shield with respect to the cathode may be synchronously rotating contacts through which the voltage on the shield is either made of broken, or may be any static modulatory device consisting of condensers and inductances capable of producing the desired voltage variation between the shield and the cathode.

By referring to Figures 4 and 5, the mode of action of my device as compared with the discharge tubes of the prior art can easily be traced and understood by one skilled in the art.

The principle of my invention thus explained, I will next describe certain forms of apparatus which illustrate and embody the points in which my device differs from the various vacuum discharge tubes of the prior art. These forms are, however, only typical examples, and variations from these constructions can be made without departing from the spirit of my invention.

Reference is made to the accompanying drawings forming a part of this specification, and in which like reference characters indicate like parts throughout the several figures.

Figure 1 is a longitudinal section, showing a form of vacuum discharge device made in accordance with my invention, and in which the heated cathode presents a knife-like edge toward the anode.

Figure 2 is a longitudinal section showing another form of vacuum discharge device embodying my invention, and in which the heated cathode presents toward the anode a number of sharp points.

Figure 3 is a section on the line 3—3 of Figure 1, and indicates the form of the cathode, as seen in cross section.

Figure 4 is a diagram indicating the manner in which I bias the polarity of the electrostatic shield relatively to the cathode, so that whenever the anode is for the moment positive, the electrostatic shield is more negative than the cathode.

Figure 5 is a diagram of the apparatus appearing in Figure 4, and indicates that whenever the anode is for the moment negative, the electrostatic shield is less negative than the cathode.

I will first described the form of my device appearing in Figure 1.

An exhausted tube 4, in this instance made of glass, has a general ellipsoidal form, and is provided with a pair of end portions 4^a, 4^b, each of substantially cylindrical shape. These end portions are provided with inwardly extending supporting members 5, 6.

Fitted upon the cylindrical portions are a pair of end caps 7, 8, made of insulating material such as hard rubber or some composition used as a substitute therefor.

Extending through the supporting member 5 and thus sealed into the tube are three metallic rods 9, 10, 11. The two rods 9 and 10 serve as conductors, and the rod 11, used primarily as a mechanical support, has also a function as a conductor. The rods 9, 10 and 11, preferably made of stout wire, are provided with terminal connections 12, 13, 14, which may be binding posts or otherwise, as required.

An electrostatic shield appears at 15, and has generally the form of a pot. It is carried by the rod 11, and is provided with a flaring portion 16, integral with it and having the form of a brim. Located within the electrostatic shield 15, but insulated from it, is the cathode 17. This cathode has the general form of a cimeter, and is adapted to be heated. For this purpose it is at its ends connected with the rods 9 and 10 through which it is energized. It is provided with a sharp edge 17^a, like the edge of a knife or razor, as indicated in Figure 3.

The electrostatic shield and the cathode are each made of highly refractory metal, such as molybdenum, nickel, tungsten or the like.

By making a conductive connection from the rod 10 to the rod 11, as for instance by extending a bit of wire from the terminal 13 to the terminal 14, the electrostatic shield 15 and cathode 17 can be connected together and thus caused to operate as a unit.

I find that when the cathode 17 is heated, the sharp edge 17 is the hottest part thereof.

The anode is shown at 18, and has the general form of an open pot, provided with a brim 19, and facing toward the cathode. The anode is made of refractory material, such as tungsten or molybdenum.

The anode is mounted upon a supporting member 20, also made of refractory metal, and having in this instance two rod-like portions 21 and 22, extending through and sealed into the in-turned portion 6 of the X-ray tube. The rod-like portion 21 also extends through the end cap 8, and carries a terminal 23, which may be a binding post.

Thus the parts are so arranged that the cathode 17 presents its sharp, knife-like edge 17^a toward the adjacent concave face of the anode 18. It follows that with my device in action a considerable portion of the dis-

charge takes place directly between the anode as a whole and the sharp edge of the cathode.

Previous to the exhaustion of the X-ray tube the anode and cathode, together with their supports, are freed from occluded gases in the manner well known, and the exhaustion of the tube is made as thorough as possible.

My purpose in giving to the tube 4 the shape shown and above described is to avoid the repulsive effects of electrons and ions which remain stored in the concave surfaces of bulbs of approximately spherical form. In my apparatus, the electrons and ions, if free of the discharge, tend to recede into the ends of the X-ray tube and thus to become less effective in opposing, limiting or otherwise interfering with the electron discharge taking place through the tube. For this purpose the X-ray tube may have, as here indicated, such form that its greatest cross diameter is approximately double the cross diameter of either end portion 4^a or 4^b.

If as above described the electrostatic shield 16 be placed in direct metallic communication with the heated cathode 17, as for instance by extending a bit of wire from the terminal 13 to the terminal 14, and an alternating current potential be impressed upon the anode and cathode, the electrostatic shield will of course develop such differences in potential relatively to the anode as are developed between the anode and cathode. If, however, the electrostatic shield remain disconnected from the cathode, and has impressed upon it from an outside source an electromotive force independent of the difference of potential between the anode and cathode, the operator by controlling the electromotive force between the electrostatic shield and cathode can regulate with great nicety the discharge through the tube.

I have made the discovery that with the X-ray tube subjected to alternations in potential, if the electrostatic shield 15 has at any particular instant a potential which is negative relatively to the cathode 17, the discharge taking place through the X-ray tube is the maximum discharge obtainable. When, however, the current reversal takes place so that for the moment the heated cathode becomes positive relatively to the anode, and yet the electrostatic shield, controllable from outside, is positive relatively to the cathode, the discharge through the tube is greatly lessened, the electrons being apparently unable to leave the cathode, or at least unable to leap to the anode. Thus the valve action of the tube is greatly pronounced.

In the form shown in Figure 2 the essential principles are the same, but the construction is somewhat different.

The tube is shown at 24, and is provided with inturned end portions 25, 26, carrying end caps 27, 28.

A number of small metallic rods are shown at 29, 30, 31, 32, 33 and 34, all extending through the inturned end portion 25. The rods 29, 30 and 34 are larger than the others, and extend through the end cap 27.

Supported upon the rods 29, 30, 31, 32 and 33 is a fine wire 35, made of refractory metal such as tungsten, molybdenum or the like, and bent at intervals to form sharp points 36, 37, 38, 39. In the particularly instance here shown, the wire may be considered as starting from the rod 29 and ending upon the rod 30. The wire is heated by currents or impulses supplied to it through these two rods, and there are four sharp points arranged in crown formation. However, this number is purely arbitrary, as a single point or any larger number may be used. While as here shown the wire presents sharp points, it may if desired be made to present a continuous linear edge, as required.

An electrostatic shield 40, made of refractory metal, and provided with a reverting edge 41 formed into a brim, is supported upon the rod 34.

Terminals 42, 43 and 44, which may be binding posts, are provided for the rods 29, 30 and 34, and their use may be understood by reference to the foregoing remarks relative to the members 12, 13 and 14.

The anode appears at 45, and is substantially pot shaped. It is provided with an edge portion 46, formed into a brim, and is mounted upon two rods 47, 48, which extend through the inturned end portion 26 of the tube, the rod 48 being longer than the rod 47, and extending through the end cap 28. The rod 48 carries a terminal 49, which may be a binding post.

Except as otherwise described, the structure and action of the structure shown in Figure 2 are the same as in Figure 1.

In Figures 4 and 5 I show in diagrammatic form the X-ray tube above described with reference to Figure 1, with the addition of a transformer apparatus arranged for energizing the tube and for biasing the potential of the electrostatic shield relatively to the potential of the cathode thereof.

A high tension transformer appears at 50, and is provided with a primary winding 51 and with a secondary winding 52. A wire 53 extends from one end of the secondary winding to the tube terminal 23, and a wire 54 extends from the opposite end of the secondary winding to the tube terminal 14.

A tap wire 55 is connected with the secondary winding 52 at a point intermediate the ends thereof, so as to tap off a few convolutions 52^a thereof, this tap wire being also connected to a wire 56, the latter being connected to the tube terminal 13. The wire 56 is connected with the secondary winding 57 of a small heating transformer 58. Another wire 59 leads from the secondary wind-

ing 57 of this transformer to the tube terminal 12.

The heating transformer 58 is provided with a primary winding 60 whereby it is energized, in the manner well known in this art, the heating transformer being energized in phase with the high tension transformer 50.

The plus and minus shown in Figures 4 and 5 indicate differences in potential at different points along the secondary winding of the high potential transformer, and thus render apparent the relative effects of these differences of potential upon the electrodes and parts immediately associated therewith.

For instance in Figure 4 the condition of the secondary winding is such that the anode 18 is for the moment positive, the heated cathode 17 negative, and the electrostatic shield 18 still more negative; but in Figure 5 the anode is for the moment energized negatively, the heated cathode 17 being positive and electrostatic shield 15 still more positive. Thus it will be noted that the extremes of potential are always greater between the anode and the electrostatic shield than between the anode and cathode.

The result of this arrangement is that with the apparatus in the condition indicated in Figure 4 the electrostatic shield 15, because its potential is negative relatively to the cathode 17, has not only a repellant effect upon the electrons hurled from the cathode, and thus drives them toward the anode, but appears also to increase their number; whereas with the apparatus in the condition indicated in Figure 5, or in other words with the polarity of the high tension transformer reversed, the electrostatic shield attracts instead of repels the electrons hurled from the cathode, and thus diverts them in considerable numbers from reaching the anode.

It follows that when the X-ray tube is energized by a transformer apparatus arranged as indicated in Figures 4 and 5, or by any other apparatus in which the X-ray tube is subjected to alternations of high potential, the valvular action of the tube is greatly accentuated. That is to say, there is a liberal passage of electrons from the cathode to the anode when the energizing current impulse is in one direction, and a practically complete stoppage of electrons when the energizing current impulse is in the opposite direction. This improves the character of the X-rays generated, and prevents the deterioration or destruction of the tube in consequence of current impulses sent through the tube in the wront direction.

I find that with an X-ray tube or other vacuum discharge device made in accordance with my invention there is no limitation due to a condition of saturation, and no limitation due to the presence or absence of interfering positive ionization as in the prior art.

I do not limit myself to the precise apparatus shown, as variations may be made therein without departing from my invention, the scope of which is commensurate with my claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is as follows:

1. The method herein described of assisting the thermionic emission between an anode of relatively large size and a cathode of small size having a sharp edge, which consists in subjecting the cathode to the double effect of a repellant negative electrostatic field from a region behind the cathode, and an attractive positive electrostatic field, from said anode of relatively large size upon said sharp edge of said cathode, for the purpose of producing an attenuated negative electrostatic field in front of said cathode.

2. The method herein described of assisting the thermionic emission between an anode and a cathode, and effecting a substantially controllable discharge between the anode and the cathode, said cathode being heated to a temperature below the normal thermionic discharge temperature, by subjecting said cathode to the repellant action of an intensified negative electrostatic field back of the electron-emitting part of the cathode, in order to produce an attenuated negative electrostatic field in front of said cathode.

Signed at Long Island City, in the county of Queens and State of New York, this 26th day of March 1926.

ARTHUR MUTSCHELLER.