Jan. 3, 1939. E. D. McARTHUR 2,142,857

VACUUM TUBE

Filed May 24, 1935 2 Sheets-Sheet 1

Fig. 1.

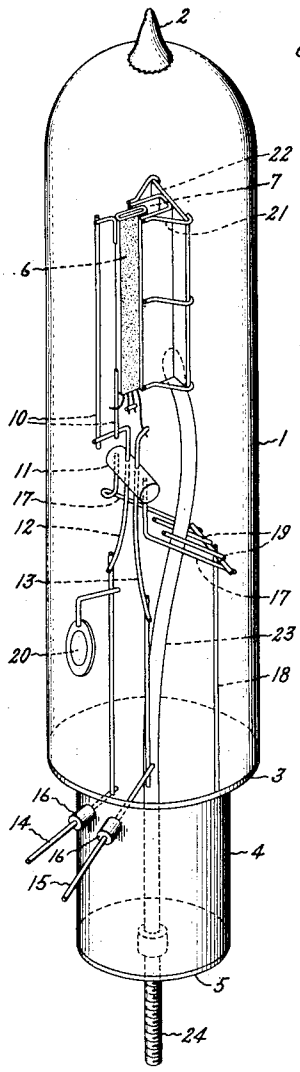


Fig. 2.

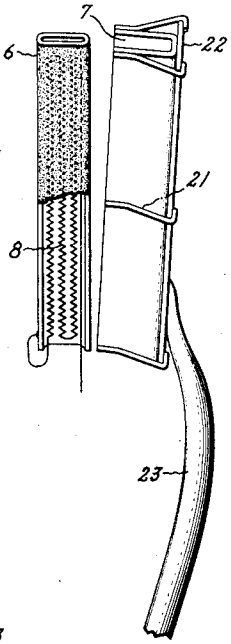


Fig. 3.

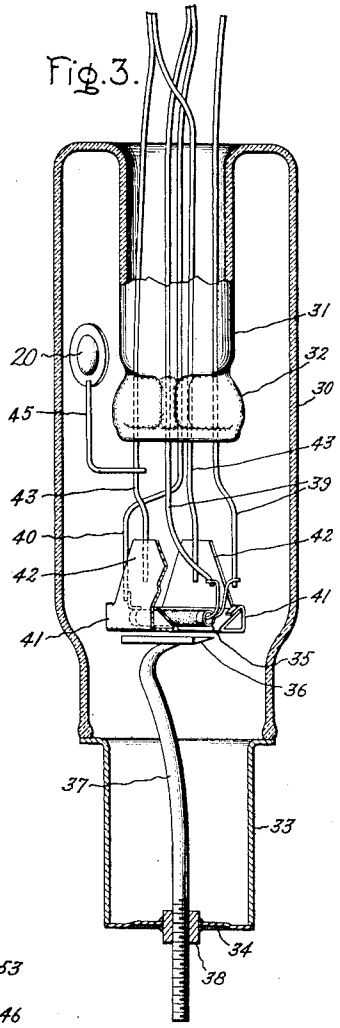


Fig. 5.

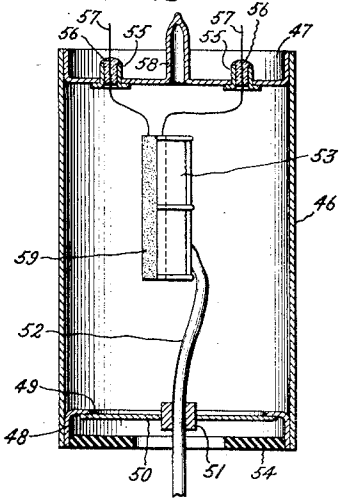
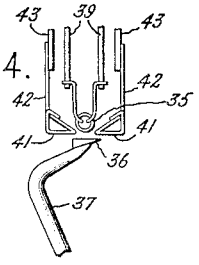


Fig. 4.



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Fig. 6.

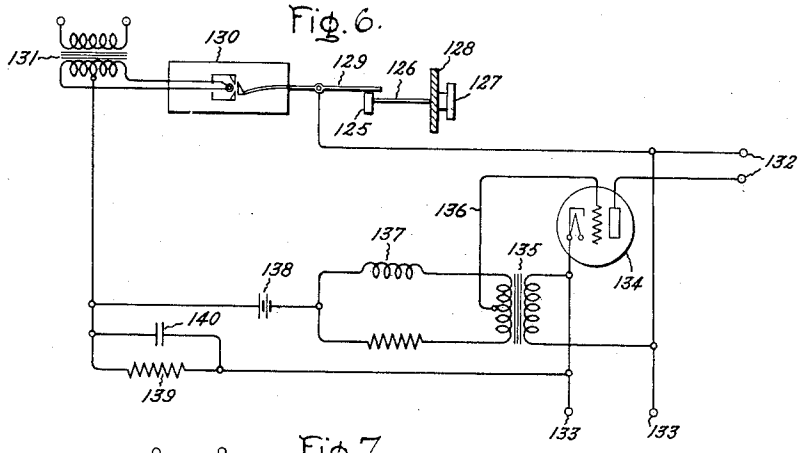


Fig. 7.

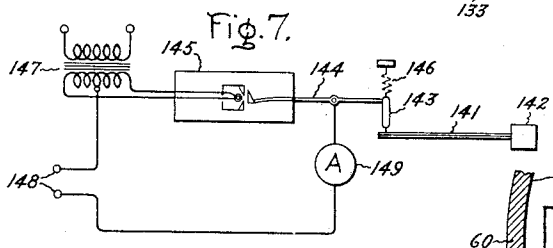


Fig. 10.

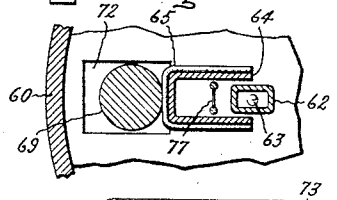


Fig. 8.

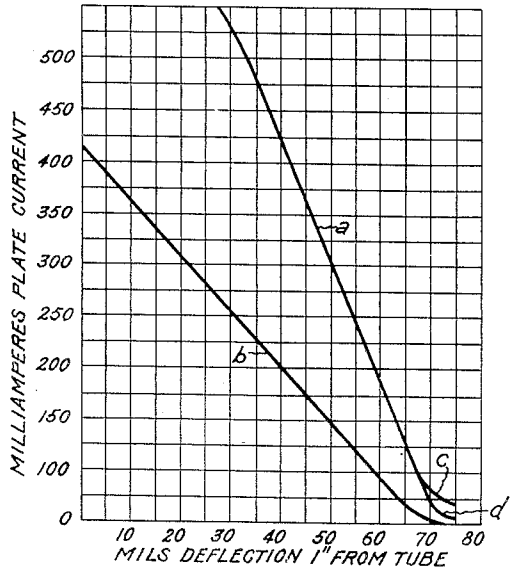
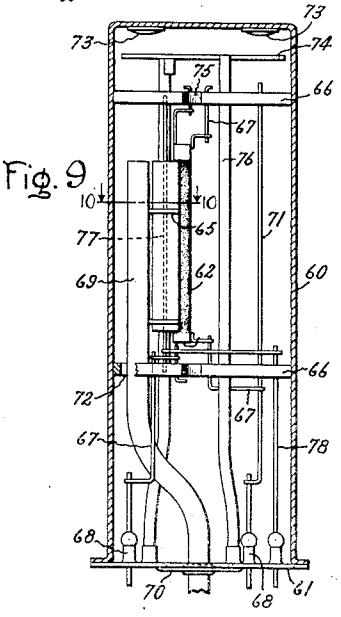


Fig. 9



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2,142,857

UNITED STATES PATENT OFFICE

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VACUUM TUBE

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Application May 24, 1935, Serial No. 23,194

10 Claims. (Cl. 250—27.5)

The present invention relates to electric discharge apparatus and more particularly to electrical devices which are adapted to be controlled and which serve to translate physical movements and changes of force and pressure, etc., into measurable changes of electric current.

In the electron discharge art, several methods have heretofore been employed for controlling an electron stream passing between a cathode and an anode. The commonest form of control is a charged electrode interposed between the main electrodes and which provides an additional electrostatic field for electrostatically accelerating or retarding the electrons. In other types of devices, the electron stream is mechanically impeded in a variable manner by a movable barrier. The anode or cathode itself may also be caused to vibrate or to move with respect to one another in order to change the length of the path through which the electrons have to move, thereby presenting variable impedance to the electron stream. The present invention concerns none of these prior methods of control but is directed to a novel type of control in which the electron-emitting or electron-receiving areas of the various electrodes are affected without necessarily changing the distance between the electrodes.

In a pure electron discharge device, i. e. a tube in which gas ionization is either entirely absent or is negligible, the discharge current passing through a given space, and assuming that the cathode is at a sufficiently high temperature for the voltages employed, varies directly as the 3/2 power of the impressed voltages. This relation may be expressed by the usual space charge equation:

$$I=\frac{aV^{3/2}}{d^2}$$

where I is the current through the tube measured in amperes per square centimeter of cathode surface; a is a constant depending on the area and configuration of the electrodes; V is the voltage impressed between the electrodes; and d is the distance in centimeters between electrodes. From a consideration of this equation it will be seen that the current through the tube varies directly as the area of the electrodes and the impressed voltage, and inversely as the square of the distance between the electrodes. The present invention contemplates an improved tube structure which operates in accordance with the space charge equation given above and one in which only the effective area of the electrodes is changed in order to produce a corresponding change in the magnitude of an electric current passing through the tube.

An object of the present invention, therefore, is to provide an improved thermionic vacuum tube and in particular, an improved device which translates physical movements, or changes in pressure or force into electric currents which may be measured or indicated. In brief, this object is attained by the use of a high vacuum thermionic device in which one electrode is moved with respect to the other in such a manner as to vary the effective area of either electrode or both, however, without necessarily changing the distance or the voltage between the electrodes. The electrodes are moved in parallel planes, the movement being preferably obtained by means of a lever arm which extends to the exterior of the envelope and is so pivoted as to provide an augmented movement of the movable electrode for relatively small movements of the opposite end of the lever.

The invention will be more fully understood when reference is made to the following description and the accompanying drawings in which Fig. 1 is a view in elevation of a tube improved in accordance with the present invention; Fig. 2 shows a partly sectional view of the cathode and anode illustrated in Fig. 1; Fig. 3 is a cross-sectional view, partly in elevation, of a modified improved tube; Fig. 4 is an end view of the cathode and anode structure shown in Fig. 3; Fig. 5 shows an adaptation of the invention to an "all-metal" tube; Figs. 6 and 7 diagrammatically illustrate the manner of application of the improved tube; Fig. 8 shows certain characteristics of the improved tube; Fig. 9 illustrates a commercial form of metal tube embodying the invention; and Fig. 10 is a cross-sectional view taken along line 10—10 of Fig. 9.

In Fig. 1, numeral 1 designates a glass envelope which terminates at the upper end as shown, in the usual seal-off tip 2, and at the lower end is butt-sealed to a metal disk 3 which carries a metal cup member 4. The disk 3 is made of a metal which has substantially the same thermal expansion characteristic as the glass envelope 1 over the entire temperature range between 0° C. and the softening temperature of the glass. Thus no stress or strain is introduced at the butt joint during fabrication of the seal or during any subsequent heat treatment. While various metals and glasses may be employed for this purpose, the freedom from stress and strain at the seal being dependent upon the amount of materials involved and the respective differences

of thermal expansion at the various temperatures reached during the manufacture of the tube, I prefer to employ materials which have been disclosed and claimed in the Burger and Hull application Serial No. 705,250, filed January 4, 1934 and entitled "Glass-to-metal seals", assigned to the same assignee as the present invention. This application has matured into Patent No. 2,071,196. As pointed out in the Burger and Hull patent, a metal which may be employed for a substantially strain-free seal, regardless of the amount of metal and glass used or regardless of the temperatures reached during manufacture, consists approximately of 18% cobalt (Co), 28% nickel (Ni), 54% iron (Fe), and the glass in this case may have the following approximate composition: 65% silica (SiO_2), 23% boric oxide (B_2O_3), 7% sodium oxide (Na_2O) and 5% aluminum oxide (Al_2O_3). The cylinder 4 may have the same composition as the disk 3 or may be constituted of entirely different metal which may be satisfactorily welded to the metal of the disk. The lower end (as shown) of the cylinder 4 is hermetically closed by a disk of metal 5 which is so thin (approximately 3 mils thick) as to be flexible and constitute a diaphragm.

Within the envelope there are a cathode 6 and an anode 7, the anode being movable as will be explained in detail hereinafter, with respect to the cathode. The cathode may constitute a flattened cylinder member coated on the exterior with an electron-emitting material, such as alkaline earth oxide, and containing a heater 8, as shown more clearly in Fig. 2, which may take the form of several loops of wire wound in any suitable and well-known manner. The cathode is maintained rigidly in position within the envelope by means of a pair of rigid supports 10 which are secured to a glass rod or bead 11. The latter is held in position by means of a pair of rigid conductors 12, 13 which are connected to a pair of stiff leading-in conductors 14, 15 respectively, passing through the metal cylinder 4. The conductors 14, 15 are insulated from the cylinder by means of glass cylinders (not shown) contained within the metal eyelets 16. These eyelets are welded to the cylinder and preferably have the same thermal expansion characteristic as the glass cylinders. The bead 11 is also rigidly held in position by means of a pair of rods 17 which are secured to an upright 18 and which in turn, is secured to the cylinder 4. The upright 18 carries a pair of horizontally extending projections or fingers 19 which serve as a guide and limit stop when the anode is moved, as will be explained hereinafter. A getter cup and pellet 20 is secured to the wire 12.

The anode consists of a U-shaped member, the distance between the sides of the U being greater than the thickness of the flattened portion of the cathode cylinder so as to leave a space between each side of the cathode and the interior adjacent surfaces of the anode. The sides of the anode are made rigid by means of several equidistantly spaced braces 21 which are secured to a flat plate 22, welded or otherwise secured to the bottom of the U-shaped anode member.

There is secured to the plate 22 a curved rod member 23 which extends between the fingers 19 through the center of the envelope and is hermetically secured to the diaphragm 5. An extension of this rod is taken out to the exterior of the envelope by means of a member 24 which preferably is threaded. The length of the rod 24 which extends exterior of the envelope is preferably less than the length of the rod 23 measured between the diaphragm 5 and the anode 7. Under these conditions, it is apparent that any small movement of the outer end of the rod 24 produces a greater movement of the opposite end of the rod 23 to which the anode is secured, due to the unequal lengths of the lever arms which extend on either side of the fulcrum 5.

After the electrodes have been mounted in position, the tube is evacuated in the most approved manner through a glass tubulation connected to the envelope at the position of the tip 2. When a sufficiently high degree of vacuum is obtained, the pellet 20 is heated, preferably by high frequency induced currents, which causes a getter within the pellet to flash and to combine with residual gas that may be present in the envelope. The tube may now be sealed off the pump.

In operation, the anode 7 is made highly positive to the cathode 6 by means of a suitably supplied direct-current potential, and the heater 8 is energized by direct or alternating current, in order to cause the coating on the cathode 6 to emit electrons which flow to the anode. Obviously, the number of electrons which reach the anode under these conditions depends not only on the accelerating voltage and the distance between electrodes but also upon the area of the anode which receives the electrons. Thus by moving the anode in a direction rectilinear with respect to the major axis of the cathode and assuming that the anode does not leave the boundary of the cathode, it is possible to vary the effective area of the electron-receiving surface without changing the distance between the electrodes. As pointed out hereinbefore with respect to the space charge equation, any change in the area, either of the electron-emitting or the electron-receiving surface or both, produces corresponding changes in the current flowing through the tube. The fingers 19 serve to prevent the rod 23 from being moved in any direction other than in a direction rectilinear with the flattened surfaces of the cathode 6. It is obvious that when the rod 24 is moved in a direction corresponding to the direction of the fingers 19, the upper end of the rod 23 and the anode 7 to which it is secured move in the opposite direction to a greater distance than the distance through which the rod 24 is moved. Accordingly, if a force is applied to the lower end of the rod 24 in such a manner as to move the anode in a plane parallel to the plane of the cathode, the intensity of the force may be measured in terms of change of magnitude of the electric current which flows through the tube.

In Fig. 8 there are shown two characteristics *a* and *b* plotted against the distance through which the end of an external lever 1 inch long is moved and the changes in plate current, measured in milliamperes, produced by the movement of the rod. The characteristics *a* and *b* are for different voltages applied between the cathode and anode. Taking a few representative figures, the characteristic *a* shows, for example, that when the rod is moved from a 30-mil deflection to a 50-mil deflection so as to have a movement of 20 mils, the plate current has been reduced from 550 milliamperes to 300 milliamperes, a difference of 250 milliamperes. Thus within the range of deflection given, there was a change of approximately 12½ milliamperes of plate current per mil deflection of the rod 24. The characteristic *b* which is for a lower order

of voltage applied between the electrodes indicates comparable changes in magnitude of plate current per mil deflection of the rod 24. From the graph and the representative figures given, it is evident that the improved tube constitutes a very sensitive device for translating movements of the rod 24 into changes of electric currents which may be readily indicated by a milliammeter or galvanometer.

In Fig. 8, it will be noted that the lower end of the characteristic *a* terminates in two curved portions *c* and *d* which diverge from one another. It has been found that when the anode takes up certain positions with respect to the cathode, the relation between the movement of the rod 24 and the change in plate current no longer varies as a substantially straight line but tends to curve off as indicated by that portion of the characteristic designated by the reference character *c*. This change in slope of the characteristic obviously prevents the improved tube from giving a correct indication of the deflection of the rod 24 in terms of plate current in the region where the plate currents are relatively small. In order to extend the usefulness of the tube throughout this region, it is necessary that the curved portion *c* of the characteristic be eliminated or at least reduced, so that the straight portion *a* may extend over a greater downward length.

While I do not wish to be limited to any particular theory as to why the straight line characteristic does not prevail over the entire range of plate current, I believe that it is due to random electric lines which fringe the edges of the anode and cathode and take irregular and curved paths so as to make it impossible for the anode to intercept the same number of electric lines per unit length of its travel. Whatever be the correct explanation, I have found that the characteristic *a* may be substantially straightened at the lower end by providing shields which tends to straighten out these random electric lines so that the anode in moving with respect to the cathode meets the same concentration of lines throughout its entire travel and substantially throughout the entire range of measurable plate current flowing through the tube. In Fig. 3, I have shown a typical example of the many forms which these shields may take.

Referring now to Fig. 3, reference character 30 designates a glass envelope which terminates at the top in a reentrant stem 31 closed by a press 32 in the form of a cross. A metal cup-shaped member 33 is butt-sealed to the other end of the envelope. As in the case of Fig. 1, the member 33 has substantially the same thermal expansion as the glass to which it is fused. The lower end of the member 33 constitutes a flexible diaphragm 34 and may take the form of a thin metal disk. The cathode 35 is of the indirectly heated type in the form of a round cylinder. This cathode contains a heater (not shown) and is coated with electronically active material in a similar manner to the cathode shown in Fig. 2. The anode 36 preferably takes the form of a wedge-shaped member and is secured, as by welding, to the upper end of the rigid rod 37. The rod 37 is hermetically secured to the diaphragm 34, preferably by means of a nut 38 through which the rod is threaded. Leading-in conductors 39 and leading-in conductor 40 are taken through the cross stem to the exterior of the tube in order that suitable potentials may be applied to the heater and cathode respectively. If desired, one of the conductors 39 may be connected to the conductor 40 in order that one end of the heater be maintained at cathode potential. In addition to this electrode structure, there is also provided a pair of triangularly shaped shields 41, positioned on each side of the cathode, with a flat side of each of the triangular members positioned in line with one another and preferably in line with the lowermost edge of the cathode cylinder, as shown more clearly in Fig. 4. These shields are conveniently formed out of sheet metal bent to proper shape and leaving an upwardly extending tab 42 to which rigid leading-in conductors 43 may be secured. These conductors are fused in the cross stem and preferably are connected together, so as to be at the same potential. A capsule 20 containing a suitable getter (not shown) may be secured by means of a rigid rod 45 to one of the conductors 43.

As stated hereinbefore, in the absence of the shields 41, the electric lines extending between the cathode and the anode are not of uniform intensity throughout the travel of the anode so when the deflection of the anode is plotted against the change in plate current, the characteristic is not substantially a straight line over its entire length and thus, does not indicate a simple or direct relation between deflection and current. However, when the shields 41 are added to the electrode structure, the area over which the lines of force run parallel to one another between the electrodes is extended to include the entire path through which the anode moves. Instead of charging the shields to cathode potential, they may be given any suitable bias with respect to the cathode or with respect to the anode. Thus the shields so cooperate with the remaining electrodes of the tube to cause the characteristic *a* to straighten out its extremity as indicated at *d* which condition obtains at the position where the anode is either just leaving the field of the cathode or is just entering the field and the plate currents are low.

Fig. 5 shows the application of my invention to a metal tube. In this figure, numeral 46 designates a metal cylinder which may be constituted of sheet steel. At each end of the cylinder there is a metal header 47, 48 provided with an upturned flange of a diameter to fit snugly within the cylinder to which it is secured by welding. The lower header 48 has an opening 49 therein and carries a diaphragm 50 of larger size than the opening and brazed to the header. The diaphragm is provided with a nut or heavy washer 51 to which the rod 52 is hermetically secured. This rod carries an anode 53 which may be similar to the anode shown and described in connection with Figs. 1 and 2. A washer 54 of insulating material is fitted snugly within the header 48 in order to protect the thin diaphragm from damage.

The upper header 47 may carry a pair of eyelets 55 which are welded to the header. Within these eyelets there is a sleeve 56 of glass to which a leading-in conductor 57 is fused. The eyelets and the conductor preferably have the same coefficients of thermal expansion as the glass 56 so that no strain is induced at any of the joints during manufacture or operation of the tube. Examples of suitable metal and glass for this purpose have been given hereinbefore. In the center of the header there may also be provided a metal tubulation 58 which communicates with the interior of the envelope and during evacuation of the tube may be connected to a pump. When the tube is exhausted and the getter (not

shown) is flashed, the tubulation 58 is sealed off by flattening the tubulation and welding the sides together. The envelope 46 also contains a cathode 59 coated with electronically active material and is provided with a heater as was described in connection with Figs. 1 and 2. One end of the heater may be connected to the cathode so that the leading-in conductors 57 are connected respectively to the other end of the heater and to the cathode. The operation of this tube is similar to that described in connection with Figs. 1 and 2. If desired, shields similar to those described in connection with Fig. 3 for modifying the electric field extending between the electrodes may be provided.

A still further form of metal tube embodying my invention is shown in Figs. 9 and 10. As will be described in connection with these figures, the shields for straightening out the normally curved fringing electric lines may be interposed between the cathode and the anode. In these figures, reference character 60 designates a cylindrical envelope which is closed at the top (as shown) by an integral portion and at the bottom by a metal plate member 61 which is conveniently welded to flanges provided on the cylinder 60 after the electrodes and the interior structure have been mounted in position. As shown more clearly in Fig. 10 which is an enlarged view of a section taken along lines 10—10 in Fig. 9 and looking in the direction of the arrows, the cathode 62 is of the indirectly heated type and is similar to the cathode 6 shown in Fig. 2, except that it is more rectangular than the flattened cylinder 6. The cathode is preferably coated with electronically active material and contains a heater 63. The anode 64 is U-shaped and is similar to the anode shown and described in connection with Figs. 1 and 2, except that there is no plate 22 provided and the reenforcing members 65 are spot-welded over their entire length to the anode. The cathode is mounted between two transverse insulating plates 66 which fit snugly within the cylinder 60 and carry the necessary rigid support rods 67 which serve as leading-in conductors for the cathode and the heater. These leading-in conductors are taken through the metal plate 61 by a metal eyelet and glass seal arrangement 68 similar to that shown and described in connection with Fig. 5. The anode is mounted in position by means of a rigid rod member 69 which extends up through the envelope and is hermetically sealed to a diaphragm 70 secured to the plate member 61. One of the leading-in conductors 67 may be secured to a vertically extending member 71 which passes through the lower insulating disk 66 and is secured to the upper insulating disk. The lower insulating disk 66 is provided with a rectangular slot 72 which permits a limited movement of the rod 69 in a direction rectilinear with the plane of the cathode. This slot therefore serves as a guide for the rod. In order to "getter" a tube of this character, so as to improve the vacuum, a pair of capsules 73 containing suitable material is provided. These capsules conveniently are secured as by welding to the underside of the top portion of the envelope. When the getter is flashed, it is desirable that the electrodes are not in the direct line of the vapor blast. For this reason, a baffle 74 is provided which is of such a diameter as to leave an annular space around the outside so as to permit the getter vapor to act on the gaseous content of the envelope. An opening 75 of restricted diameter is also provided for this purpose in the upper and lower disk members 66. The baffle 74 is conveniently held in position by means of three equidistantly spaced rods 76 which extend through suitable openings in the disks 66 and are secured to the bottom plate 61. A metal tubulation (not shown) may be provided at any suitable place in the envelope in order that the latter may be evacuated.

Instead of providing triangular shields for straightening out the characteristic *a* (Fig. 8), a shield member 77 of flat configuration is employed for this purpose. This shield member is positioned between the anode and cathode as shown more clearly in Fig. 10, and may be supported by the disks 66. The shield may be constituted of a pair of parallelly disposed wires with a metal ribbon extending between the wires over a distance corresponding to the length of the active areas of the cathode and anode. A leading-in conductor 78 is brought out to the exterior of the tube so that a suitable potential may be applied to the shield. The operation of the tube shown in Figs. 9 and 10 is similar to that described in connection with the tubes illustrated in the other figures.

The improved tube of the present invention has been found to be capable of numerous applications where it is desired to translate physical movements and changes in force or pressure into changes of electric current. The mode of application of the invention may best be understood by reference to Figs. 6 and 7.

In Fig. 6 I have illustrated the use of my improved tube as a practical means for varying a given current. Reference character 125 designates a cam secured by a shaft 126 to a knob 127. The cam arrangement may be mounted on the panel 128 of a switchboard. Bearing against the surface of the cam, there is a rod 129 which carries the anode of one of the improved tubes 130. The heater of the tube may be energized through a transformer 131. Reference character 132 designates terminals to which a load circuit (not shown) may be connected. This load circuit may consist of a saturable reactor such for example, as is used for dimming theatre lights, or may comprise a lamp bank. The current for the load is supplied from a circuit indicated by the open terminals 133 and having an electrostatically controlled arc discharge device 134 connected in series therewith. A biasing potential for this device may be obtained from a transformer 135 through a connection 136 from the mid-point of the secondary of the transformer to the grid of the tube 134. A phase-shift network 137 is connected across the end terminals of the secondary of the transformer 135, and a battery 138 is connected between the network 137 and the mid-tap of the secondary of the transformer 131. A biasing resistance 139 and a shunt condenser 140 are connected between one of the terminals 133 and the mid-tap of the secondary of the transformer 131. It is apparent that as the knob 127 is rotated, the cam 125 serves to deflect the rod 129, either upwardly or downwardly, depending upon the position and shape of the cam. As the anode moves within the tube 130, the current through the tube changes in a corresponding manner, and these current changes produce variations of voltage drop across the resistor 139. These changes of voltage drop across the resistor either add to or subtract from the bias potential provided by the battery 138, causing the arc tube 134 to fire at a different point in the recurring positive half-

cycles of the voltage impressed between the cathode and anode of the device 134. The average current through the device 134 is therefore caused to change in accordance with the movement of the cam 125 which in turn, is controlled by the rotation of the knob 127. Thus by turning the latter, the current supplied to the load which is connected to the terminals 132 may be varied at will in a very practical and expedient manner.

Fig. 7 shows a temperature-recording or temperature-controlling apparatus. In this figure, reference character 141 designates a bimetallic strip which is rigidly secured at one end to a support 142. These strips are constituted of the usual materials which cause flexure when the strip is heated. The end of the strip remote from the support 142 is secured through an adjustable link 143 to a rod 144 which carries the anode of an improved tube 145 as described hereinbefore. A biasing spring 146 may be secured to the link end of the rod 144 so as to apply a tension to the bimetallic strip. The heater of the improved tube is energized by a transformer 147. A connection is taken from the mid-tap on the secondary of the transformer 147 through a supply of direct current indicated by the terminals 148 to a meter 149 and from thence to the anode. A relay may be substituted for the meter 149 in order to control other circuits (not shown), if desired. It is apparent that when the temperature to which the bimetallic strip is subjected, is changed, the strip will flex in one direction or the other and cause a movement of the anode. The current through the meter 149 will indicate the amount of anode deflection and will give an accurate indication as to the change in temperature which caused the strip to flex. If desired, the changes in current may be taken through a device for recording changes in the temperature.

While throughout the various figures I have described my invention more especially in connection with a tube in which the effective area of one or more anodes is changed in response to physical movement, it will be understood that if desired, the anode of the tube may be maintained stationary and the cathode structure arranged to move. Under certain circumstances it may be desirable to provide a tube having flexible diaphragms at each end so that both electrodes are movable and are actuated by different forces which may be independent of one another. In all of these cases, either the electron-receiving area or the electron-emitting area, or both, of the electrodes is varied in response to physical movement or changes in force or pressure. While, in some of the figures, I have indicated that the improved tube is energized by direct current, it is obvious that alternating current may also be employed in these cases, together with suitable circuits, because the tube is a self-rectifier.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electric discharge device comprising an envelope including a flexible diaphragm portion and containing an electron-emitting electrode and an electron-receiving electrode, one of which is movable with respect to the other but the distance therebetween is maintained substantially constant, a rigid member secured to said movable electrode and the flexible diaphragm, said member extending beyond the diaphragm to the exterior of the envelope to constitute a lever with said diaphragm as a fulcrum.

2. An electric discharge device comprising an envelope containing a plurality of spaced discharge-supporting electrodes, said electrodes being mounted to allow relative motion with respect to one another in parallel planes, a shield mounted adjacent to one of said electrodes and extending in a plane parallel to the plane in which another of the electrodes moves.

3. An electric discharge device comprising an envelope containing an anode and a cathode, said anode being movable with respect to the cathode, a shield mounted adjacent to said cathode and extending along the direction in which the anode moves, said shield being connected to said cathode whereby during operation of said device an electrostatic field is produced at a position near the cathode and the field is intercepted by the anode in moving toward the cathode.

4. An electric discharge device comprising an envelope containing a plurality of electrodes including a movable electrode and a stationary electrode, means for moving said movable electrode to change the effective area of that electrode while maintaining the distance between the electrodes substantially constant, and a stationary shield mounted adjacent the movable and stationary electrodes in a plane parallel to the plane in which the movable electrode moves.

5. An electric discharge device comprising an envelope containing a plurality of electrodes including an indirectly heated cathode and an anode, said cathode having a rectangular configuration and containing a heater, said anode comprising a U-shaped member which surrounds the cathode, means for producing relative motion between the anode and cathode in parallel planes whereby the effective area of one of the electrodes is changed and the distance between the electrodes is maintained substantially constant.

6. An electric discharge device comprising an envelope containing a plurality of electrodes including an indirectly heated cathode and an anode, said cathode having a rectangular configuration and containing a heater, said anode comprising a U-shaped member which surrounds the cathode, means for producing relative motion between the anode and cathode in parallel planes whereby the effective area of one of the electrodes is changed and the distance between the electrodes is maintained substantially constant, and means for straightening out the normally curved fringing electric lines which have their inception at the edges of the cathode and anode.

7. An electric discharge device comprising an envelope containing a plurality of electrodes including an indirectly heated cathode and an anode, said cathode having a rectangular configuration and containing a heater, said anode comprising a U-shaped member which surrounds the cathode, means for producing relative motion between the anode and cathode in parallel planes whereby the effective area of one of the electrodes is changed and the distance between the electrodes is maintained substantially constant, and means including an electrode interposed between the cathode and anode for providing an electrostatic field substantially normal to the planes in which the electrodes move.

8. An electric discharge device comprising an envelope containing a plurality of electrodes including an indirectly heated cathode and an anode, said cathode having a rectangular configuration and containing a heater, said anode comprising a U-shaped member which surrounds the cathode, means for producing relative motion

between the anode and cathode in parallel planes whereby the effective area of one of the electrodes is changed and the distance between the electrodes is maintained substantially constant, and means for straightening out the normally curved fringing electric lines which have their inception at the edges of the cathode and anode, said means including a shield electrode interposed between the cathode and anode.

9. An electric discharge device comprising an envelope containing a plurality of spaced electrodes including a cathode, said electrodes being mounted to allow relative motion with respect to one another, means for extending the field of the cathode over the entire path of movement between the electrodes, said means including a pair of shield members adapted to be charged and mounted on opposite sides of the cathode, the field of which is to be extended.

10. An electric discharge device comprising an envelope containing an anode and a cathode, said anode being movable with respect to said cathode, and means for extending the field of said cathode over the entire path through which the anode moves, whereby the anode intercepts a cathode field of uniform intensity, said means including a pair of shield members adapted to be charged and mounted adjacent said cathode, on opposite sides thereof.

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