My invention relates to electron discharge devices, more particularly to so called beam tubes in which an electron beam can be deflected by one or more sets of deflecting electrodes for providing various novel results.

It is the principal object of my invention to provide an electron discharge device of the beam type particularly suitable for measuring quantities including the phase angular displacement between electric oscillations, current, voltage, power and for other purposes.

Another object of my invention is to provide such a device in which the output current can be used to maintain a specific condition governed by phase angular displacement.

In its simple form an electron discharge device made according to my invention includes a cathod for supplying electrons, means for forming the electrons into a beam, an output electrode, and positioned between the cathode and the output electrode an electrode having an aperture through which the beam is normally directed. On each side of the output electrode are positioned deflecting electrodes on opposite sides of the beam. Each pair of deflecting electrodes is connected to a different source of voltage whereby the phase angle difference may be measured. The second pair of deflecting electrodes between the output electrode and the cathode can affect the beam only while it passes through the aperture in the output electrode and if both voltages are in phase the beam will strike the output electrode at a point directly opposite the aperture. If the voltages applied to the deflecting electrodes are out of phase the degree to which the beam is deflected by the second pair of deflecting electrodes may be used to measure the phase angle difference between the two applied voltages, the beam striking the output electrode to the right or left of the mid or normal point of contact of the beam with the output electrode.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will be best understood by reference to the following description taken in connection with the accompanying drawings in which Figure 1 is a schematic diagram and associated circuit of an electron discharge device made according to my invention, Figure 2 is a transverse section of another form of electron discharge device made according to my invention, Figures 3 and 4 are still further modifications of electron discharge devices and their associated circuits made according to my invention.

Referring to Figure 1 an electron discharge device made according to my invention includes an elongated evacuated envelope 18, having positioned at one end a cathode 11 which may be electrically connected to a shield or focusing electrode 12. The beam is directed between output electrode 17 positioned at the other end of the envelope. For the purpose of focusing the electrons from the cathode 11 into a narrow beam there is provided a pair of rods 13 positioned on opposite sides of the beam and have applied to them a low positive potential. A first pair of deflecting electrodes in the form of rods 14 are positioned between the cathode 11 and the apertured electrode 16. An alternating voltage applied to these electrodes causes the beam to be deflected so that the beam either strikes the surface of the electrode 15 or passes through the aperture provided in this electrode. Between the apertured electrode 18 and output electrode 17 is a second pair of deflecting electrodes in the form of plates 16 to which a second alternating voltage may be applied. These electrodes affect the beam of electrons only between the apertured electrode 16 and the output electrode 17, the amount of deflection of the beam being dependent upon the difference in phase of the voltage applied to the plates 16 and the rods 14. The input voltage to the rods 14 is introduced by means of the coupling transformer 17 which may be connected to one input and the other alternating voltage applied to the deflecting plates 16 is applied through the coupling transformer 18 connected to another input. The voltage to the various electrodes is applied from a source of voltage 19, the apertured electrode 15 and anode 17 being maintained at the higher positive potentials. The deflecting plates 16 are maintained at a higher biasing potential than the deflecting rods 14. To limit the beam deflection and loading of the input circuit when either of the deflecting rods 14 swings highly positive so that it draws current, limiting resistors 14’ may be inserted as well as limiting resistor 17’. One or the other could be used alone. On drawing current a drop occurs across the resistors dropping the voltage on the deflecting rods and reducing the beam deflection and current to the rods. The same arrangement could be used with deflecting plates 16.

In operation a narrow beam of electrons from the cathode 11 receives a double deflection; first, back and forth about the slot or aperture in
the electrode \(15\) and a second deflection after it emerges through the aperture into the region beyond. The first deflection may be caused by a voltage \(V_1 \sin \phi\) impressed between the rods \(14\) by the input coupling \(17'\) and the second deflection may be caused by another voltage \(V_2 \sin (\omega t - \theta)\) between the deflecting plates \(16\), the second voltage between the two plates differing in phase from the first voltage between the two rods \(14\) by an angle \(\theta\). The electrodes \(16\) are active in deflecting the beam only part of the time, that is, when the electrons pass through the aperture in the region containing the electrode \(16\). This instant of time occurs when \(V_1 \sin \phi\) is equal to zero and is of a short duration depending upon the width of the aperture in the electrode \(15\) and the narrowness of the beam. At this instant a voltage \(\pm V_2 \sin \theta\) is effective in deflecting the beam in the region beyond the slotted electrode \(15\) so that the beam will arrive at electrode \(17\) in either of two positions to the right or to the left of the center line indicated by the dot-dash line in Figure 1, except when \(\theta\) equals zero, zero phase angle between voltages, the beam is in the center. Thus the point of contact of the electron beam and hence the amount of deflection of the beam is a function of \(V_2 \sin \theta\) and serves as a measure of this quantity. The electrode \(17\) may be in the form of a translucent or transparent base coated with fluorescent material so that it can be used for indicating purposes or electrode \(17\) can be so constructed that the output could be used for controlling different operations of electrical devices in accordance with the amount of deflection of the beam.

While the electron discharge device made according to my invention is shown in Figure 1 as a single beam device, it may be constructed to provide a plurality of beams as shown in Figure 2. The cathode \(21\) is coaxial and concentric with the anode or output electrode \(22\). Disposed around the cathode \(21\) are the beam forming rods \(23\) which in this particular case form the electron emission from cathode \(21\) into four beams. The pairs of deflecting electrodes \(24\) in the form of rods are positioned between beam forming rods \(23\) and the apertured electrode \(25\) having four apertures through which the electron beams may be focused on to the output electrode \(22\). Positioned between the electrode \(25\) and the output electrode \(22\) are the deflecting plates \(27\), which correspond in function to the deflecting electrodes \(16\) of Figure 1. The tube functions in the same manner as the tube shown in Figure 1.

In Figure 3 I show a modification of the construction of an electron discharge device as shown in Figure 1, particularly suitable for utilizing the output current for maintaining some specific condition governed by phase angle. The envelope \(30\) contains the cathode \(31\) and anode \(32\), as in Figure 1. The shield and beam forming electrode \(33\) and beam forming rods \(34\) govern the formation of a narrow beam of electrons from the cathode, the electrode \(33\) serves to utilize the emission to the maximum. A first pair of deflecting rods \(35\) are positioned between the beam forming rods \(34\) and a first apertured electrode \(36\). A second pair of deflecting electrodes in the form of plates \(37\) are positioned between apertured electrode \(36\) and apertured electrode \(38\), which may be used as a second output electrode, the anode \(32\) serving as the first output electrode. The aperture or slot in the first apertured electrode \(36\) is just wide enough to allow all the electrons in the beam to pass through it to the output anode \(32\) at zero phase angle. As the phase angle differs from zero the current to the anode \(32\) decreases while the current to the second output increases by substantially the same amount. These two electrodes are connected to separate output transformers \(39\) and \(40\), the input voltages to the deflecting electrodes being introduced by means of coupling transformers \(41\) and \(42\). In addition to subjecting the electron stream to the influence of two alternating voltages of the same frequency as deflecting agencies, I may also subject the beam to multiple deflections by alternating agencies of the same or different frequencies, especially when the frequencies are of the ratio of integers. An example of such an arrangement is shown in Figure 4 where a third set of deflecting electrodes is included. With such an arrangement the operation becomes more complicated than in the cases described above. Thus in the arrangement shown in Figure 1, the beam could be made to strike the output anode in six distinct positions merely by utilizing a voltage on the first deflecting electrodes \(16\) of three times the frequency and on the second deflecting electrodes \(16\). By modulation of the current in the electron stream the use of multiple deflections with one or more slits in each slotted electrode per electron beam and the staggering of the slots and the amplification of voltages of different frequencies and phase to the deflecting electrodes, the combination and permutations are numerous. Applications which might suggest themselves are means for remote control by carrier current on radio waves of such things as airplanes steered from the ground and the like. There is also the possibility of secrecy in communication.

In the electron discharge device shown in Figure 4 the envelope \(45\) contains the cathode \(46\), output anode \(47\), the cathode being provided with its focusing electrode \(48\). Positioned between the cathode \(46\) and anode \(47\) are in the order named, beam forming rods \(49\), first deflecting electrodes \(50\), first apertured electrode \(51\), second deflecting electrodes \(52\), second apertured electrodes \(53\), third deflecting electrodes \(54\), the alternating voltages to be applied to these deflecting electrodes being introduced by means of coupling transformers \(55\), \(56\) and \(57\), the output being indicated at \(58\). Electrodes \(51\) and \(55\) could also of course be used. The voltage source is indicated at \(59\).

The properties of the electron discharge device described above which are believed to be of particular importance are as follows: first, the electron beam passes through the first aperture when the first deflecting agency is zero, therefore the magnitude of this agency has no effect on the magnitude of space current when it passes the aperture or on its deflection beyond the aperture. This property permits the use of an alternating magnetic field as well as internal electrodes for deflecting purposes. Second, assuming a sinusoidal agency for deflection, a first phase deflection at least two or three times greater than both the aperture and beam width, and a deflection linear with voltage for not less than the beam plus the aperture width, the average current which passes through the aperture is inversely proportional to the amplitude of the sinusoidal deflection agency. This relation is independent of current density distribution of the electron beam, space charge, beam width, its
deformation in being deflected, and the width of the slit. Third, although the number of electrons passing through the aperture is substantially independent of the factors given above, the phase angle indication is affected by beam and aperture widths which should be small. However, there is a practical limit to these widths, and I have devised means for compensation of the slight error which would otherwise remain even after widths were made as narrow as possible. My method is to apply voltages to the deflectors in said a potential such that in the short interval of time that the beam passes the apertures from left to right the second deflectors tend to deflect it from right to left, keeping the beam stationary on the plate.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or to the specific application to which I have put it, but may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and having a cathode for emitting electrons, means for forming said electrons into a beam, an output electrode for receiving said electrons, an apertured electrode positioned between said cathode and output electrode, and means on each side of said apertured electrode for deflecting the beam of electrons in the same plane, said electron discharge device having no other deflecting means positioned between the means on each side of said apertured electrode and said output electrode.

2. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and having a cathode for emitting electrons, means for forming said electrons into a beam, an output electrode for receiving said electrons, an apertured electrode positioned between said cathode and output electrodes, a pair of deflecting electrodes between said cathode and said output electrodes, said deflecting electrodes being adapted to deflect the beam in the space between said cathode and said apertured electrode, and a second pair of deflecting electrodes positioned between said apertured electrode and said output electrode, means for forming the electrons into a beam comprising a pair of rod electrodes positioned adjacent the cathode, and a semicylindrical electrode on the opposite side of the cathode from said pair of rod electrodes, a pair of apertures in said rod electrodes, and provided with aligned apertures, a first pair of deflecting electrodes positioned between the beam forming rods and the first apertured electrode and a second pair of deflecting electrodes positioned between said apertured electrodes, said deflecting electrodes being positioned parallel to each other for deflecting said beam in the same plane, said electron discharge device having no other deflecting means positioned between said pairs of deflecting electrodes and the output electrode.

3. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and having a straight thermionic cathode surrounded by an output electrode, a plurality of beam forming electrodes parallel to and surrounding said cathode, a cylindrical electrode coaxial with said cathode and positioned between said cathode and said output electrode and provided with a plurality of slots registering with the beam paths formed by said beam forming electrodes, a plurality of pairs of deflecting electrodes positioned between said apertured electrode and said cathode, and a plurality of pairs of deflecting electrodes positioned between said apertured electrode and said output electrode, all of said deflecting electrodes being adapted to deflect the beam in the same plane, said electron discharge device having no other deflecting electrodes positioned between said pairs of deflecting electrodes and the output electrode.

4. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and having a cathode for emitting electrons, means for forming said electrons into a beam, an output electrode for receiving said electrons, a pair of apertured electrodes positioned between said cathode and said output electrode, a pair of deflecting electrodes positioned between the cathode and the first apertured electrode, and a second pair of deflecting electrodes positioned between said apertured electrodes, said deflecting electrodes being positioned parallel to each other, whereby said beam is subjected to two deflecting forces in the same plane in its passage from the cathode to the output electrode, said electron discharge device containing no other deflecting electrodes positioned between said pairs of deflecting electrodes and the output electrode.

5. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and comprising an elongated envelope having a cathode at one end for emitting electrons, and an output electrode at the other end for receiving electrons, means for forming the electrons into a beam comprising a pair of rod electrodes positioned adjacent the cathode, and a semicylindrical electrode on the opposite side of the cathode from said pair of rod electrodes, a pair of apertures in said rod electrodes, and provided with aligned apertures, a first pair of deflecting electrodes positioned between the beam forming rods and the first apertured electrode and a second pair of deflecting electrodes positioned between said apertured electrodes, said deflecting electrodes being positioned parallel to each other for deflecting said beam in the same plane, said electron discharge device having no other deflecting means positioned between said pairs of deflecting electrodes and the output electrode.

6. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and comprising an elongated envelope having a cathode at one end for emitting electrons, and an output electrode at the other end for receiving electrons, means for forming the electrons into a beam comprising a pair of rod electrodes positioned adjacent the cathode, and a semicylindrical electrode on the opposite side of the cathode from said pair of rod electrodes, a pair of apertures in said rod electrodes, and provided with aligned apertures, a first pair of deflecting electrodes positioned between the beam forming rods and the first apertured electrode and a second pair of deflecting electrodes positioned between said apertured electrodes, said deflecting electrodes being positioned parallel to each other for deflecting said beam in the same plane, said electron discharge device having no other deflecting means positioned between said pairs of deflecting electrodes and the output electrode.

7. An electron discharge device for utilizing
phase angular displacement of electrical conditions in different circuits and having a cathode for emitting electrons, means for forming said electrons into a beam, an output electrode for receiving said electrons, an apertured electrode positioned between said cathode and output electrode, and means on each side of said apertured electrode for deflecting electrons being positioned to deflect the beam in the same plane, said electron discharge device having no other deflecting means positioned between the means on each side of said apertured electrode for deflecting the beam of electrons and the output electrode.

8. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and having a cathode for emitting electrons, means for forming said electrons into a beam, an output electrode for receiving said electrons, an apertured electrode positioned between said cathode and output electrode, and means including deflecting rods on one side of said apertured electrode and deflecting plates on the other side of said apertured electrode for deflecting the beam of electrons, said plates and rods being positioned parallel to each other, a source of voltage, connections from said apertured electrode and said output electrode to said source of voltage for applying a positive potential to said apertured electrode and said output electrodes with respect to said cathode, an input circuit connected to said deflecting rods and another input circuit connected to said deflecting plates, said rods and said plates being maintained at a positive potential with respect to said cathode, said plates being at a higher positive potential, said rods and plates deflecting the beam in the same plane, said electron discharge device having no other deflecting electrodes positioned between said rods and plates and the output electrode.

9. An electron discharge device for utilizing phase angular displacement of electrical conditions in different circuits and having a cathode for emitting electrons, means for forming said electrons into a beam, an output electrode for receiving said electrons, a pair of apertured electrodes with their apertures in alignment positioned between said cathode and said output electrode, a pair of deflecting electrodes positioned between the cathode and the first apertured electrode, and a second pair of deflecting electrodes positioned between said apertured electrodes whereby said beam is subjected to two deflecting forces in its passage from the cathode to the output electrode, said deflecting electrodes being parallel and deflecting the electron beam in the same plane, a source of voltage, an output circuit connected to said output electrode and said source of voltage, and another output circuit connected between said second apertured electrode and said source of voltage and separate input circuits connected to each of said pairs of said deflecting electrodes, said deflecting electrodes and apertured electrodes being connected to said source of voltage, the voltages to which said various electrodes are biased increasing in a positive direction from said cathode to said output electrode, said electron discharge device having no other deflecting electrodes positioned between the output electrode and said pairs of deflecting electrodes.

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