Sept. 27, 1955 B. A. S. JOSEPHSON ET AL 2,719,248

ELECTRON DISCHARGE DEVICE

Filed June 8, 1948 4 Sheets-Sheet 1

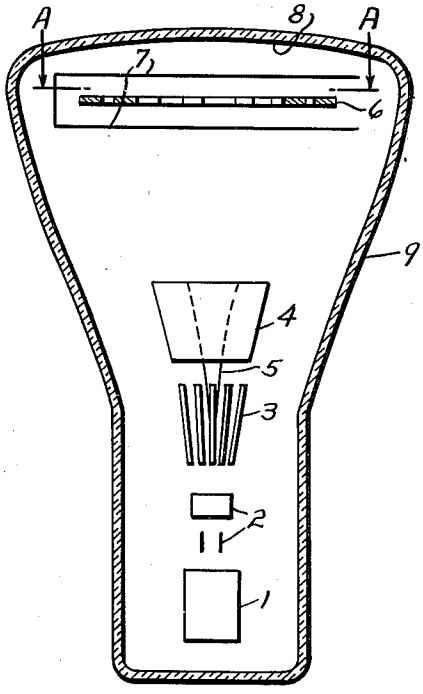


FIG. 1

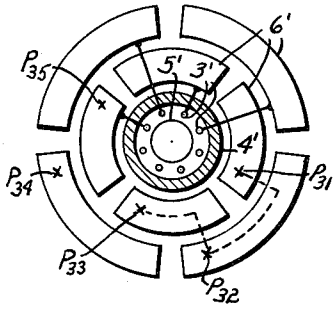


FIG. 3

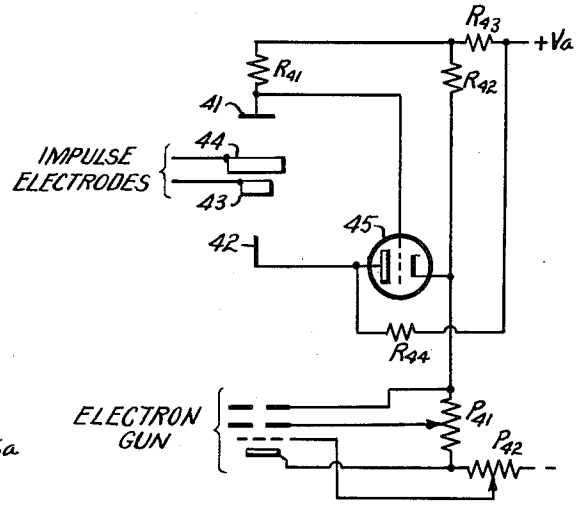


FIG. 4

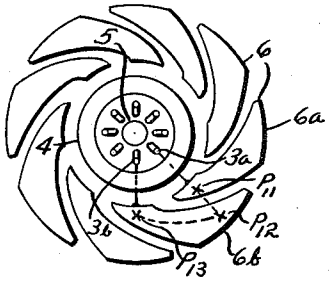


FIG. 1A

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ELECTRON DISCHARGE DEVICE

Filed June 8, 1948 4 Sheets-Sheet 2

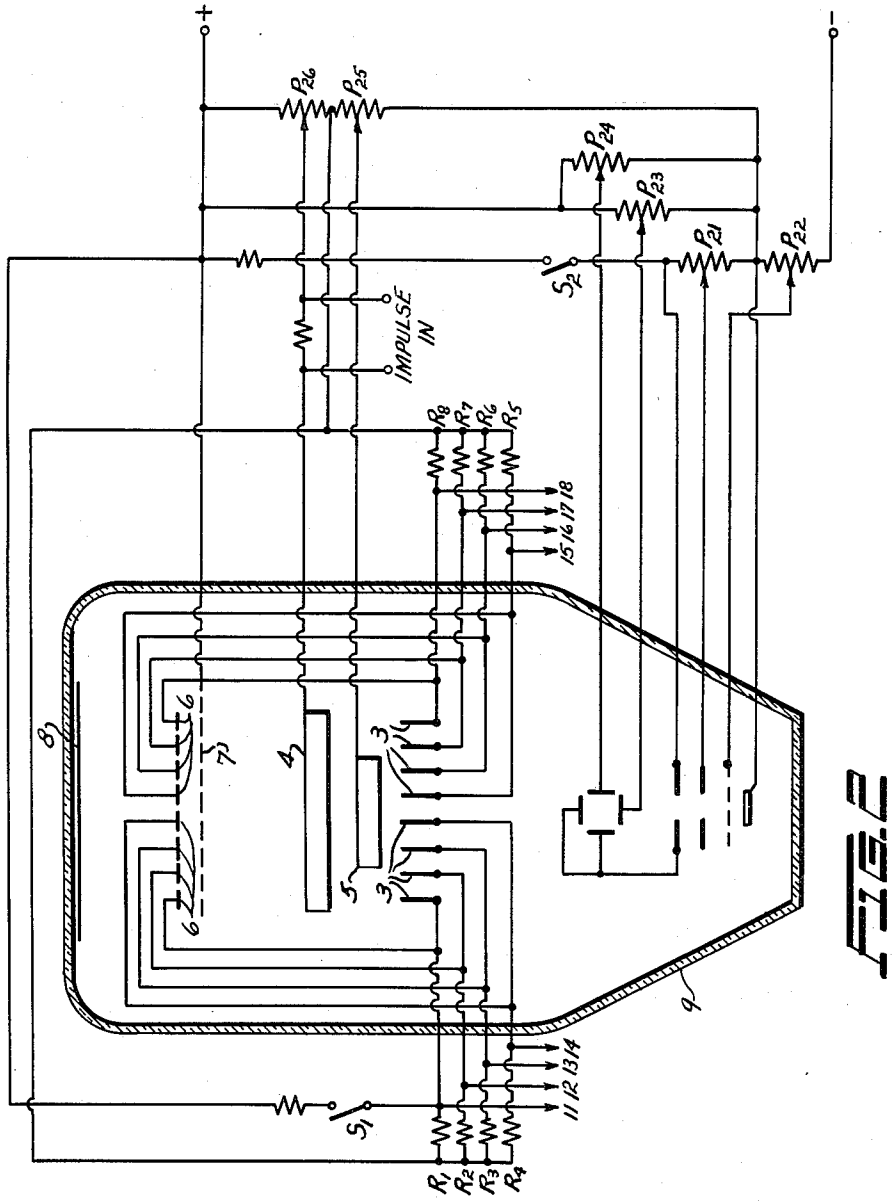


FIG. 2

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ELECTRON DISCHARGE DEVICE

Filed June 8, 1948 4 Sheets-Sheet 3

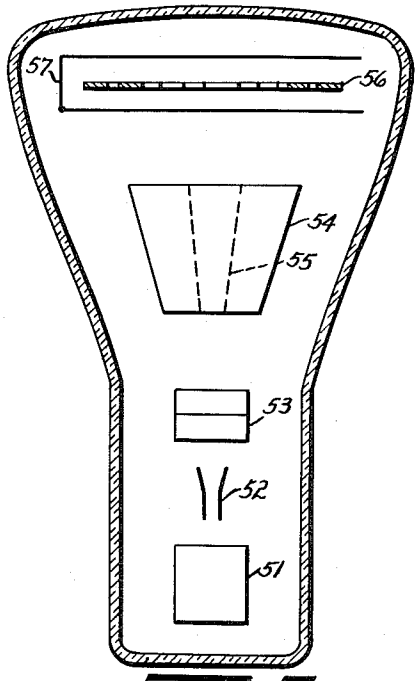


FIG. 5

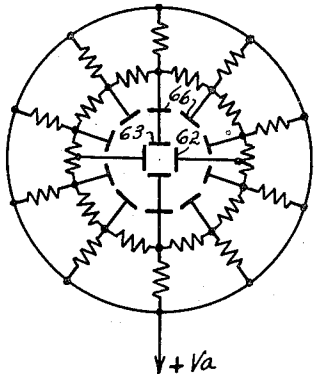


FIG. 6

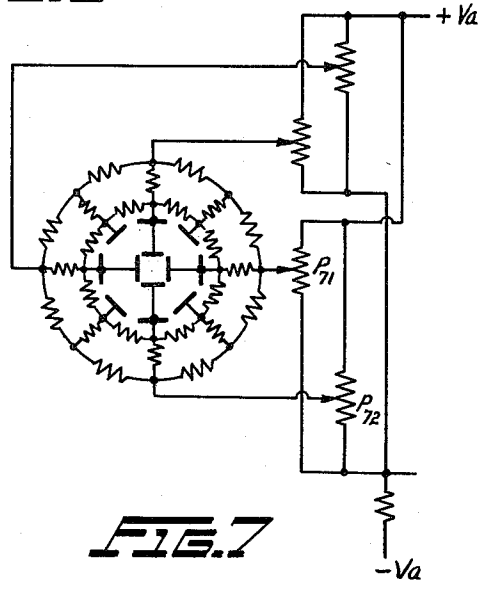


FIG. 7

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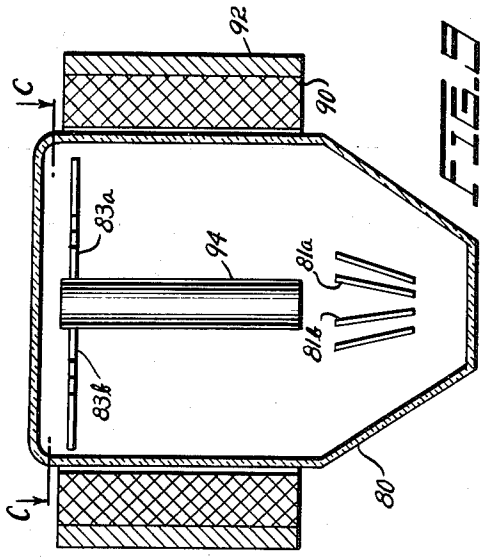


FIG. 9

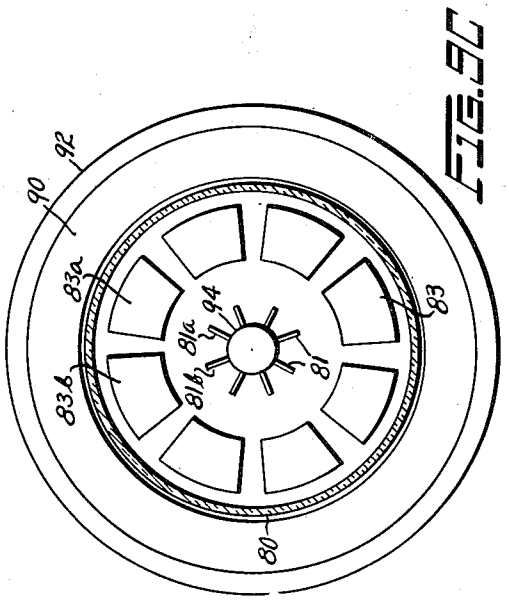


FIG. 9C

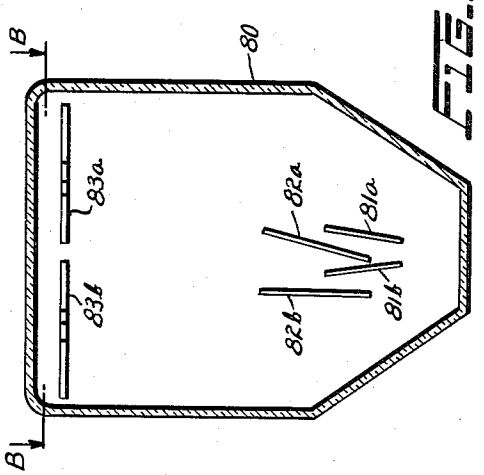


FIG. 8

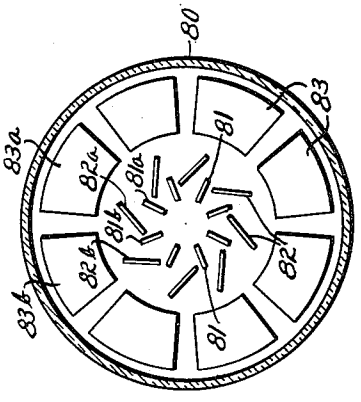


FIG. 8A

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ELECTRON DISCHARGE DEVICE

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Application June 8, 1948, Serial No. 31,686

Claims priority, application Sweden July 11, 1947

10 Claims. (Cl. 315—12)

The present invention relates to an electron discharge tube, which is particularly intended for use as a frequency divider, selector or counting device.

Generally speaking, the tube comprises an electron gun, a plurality of target electrodes, on which the electron beam produced by the gun may impinge, and at least two independent deflecting electrode systems, one of which makes it possible to direct the beam toward any one of the said targets, while the other makes it possible to deflect the beam through a small angle corresponding to a displacement of the beam from one target to an adjacent target. The latter system may consist of a deflecting coil.

The invention is more specifically disclosed in the annexed drawings, Fig. 1 of which is a schematic diagram illustrating in longitudinal section the essential components of a tube according to the invention. Fig. 1A is a view taken in the direction of the arrows A—A of Fig. 1. Fig. 2 is a circuit diagram showing suitable connections for this tube. Fig. 3 is a view similar to Fig. 1A showing an alternative target arrangement. Fig. 4 is a circuit diagram showing a phase-inverter applied to a target and a corresponding control electrode. Fig. 5 is a view similar to Fig. 1 showing a modification of a tube according to the invention. Figures 6 and 7 are schematic circuit arrangements for deflecting electrodes. Fig. 8 is a view similar to Fig. 1 showing another embodiment of the tube. Fig. 8B is a view taken in the direction of the arrows B—B in Fig. 8. Fig. 9 is a view of a modification of Fig. 8. Fig. 9C is a view taken in the direction of the arrows C—C of Fig. 9.

In Fig. 1 the numeral 1 designates an electron gun, which delivers a narrow electron beam. The tube further comprises two pairs of deflecting plates 2, eight control electrodes 3, an impulse electrode 4, a counterelectrode 5 cooperating with the impulse and control electrodes, eight targets 6, two grids 7 and a fluorescent screen 8. The electrodes are enclosed within a vacuum envelope 9.

The control electrodes 3 are in the form of straight or slightly curved rods and annularly disposed around and slightly inclined with respect to the axis of the tube. The impulse electrode 4 has the shape of a frustoconical shell. The counterelectrode 5 is slightly funnel shaped and is disposed within the impulse electrode 4 and the annulus formed by the control electrodes 3. The targets 6 are so shaped and positioned that it is possible by radial displacement of the beam to move it from one target to the other. The targets 6 have the further characteristic that, when struck by the electron beam, they give off a number of secondary electrons in excess of the number of impinging electrons. Each target 6 is directly connected to a control electrode 3 aligned with an inner portion thereof. The grids 7 absorb the secondary emission from the targets 6 and the fluorescent screen 8.

Fig. 2 show a circuit arrangement for the tube. The control electrodes 3 and the targets 6 connected with them are connected to a common point via coupling resistors R_1—R_8. The potentials on the electrodes 4 and 5 are adjusted by means of potentiometers P_{25} and P_{26} so as to give a suitable deflection to the beam outwardly from the tube axis. Voltage impulses are applied to electrode 4 via the terminals shown connected across the resistor included in the lead to the electrode from potentiometer P_{26} and are superposed on the polarizing potential obtained from the potentiometer.

The operation of the tube is as follows:

First switch S_1 is closed, whereby the control electrode 3*a* connected to a terminal designated by numeral 11 obtains a higher potential than the other control electrodes. Voltage is then applied to the acceleration anodes of electron gun 1 by closing of switch S_2. The electron beam is thereby directed past control electrode 3*a* towards the target designated 6*a* in Fig. 1A, which is connected to terminal 11. This target then gives off a secondary emission current greater than the primary current, whereby both the target 6*a* and its control electrode 3*a* assume a higher positive potential than the other targets and control electrodes. The field thus set up between the control electrode 3*a* and the counterelectrode 5, by proper dimensioning of the potentials applied to the electrodes of the tube and suitable positioning of the control electrode with respect to the target, maintains the beam in position to strike the target 6*a* in point P_{11} (Fig. 1A). The electron beam will thus be automatically retained in this position as long as the potentials applied to electrodes 4 and 5 are constant.

If there is applied to the impulse electrode 4 a positive impulse of suitable amplitude the electron beam is deflected radially from point P_{11} so as to strike the adjacent target 6*b* at the point P_{12}. Target 6*b* and its control electrode 3*b* then begin to charge positively while the potential of the anode 6*a* and control electrode 3*a* falls due to the leaking off of its charge over coupling resistor R_1. The beam is deflected along target 6*b* by the increased potential of electrode 3*b*. The impulse shape has to be so selected with regard to the time constant provided by the ground capacitance of a target and the resistance of its coupling resistor that the beam is displaced approximately along the broken line shown in Fig. 1A to the point P_{13}, where it is retained in the manner described above until another impulse is applied to electrode 4. If a series of impulses are applied to electrode 4 the beam will thus successively strike all the targets 6 and return to the first. From terminals 11—18 of Fig. 2 there will then be obtained a corresponding series of positive impulses. Each terminal thus gives an impulse for every eighth applied impulse, which is equivalent to a division of the applied frequency by 8.

The targets 6 may be either wholly made up of a finely meshed grid or perforated, at least in the vicinity of points corresponding to points P_{11} and P_{13} of Fig. 1A. When the beam strikes the targets at these points, which occurs when it is in its idle position, a portion of the electrons pass through the target and hit the screen 8, which fluoresces at the corresponding spot and indicates the position of the beam. These positions may be numbered on the outside of the tube. Instead of making a portion of the electron beam strike the screen 8 to indicate its position it is possible to make a portion of the secondary emission from the targets hit the screen and similarly

indicate the position of the beam. This "self-indicating" feature is independent of the construction of the tube in other respects.

Immediately adjacent the electron gun **1** in Fig. 1 are two pairs of deflecting plates **2**. By this means it is possible by adjustment of potentiometers P_{23} and P_{24} of Fig. 2 to accurately center the beam, so that, in the presence of equal potentials on the control electrodes, it is directed along the tube axis towards the tip of electrode **5**. An indication of the proper centering of the beam is provided in that the beam, when properly centered, passes through the hole in the tip of electrode **5** onto the fluorescent screen to produce thereon a brilliant spot.

Alternative target arrangements

Independently of the construction of the other tube electrodes it is possible, instead of giving all targets the same shape and position relative to the axis of the tube, as shown in Fig. 1A, to dispose them in a staggered arrangement, as indicated in Fig. 3. The control electrodes **3'** are so disposed relative to the targets **6'** with which they are connected, that, when electrode **4'** has a predetermined potential, the beam is at rest on the inner targets at points such as P_{31}, P_{33}, and P_{35} and when electrode **4'** has a certain higher potential, the beam is at rest on the targets at points P_{32}, P_{34}, etc. Fig. 3 shows a manner of connecting the targets and control electrodes.

In operation, if a positive impulse is applied to electrode **4'**, the beam will move outwardly from P_{31} to P_{32} approximately along the broken line indicated in Fig. 3 and if electrode **4'** then reassumes its former potential the beam proceeds inwardly from P_{32} to P_{33}. The tube of Fig. 3 is then assumed to differ only with regard to its target arrangement from that of Fig. 1.

In the tube of Fig. 1 the beam is displaced by a step (from one target to the next) for each positive impulse applied to electrode **4**. The Fig. 1 tube thus counts positive impulses. In the Fig. 3 tube the beam is deflected from an inner target to an outer one for a positive impulse and from an outer target to an inner one for a negative impulse. Thus both positive and negative impulses are counted. If it is desired to count positive impulses with the latter tube the impulse electrode **4'** is preferably made to receive its impulses from a frequency-halving triggering device of well-known kind.

The number of targets obviously may be varied in both embodiments described, the number **10** being of special importance.

In the Fig. 1 and Fig. 3 tubes the targets emit secondary electrons. Tubes according to the invention may also be used without secondary emission. In such case, in the Figs. 1 and 3 arrangements, each target, instead of being connected to the nearest control electrode, should be connected to the diametrically opposite one, since the target potential will now fall when the beam strikes a target. Preferably, however, phase shifters are then interposed between targets and control electrodes. The phase shifters may comprise, for instance, small triodes, which may suitably be disposed within the tube. Fig. 4 is a schematic diagram showing a triode **45** connected between a target **41** and its corresponding control electrode **42**. The same coupling is provided for all the targets in the tube. The cathodes of all the triodes are joined together, while the anodes and grids thereof obtain their biases via separate resistors.

The use of amplifier tubes as phase shifters between the targets and control electrodes of the tube has the advantage that the control electrode potentials may be more easily controlled than in the Fig. 1 arrangement, since it is possible to select the voltages in such a manner that, when target **41** in Fig. 4 is hit by the beam, the tube **45** is cut off completely, which makes the potential on control electrode **42** equal the potential applied via resistor R_{44}, whereas in the case when the target is not being struck by the beam the control grid potential of tube **45** is limited by grid current flowing through R_{41}, which makes the voltage drop in tube **45** and thus also the potential on control electrode **42** relatively constant.

Alternative control electrode arrangements

Independently of the construction of the tube in other respects the control electrodes of the tubes may take various forms, one of which has already been described in connection with Fig. 1 and Fig. 3. In these cases the number of the control electrodes equalled that of the targets. Approximately the same function, except with regard to the swiftness of operation, may be achieved with two pairs of conventional type deflecting plates. Fig. 5 shows how the electrodes may then be arranged. **51** is an electron gun, **52** and **53** are pairs of plates for electrostatic deflection in two mutually normal directions. **54** and **55** are a pair of "impulse electrodes" causing radial deflection of the beam, **56** is a number of targets, for example as shown in Fig. 1 or Fig. 3. **57** is a secondary emission collecting electrode. Fig. 6 shows how it is possible in a tube with ten targets suitably to connect the targets **66** with the plates **62** and **63** via resistors and apply a positive voltage. If, in a tube of the last-mentioned type, targets of the type exhibiting no secondary emission are used, in which case the targets will be charged negatively by the beam, it is possible to use the Fig. 6 coupling arrangement with the modification that the pairs of plates **62** and **63** are turned through an angle of 180° with respect to the targets, the coupling arrangement otherwise remaining as indicated. If it is intended to make the targets **66** function without secondary emission it will be necessary to place a suppressor electrode in front of the targets, as viewed from the electron gun, and possibly also to insert screens between the targets. The screens as well as the suppressor electrodes have to have a lower potential than the targets.

In the Fig. 5 electrode arrangement, also, it is important to properly center the beam in the tube. Instead of an additional pair of deflecting plates, as in Fig. 1, the Fig. 7 coupling arrangement may be employed, according to which the deflecting plate potentials may be adjusted by means of potentiometers P_{71} and P_{72} so as to center the electron beam upon the geometrical axis of the tube, when the beam is not striking and charging any of the targets. The Fig. 7 coupling arrangement can be employed also with control electrode tubes, as that shown in Figure 1.

Since the pairs of plates **52** and **53** of Fig. 5 are differently spaced from the impulse electrodes **54** and **55** and the targets **56**, the beam, if targets **56** are successively charged to a certain potential leaving all the other targets at a different potential, will trace an elliptic path. By providing different angular deflection sensitivity values for the two pairs of plates **52** and **53** it may nevertheless be achieved that the beam traces a circular path in a plane including electrodes **54** and **55** normal to the tube axis, in which case electrodes **54** and **55** may be of circular cross-section. Targets **56** should be positioned along the elliptic path of the beam in the target plane.

Alternative impulse feed arrangements

Instead of making the impulse cause radial deflection of the beam, the tube may be arranged to cause in response to an applied impulse a tangential deflection of the beam corresponding to the angular distance between two adjacent targets, in which case the beam will thus follow a path with substantially constant radius in the target plane. This has the advantage that the targets may be of simpler shape, for instance rectangular or trapezoidal, as shown in Fig. 8. The tangential deflection can be achieved either electrostatically or magnetically. In the case of electrostatic deflection the impulse electrodes may consist of rods **82** disposed between the control electrodes **81**, as shown in Fig. 8. All im-

pulse electrodes **82** are connected together and are brought by an applied impulse to a higher potential than that of the control electrodes **81**, including the one **81***b*, for example, that is holding the beam on target **83***b* at the instant of the impulse. The beam is then attracted towards that impulse electrode **82***a* whose lower end is closest to the electron beam and is thereby deflected to the next target **83***a*.

Magnetic deflection in a tangential direction (by impulses) may be achieved by a cylindrical coil **90** disposed outside the tube envelope **80** so as to have its axis coincide with the axis of the tube, as shown in Figs. 9 and 9C. This coil should reach from the upper part of the control electrode system **81** to the region of the targets **83**. When receiving an impulse the coil **90** then generates a radial field immediately behind the control electrodes **81**, as viewed from the electron gun, and this field deflects the beam, whereas the field lines running in the opposite direction at the upper end of the coil are behind the targets and therefore do not affect the beam. In order to emphasize the radial field a tubular iron powder core **92** may be disposed surrounding the coil **90** and the tube and a cylindrical core **94** may be placed inside the tube envelope **80** so as to have its axis coincide with that of the tube.

Automatic control of the idle positions of the beam

The secondary emission collector electrode **7** in Fig. 1 has been described as a wide-meshed grid. It may also have the form of a plate having apertures of target shape and size in register with the targets or of two concentrical annuli of such dimensions that they cover thin strips at the outer and inner rims of the targets from the beam, which is otherwise given free access to the targets. If, in the Fig. 1 tube, the last mentioned electrode is inserted instead of the inner one of the grids **7** and the electrode potentials are adjusted in such a manner that the beam has its idle positions on the outer parts of the targets, for instance at points corresponding to P_{12}, an automatic control is afforded of the radial position of the beam when idle, in that an excessive radial deflection will cause a portion of the beam to be intercepted by the secondary emission collector annulus and a reduced electron current will reach the target, causing a change in control electrode potential tending to decrease the radial deflection. This implies a more reliable functioning of the tube. In the case when the idle positions are at the outer rim of the targets the impulses obviously have to be of negative sign, making the beam move in a direction opposed to that previously assumed.

If a separate electrode is placed in the vicinity of one of the targets of the tube in order to collect the secondary emission from that target and is coupled via a resistor to the same, or a slightly higher, potential than that applied to a second collector electrode common to the remaining targets, an impulse will be obtained at the resistor each time the first-named target is struck by the beam. By this means it is avoided to have impulses derived from a target and all the targets remain unloaded, which may be important in case high-frequency impulses are to be counted.

In the Fig. 4 tube it is possible to a certain extent to modulate the beam without affecting the potential of the control electrode holding the beam. The modulation frequency can be derived from the target being struck by the beam.

What is claimed is:

1. An electron discharge device comprising: an electron gun for projecting along the axis thereof an electron beam, a plurality of targets disposed around said axis so as to form a substantially annular structure and having a secondary emission coefficient greater than unity, and means comprising a plurality of electrodes equal in number to the number of targets and each directly connected to a corresponding target and responsive to the position of said beam when striking any one of said targets to retain the beam on said target, whereby when struck by the beam each target becomes more positive and transmits a positive charge to the electrode connected thereto.

2. An electron discharge device as in claim 1, further comprising means for deflecting said beam from one target to an adjacent target.

3. An electron discharge device as in claim 2, wherein said deflecting means comprises a plurality of electrostatic deflecting elements positioned in the path of said beam and between said electrodes and said targets.

4. An electron discharge device as in claim 2, wherein said deflecting means comprises a magnetic coil having its axis coinciding with the axis of said device and adapted to be pulsed to generate a radial magnetic field in the region of said electrodes.

5. An electron discharge device comprising: an electron gun for projecting along the axis thereof an electron beam, a plurality of targets disposed around said axis so as to form a substantially annular structure and having a secondary emission coefficient greater than unity, a number of electrodes equal in number to the number of targets, each directly connected to a corresponding target,, whereby when struck by the beam each target becomes more positive and transmits a positive charge to the electrode connected thereto, said electrodes being substantially annularly disposed around said axis, and means for adjusting the inoperative position of said beam with respect to said electrodes.

6. An electron discharge device comprising a plurality of elongated targets arranged in two concentric circles, each target in one circle overlapping portions of two adjacent targets in the other circle, means for projecting an electron beam toward said targets, and means for sweeping said beam over all of said targets in succession.

7. A device as in claim 6, wherein said last-named means comprises means for deflecting said beam in a circular path along each target and means for deflecting said beam radially from one circle of targets to the other circle of targets.

8. A device as in claim 7, wherein said first-named deflecting means comprises a plurality of deflecting electrodes equal in number to the number of targets mounted in a circular array around the path of the beam and each coupled with one of said targets located in the same angular position as a part of said one of said targets, whereby the beam is retained on a particular target by the deflecting electrode coupled thereto until said second-named deflecting means is energized.

9. A device as in claim 8, wherein each of said targets has a secondary emission coefficient greater than unity and is directly connected to the corresponding deflecting electrode, whereby when struck by the beam each target becomes more positive and transmits a positive charge to the deflecting electrode connected thereto.

10. An electron discharge device comprising: an electron gun for projecting along the axis thereof an electron beam, a first plurality of targets annularly disposed around said axis, a second plurality of targets annularly disposed outside of said first plurality, each target of said second plurality overlapping angularly a portion of two adjacent targets of said first plurality, means responsive to the current drawn by any one of said targets when struck by the beam to retain the beam on said one target in an angular position corresponding to the overlapping portion of a succeeding target, and means selectively responsive to impulses of alternating signs to increase or decrease the radial deflection of said beam, so as to cause said beam to be stepped successively from one target to another.

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