MULTI-POSITION BEAM TUBE

Filed July 24, 1953 2 Sheets-Sheet 1

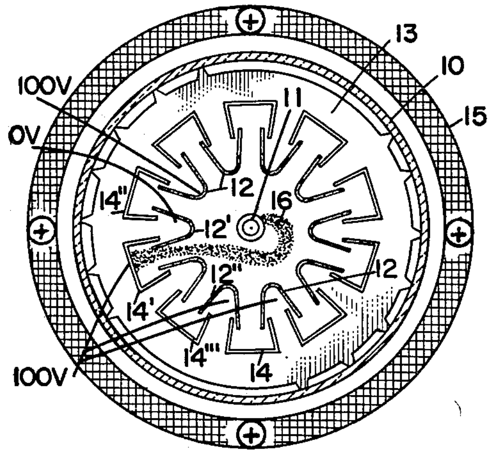


FIG. 1

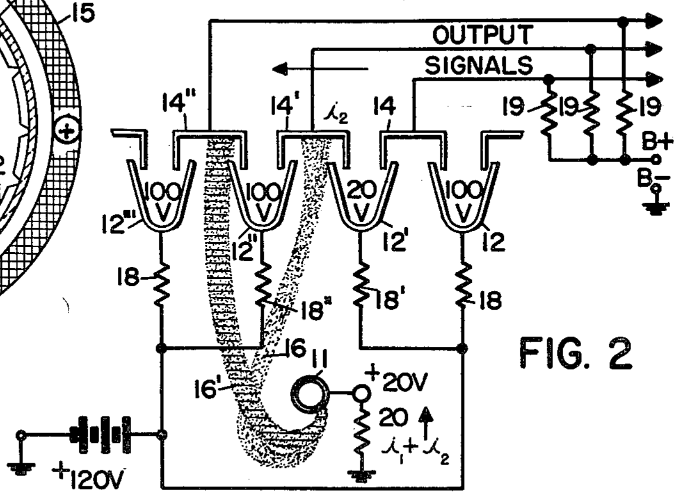


FIG. 2

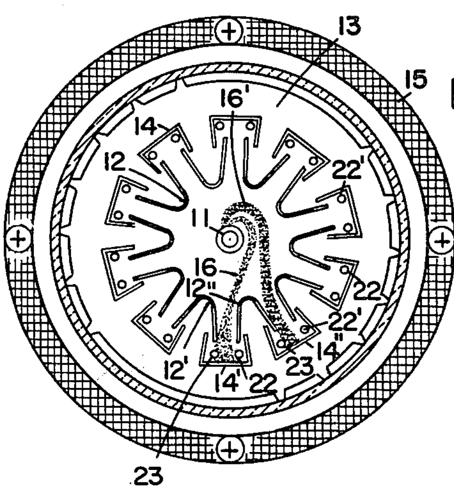


FIG. 3

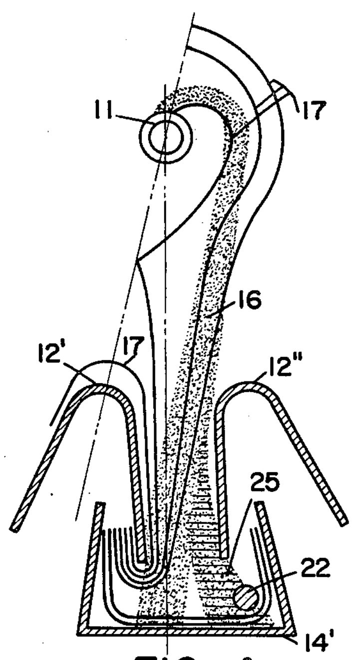


FIG. 4

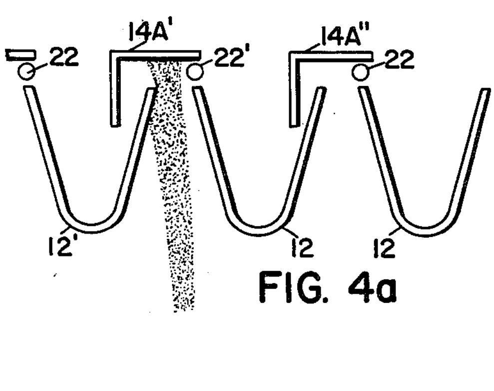


FIG. 4a

INVENTORS
SIN-PIH FAN
SAUL KUCHINSKY
BY
Earl D. Ayers
AGENT

MULTI-POSITION BEAM TUBE

Filed July 24, 1953 2 Sheets-Sheet 2

FIG. 5

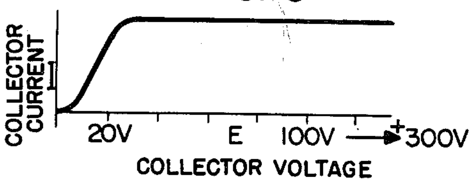


FIG. 6

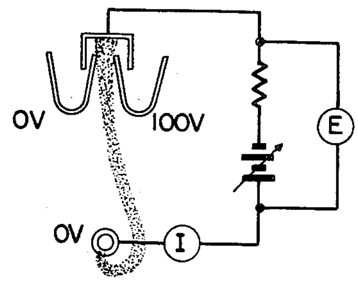


FIG. 7

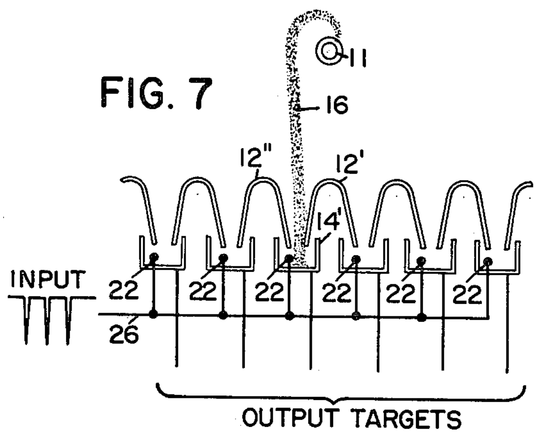


FIG. 8

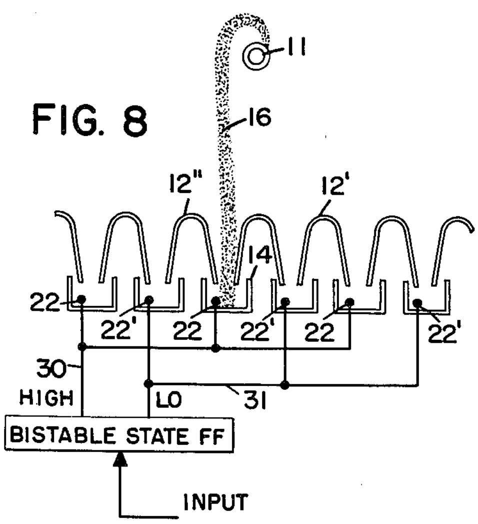
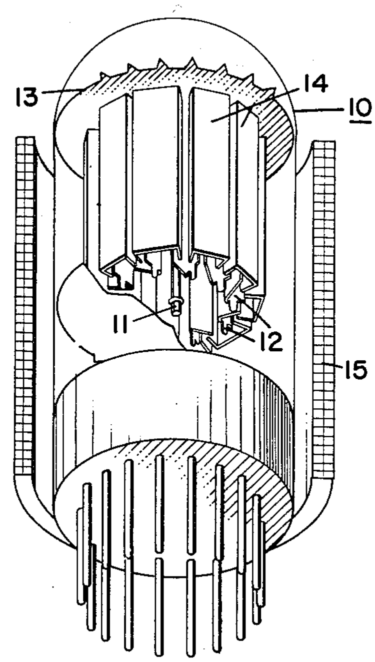


FIG. 9



INVENTORS
SIN-PIH FAN
SAUL KUCHINSKY
BY
Earl D. Ayers
AGENT

United States Patent Office

2,721,955

Patented Oct. 25, 1955

2,721,955

MULTI-POSITION BEAM TUBE

Sin-Pih Fan, Marlton, N. J., and Saul Kuchinsky, Philadelphia, Pa., assignors to Burroughs Corporation, Detroit, Mich., a corporation of Michigan

Application July 24, 1953, Serial No. 370,086

16 Claims. (Cl. 315—21)

This invention relates to electron discharge devices and particularly to multi-position beam tubes.

Multiple position beam switching tubes are known in the art. Tubes of this type are disclosed, for example, in a copyrighted paper entitled "Multi Output Beam Switching Tubes for Computers and General Purpose Use" presented by Saul Kuchinsky at the March 1953 convention of the Institute of Radio Engineers in New York, N. Y.

Briefly, a multi-position beam switching tube of the type referred to above is one in which the switching is accomplished by deflecting an electron stream or beam from one tube electrode to another at a desired rate or in a desired pattern, or both.

Structurally, a tube of the general type referred to above may comprise, within a hermetically sealed envelope, an elongated cylindrical cathode around which are disposed coaxial and concentric arrays of electrodes. The array nearest the cathode comprises a plurality of trough-shaped elements, known in the art as spades, radially disposed with respect to the cathode. Surrounding the first array may be a tubular slotted or sleeve type apertured anode electrode, the slots or apertures being disposed generally between the areas of the anode which are radially opposite the trough-like elements.

Another array of electrodes, the array farthest removed from the cathode, may comprise either a single tubular collector electrode or a plurality of individual collector electrodes, each of the individual collectors being radially aligned with respect to the apertures or slots of the anode electrode or similarly disposed with respect to the space between the spades if no anode is used in the tube. The collector electrode or electrodes may be utilized as the output means of the tube.

Because the tube is intended to be used in conjunction with a magnetic field whose lines of force extend through the tube in a direction substantially parallel with the longitudinal axis of the cathode, it is desirable, in most cases, that the electrodes be made of non-magnetic materials in order to avoid distorting the magnetic field which is usually provided by an external magnet.

The operation of the above described tubes, broadly stated, is as follows: In the static state, all the spades are at substantially the same potential, say 100 volts positive with respect to the cathode. Under this condition an electrostatic field is formed between the cathode and the spades in which, due to the electrode configuration of the tube, equipotential lines in the space between the cathode and spades tend to be circular in shape.

The previously mentioned magnetic field is applied to the tube in sufficient strength and direction to overcome the attractive force of the rather symmetrical electric field for the electrons emanating from the cathode and thus "cut off" the tube. That is, "cut off" represents the condition where the electrons are forced by the magnetic field to follow curved paths around the cathode and are substantially confined to the space between the cathode and the spades, thus preventing the electrons from reaching the spades or the other electrodes.

If, however, one of the spade elements is reduced in potential to somewhere near the cathode potential, for example, the symmetry of the electric field is changed to the extent that the effect of the magnetic field in cutting off the tube is modified and electrons are attracted in the general direction of the spade having the lowered potential. Applicant's structure is such that, although some electrons do impinge on the spade having the lowered potential under this condition, a large part of the electrons are attracted to the adjacent target electrode or electrodes which usually, but not necessarily, are maintained, under no-load conditions, at a higher potential than the spades. Since there are target electrodes on each side of each spade, the target electrode on which the electrons will impinge depends on the polarity of the magnetic field, for this field determines the direction of rotation (either clockwise or counterclockwise) the electrons tend to follow with respect to the longitudinal axis of the cathode.

Several embodiments of multiple position beam tubes which are generally similar to those described above are described and claimed in Saul Kuchinsky's copending application Serial No. 291,531 filed June 3, 1952, and entitled "Trochoidal Beam Counter Tube."

While the tubes disclosed in the Kuchinsky paper and copending application perform in a satisfactory manner in a number of applications, the number of applications could be greatly increased or the performance improved in existing applications by doing one or more of the following:

1. Reduce cross talk and noise to a minimum. That is, the current flow at any one of the different output positions should be electrically isolated from current in any other one of the output positions and the tube structure must be such that the beam path is confined to the desired output electrode.

2. Increase the output current. While the previous Kuchinsky tubes represent an improvement over existing prior art tubes in this respect, an even further increase in power output is always desirable in order to extend the utility of the tube.

3. Isolate the holding and beam switching and other functions of the tube from each other. This would enable each element to perform its function substantially independently of the others.

4. Provide a tube in which a change of potential at the output electrodes does not substantially tend to change the output current afforded by the beam over a wide range of output potential variations. This characteristic is common in pentode tubes and is desirable when varying amplitude signals are to be used such as audio, video, radio or other signals modulated by some intelligence pattern.

5. Provide a structure which is capable of handling a signal having a high percentage of modulation without affecting stability of operation.

6. Provide a tube structure in which the beam switching may be rapid and in which the un-modulated output signal approaches a square wave in form.

7. Provide a beam switching tube which requires a minimum of extrenal circuitry for the operation thereof.

It is, accordingly, an object of the present invention to provide an improved electron discharge device.

Another object of the invention is to provide an improved multiple position beam tube having improved beam switching means.

A further object of the present invention is to provide an improved multiple position beam tube in which cross talk is substantially reduced.

Still another object of the invention is to provide a multiple position beam tube having increased power output capabilities.

A still further object of the invention is to provide an improved multiple position beam tube in which the input, holding, beam switching and output functions of the tube are each isolated from the other.

A related object of the invention is to provide an improved multiple position beam tube in which the output current is substantially constant over a wide range of output potential variations.

An ancillary object of the invention is to provide a multiple position beam tube in which the beam position may be switched rapidly and whose un-modulated output waveform approaches a square wave in shape.

Yet another object of the invention is to provide a multiple position beam tube having improved operating characteristics and which requires a minimum of external circuitry for the operation thereof.

In accordance with the present invention, there is provided an improved magnetron type switching tube having, within a hermetically sealed envelope, a thermionic cathode, a first array of trough-shaped spade electrodes disposed generally in parallel spaced relation with respect to said cathode, and a second array of trough-shaped target electrodes spaced further from the cathode than said first array and interleaved with, but insulated from the electrode of said first array. Each of the electrodes of the first array have the "bottom of the trough" facing in the general direction of he cathode. The sides of each of the electrodes of the second array face in the general direction of the cathode and are telescoped over, or interleaved with adjacent sides of adjoining pairs of spade electrodes in the first array.

By interleaving the target electrodes with the spade electrodes, the electron beam is prevented from impinging on targets other than the intended one. This arrangement substantially eliminates cross talk between targets, since substantially all the target electrons are attracted to the intended target.

By providing a somewhat greater distance between the bottom or beam receiving portion of the targets and the spades, no buffer electrodes are required between the targets and spades in order to isolate the target field from the spade field and thus achieve beam holding and switching stability over a wide range. Elimination of the buffer electrode and the interleaving of targets and spades permits a considerable increase in target current and consequently in increased power output.

The interleaving of targets and spades and the spacing therebetween further provides a tube having pentode characteristics in which output current is relatively unaffected by changes in output voltage. The pentode characteristics may be improved, beam holding and switching functions isolated, and other advantages achieved which will be enumerated below when an additional array of electrodes are incorporated into the tube in accordance with further embodiments of the present invention.

In the further embodiments of the invention, either a pair of elongated electrodes or a single electrode is disposed in the space between each target and the side or sides of the spades with which the target is associated. These elongated electrodes, insulated from both targets and spades, provide means for switching and holding the beam which do not adversely affect the load characteristics of either the target or spades. The potential on each of the elongated electrodes may be separately controlled or connections made either within the tube or external thereto for providing a step-by-step beam switching pattern or other switching pattern. The pentode characteristic of the tube is further improved by the addition of the elongated electrodes, since these electrodes permit a wider output voltage range without adversely affecting the operating stability of the tube. The field surrounding the elongated electrodes may be so adjusted that modulation of the electron beam approaching 100% modulation of the beam may be achieved without adversely affecting beam stability.

In addition, in tubes having electrode structures in accordance with the present invention, the time required to switch the beam from one target to another is very short and the slope of the output wave during switching is steep. These and the above mentioneld improved characteristics enable the tube to be used in a wider number of multiplexing, signal distribution and other applications than was possible with prior art devices.

Finally, the elongated beam switching and holding electrodes, which substantially extend the field of use of multiple position beam tubes, require only relatively simple external circuitry, such as a bistable flip flop, to control the switching and holding of the beam. The use of the elongated electrodes as switching elements further facilitates the use of spade load resistors which are mounted within the tube, since switching need not be done by pulsing individual spades. The internal resistors allow a faster switching time by providing uniform spade operating characteristics and permit the use of a stem having fewer base pins.

Referring to the accompanying drawings, wherein similar component parts are designated by the same reference characters to facilitate comparison of the several views,

Fig. 1 is a sectional plan view of a magnetic multi-position beam tube constructed in accordance with the invention;

Fig. 2 is a schematic circuit diagram illustrating operation of multi-position tubes constructed in accordance with the invention;

Fig. 3 is a sectional plan view of a multi-position beam tube constructed in accordance with a further aspect of the invention;

Figs. 4 and 4*a* are sectional diagrammatic views of a modified tube in accordance with a further aspect of the present invention;

Fig. 5 is a graph illustrating operating characteristics of multi-beam switching tubes of the invention;

Fig. 6 is a simplified schematic diagram of apparatus connected for operation in accordance with the characteristics shown in Fig. 5;

Figs. 7 and 8 are diagrammatic views of means connected for advancing the beam position of multi-output tubes from one target electrode to another; and

Fig. 9 is an isometric assembly view, partly broken away, of a multi-position beam tube in accordance with the present invention.

Referring to Figs. 1 and 9, there is provided in accordance with the present invention a ten position switching type tube **10** having, within a hermetically sealed envelope, a thermionic cathode **11**, a coaxial array of beam deflecting elements or spades **12** disposed along and about said cathode **11**, and a coaxial array of target electrodes **14** disposed along and about and further removed from said cathode **11** than said beam locking or spade elements **12**. The spades **12** have a substantially **V** shaped transverse cross section, the rounded apex of the **V** facing the cathode. The target electrodes **14** have a substantially **U** shaped transverse cross section, the open part of the **U** extending towards the cathode **11**. The disposition of the target electrodes **14** is such that the inwardly extending portion or sides of each electrode is telescoped over or interlocked with. adjacent sides of each pair of beam deflecting or spade elements **12**. The electrodes are maintained in their spaced relationship within the envelope by top and bottom mica spacers **13**. A magnetic field whose lines of force extend generally parallel to the cathode **11** (perpendicular to the plane of the drawing in Fig. 1) is provided either as a part of the tube or external thereto. In Figs. 1 and 9, the magnetic field above referred to is provided by the external magnet **15**. Leads to the various elements or electrodes are connected to pins in the tube base or stem.

As is well known in the art, with the proper application of magnetic and electric fields through the tube an electron stream or beam **16** will be formed and caused to enter a single pocket or space between two spades and impinge upon a single selected target electrode such as that identified as **14'**. A small part of the beam may also impinge upon the adjacent beam locking element **12'** associated with the target element **14'**, and with a characteristic which may therefore be utilized to maintain the beam in a locked-in position. In the illustrated embodiment, therefore, if the cathode is about 20 volts, for example, and all the beam locking elements **12** are at about +100 volts with the exception of element **12'** which is at about cathode potential the electrostatic field existing under these conditions will modify the cut-off effect of the magnetic field in the area near the beam locking element **12'** and the beam will be directed to the target electrode **14'**. With a small portion of the beam impinging upon the beam locking element **12'**, its potential may be held at near cathode potential by means of current flow through an external resistor and thereby maintain the beam in locked-in position. Because of the direction of the magnetic field the beam will impinge upon target electrode **14'** rather than the adjacent target electrode **14''** which the spade **12'** is also associated.

By lowering the potential of a single adjacent beam locking element **12''** the beam may be made to switch to the adjacent target **14'''** in the direction dictated by action of the magnetic field.

The general operation of tubes of this type is well known in the art and, therefore, need not be explained in further detail for an understanding of the present invention. Reference is made to United States Patents 2,513,-260 and 2,591,997 issued respectively to H. Alfven et al. and N. Backmark for further discussion of the theory of operation of this general type of tube.

In the tube of the present invention, improved operation is afforded by the novel constructional features incorporated therein. Thus, the target electrodes **14** comprise substantially U shaped anodes which interleave with two or telescope oversides of adjacent substantially V shaped position control or beam locking spade elements **12**. (Since the open ends of the beam locking elements **12** extend away from the cathode **11**, the U shaped anodes **14** have open ends spanning and overlapping two adjacent spade electrodes **12**.) Both the open ends of the spade electrodes and target electrodes are generally radially disposed about the cathode in a coaxial type tube such as shown in Figs. 1 and 9. By interleaving the position control and target elements with an overlapping but spaced relationship between the ends of the respective electrodes, the beam path is entirely intercepted in all beam positions. With this type of construction, therefore, the possibility of cross talk due to the beam escaping to different target electrodes than the particular selected one, is very small.

For a general understanding of circuitry connected to operate a multiposition beam tube of the type shown, reference is made to Fig. 2. For circuit simplicity hereafter the elements and beam position of the tube may be diagrammatically shown and the magnetic fields understood. It is seen that each spade electrode **12** is connected by means of an associated resistor **18** to a +120 volt supply potential terminal. Thus, the spades are kept at +120 volts unless current flows thereto and causes a potential drop across the associated resistor. The spade resistors **18** may be mounted within the tube if desired. Mounting the resistors within the tube has the advantage that the switching rate is increased due to the uniformity of spade impedances which may be achieved by eliminating long leads between resistors and the spades with resultant nonuniformity in lead caapcitance. Further, uniform resistance is provided since all resistors operate at substantially the same temperature and are not subject to variations in the ambient atmosphere. Further, the use of internal resistors results in a more compact unit and one which requires less leads through the tube base. It may be assumed that the beam is in the illustrated position **16** thereby causing current i_1 flow through spade **12'** and the associated resistor **18'** to change the spade potential to the order of the cathode potential. This causes the required field path to occur between spades **12'** and **12''** and thereby maintains the beam in a locked-in position upon target or anode electrode **14'**. Output signals are attained from current flow i_2 to the target electrodes as developed across corresponding anode resistors **19**, and may be used with any desired utilization circuit. A source of anode potential, supplied at the B+ terminal, is applied through the resistors **19** to the corresponding anodes **14**. By way of a cathode resistor **20**, the combined spade and anode current flow i_1+i_2 develops a cathode potential of +20 volts.

In order to switch the beam which tends to travel in the direction of the arrow because of the orientation of the magnetic field, the spade **12''** might be reduced in potential, for example, by means of an external commutating source (not shown). Since the spade potential in this manner is reduced to about the potential of the spade **12'**, the electrostatic field will be further altered, causing a portion of the beam **16** to impinge upon spade **12''**. Current flow through the corresponding resistor **18''** will cause the spade potential to drop and by means of the magnetic field lock the beam into a succeeding beam position **16'** to impinge upon the succeeding target electrode **14''**.

Alternatively, beam switching may be provided by varying the characteristics of the beam discharge path, such as by lowering anode potential below the spade potential and still other means. It is noted that with either manner of beam switching certain limitations are imposed upon external apparatus associated with the tubes. For example, commutating circuits for successively lowering spade potentials are expensive and inconvenient, and, to an extent, bulky. Also the change of beam characteristics is not desirable should modulation of the beam be desired. For these reasons improved beam switching structure is desirable for stepping the beam from one position to another without complex external switching circuitry or without changing the beam density or without requiring discrete width pulses.

Therefore, the multi-position beam tube of Fig. 3 has included therein additional beam switching elements **22** and **23**. The beam switching elements are spaced, as shown in Fig. 3, between the open ends of the spade electrodes **12** and the closed ends of the target anodes **14**. For a tube adapted to sweep the beam in a single direction only a single set of beam switching elements **22** is necessary. These elements **22** or **23** are located adjacent the end of the spade associated with the advanced position target electrode in the direction of beam travel. The beam switching elements may conveniently be rod-like in form. However, the cross-sectional configuration may be varied to provide a change in operating characteristics. In the tube shown, therefore, the beam switching elements **23** are only provided for tubes adapted to switch in two directions, and further discussion will be limited to the elements **22** since operation of the two different sets of elements will be similar.

Considering the beam switching element **22** located at the open end of spade **12''**, it is seen that a change of its potential, either direct current or pulse, will cause the usually well defined beam in the vicinity of anode **14'** to spread or change its potential, or both, and also impinge upon the spade electrode **12''**. By the locking action heretofore described, the beam advances to adjacent target electrode **14''** as indicated by the new beam position **16'**. Because of the tube structure and the beam switching element position, alternate ones of beam positioning elements **22** and **22'** may be commonly connected. By respectively connecting the two sets at high and low potentials alternately, the beam may be switched without discrete width pulses. In this manner the beam may be advanced with simple external circuitry to be discussed in more detail hereinafter and with a minimum of voltage amplitude, and with a minimum of loading.

The beam positioning effect of the novel structural elements of the present tube is illustrated in Fig. 4. The beam 16 indicated as impinging upon target electrode 14′ defines a narrow beam along a generally equipotential path illustrated by the field lines 17 between spades 12′ and 12″. It is readily seen that the field configuration is such that the beam is well confined in position and does not tend to sneak behind the spade to an adjacent collector target and give cross talk. Only a very small portion of the beam is intercepted by the spade and holding electrode 12′, so that a large amount of output current is available in a tube constructed in this manner. When the beam switching element 22 has its potential reduced, it is seen that the beam path will be displaced or defocussed as indicated by the shading 25 in the right hand corner of the collector anode 14′ as viewed in Fig. 4 and thus toward and into contact with the adjacent spade 12″. Thus, as the beam impinges upon the outer end of the adjacent spade 12″ the potential of spade 12″ will drop and cause the beam to switch to the adjacent target electrode (which would correspond to target 14″ in Fig. 3).

In the embodiment of Fig. 4*a* it is seen that the target electrodes 14*a* need not completely interlock with the spade electrodes 12 when the beam positioning elements 22 are afforded but may be L shaped. This occurs since the high potential (+100) volts of these elements tends to focus the beam upon the target region nearest the spade electrode 12′. Only during the switching interval when the potential of the beam positioning elements 22′ is lowered would the beam tend to escape but then the beam goes to the succeeding spade electrode 12, which is at that time desirable because this is the condition which causes the beam to shift to target electrode 14*a*″. Accordingly, no undesired cross talk due to beam dispersion is possible in this embodiment.

In general the target electrodes or U shaped anodes are spaced away from the open ends of two adjacent V shaped spade a distance approaching or greater than that of the spacing between the open ends of two adjacent spades. When the beam switching elements 22 are included they may therefore be located at a position not affecting the beam formation, yet enabling the desired defocussing or switching when the beam is pocketed on a desired target electrode 14. Further, a change in potential on a beam switching element 22 affects the beam switching of the tube only if the beam is locked in on the position with which the particular beam switching element 22 is associated.

In accordance with the present invention, it has been found that a large change in the beam collecting target potential may be afforded without appreciably affecting the beam current flow available from the tube. Thus the tube provides a pentode type characteristic with output collector current i_c substantially constant as compared with target potential as shown in the graph of Fig. 5.

The diagram of Fig. 6 illustrates the conditions under which this characteristic may be obtained. As the battery voltage is changed from 50 to 300 volts very little change in output current results. This is a highly desirable feature since many multi-position beam tubes will tend to switch the position of the beam with a small change of target potential. Such tubes are well suited for varying beam current applications, such as necessary in communications multiplexing equipment. The present tube, therefore, provides highly stable beam positioning which is readily locked in and maintained over large variations of target potential.

The pentode characteristics illustrated in Fig. 5 apply

to tube structures generally similar to the tube of Figs. 1 and 9. These characteristics are considerably improved by the addition of the separate beam positioning elements 22, as illustrated in Fig. 3. In tubes having structures as illustrated in Fig. 3 and similar thereto, substantially constant output current was obtained until the collector potential was only a few volts positive, less than 10, for example, with respect to the cathode. These excellent performance characteristics may be attributed to the normally higher potential on the beam switching elements 22 when the beam is locked in, for this higher potential thereon tends to focus the beam on the target 14′ even though the target potential falls substantially below that of the spade 12″. At the same time this prevents spade 12″ from receiving sufficient current to switch the beam.

It may be seen from the above that considerable modulation of the electron beam may be achieved without affecting adversely the operating stability of the tube. The electron beam may be cathode modulated or modulated by means of a grid surrounding the cathode, although the latter method is the less satisfactory in many applications.

When the tube is constructed as shown in Fig. 3, with beam switching elements 22 provided, they may be commonly connected in a single set as diagrammatically shown in Fig. 7 by way of lead 26. A single periodically repetitive switching signal source may therefore be connected with the switching electrodes to adapt the tube as a multi-position counter device. It is however to be recognized that the switching signals need not be periodical should it be desired to change the beam position in response to randomly occurring signals.

A discrete pulse width is required for the embodiment illustrated in Fig. 7 to provide step-by-step switching from one beam position to the next adjacent position. With too short a pulse the beam will not switch. With longer switching pulses the beam may be caused to switch to any desired number of positions automatically, since the field will be distorted such that the beam automatically advances as soon as enough beam current flows between two adjacent spades to cause the beam defocussing to occur.

An alternative beam switching circuit is diagrammatically shown in Fig. 8. In this instance, alternative sets of switching electrodes 22 and 22′ are respectively connected to a corresponding pair of leads 30 and 31. By respectively raising the potential of one commonly connected set of switching electrodes while lowering the potential of the other commonly connected set of switching electrodes, such as provided by the operation of the bistable state flip-flop circuit 33 in response to complementing input signals, the beam may be caused to advance position by position by alternately changing the potential in either a pulse or D. C. manner of the two sets of electrodes. It is of course to be recognized that several sets of elements could be connected for alternative counts.

It is clear from the foregoing description that improved operation is provided by the novel structural features of the present invention. It is to be recognized moreover that from the teaching of this invention certain adaptations will be immediately suggested to those skilled in the art which may not depart from the spirit or scope of the invention as defined in the following claims.

What is claimed is:

1. An electron tube for operation under the influence of crossed magnetic and electric fields comprising an elongated substantially evacuated envelope, an indirectly heated thermionic cathode centrally disposed therein, an array of similar spades disposed adjacent to said cathode, each of said spades having a trough-shaped transverse cross section, the sides of said spades extending generally away from said cathode, an array of similar target electrodes disposed adjacent to said array of spades and on the side thereof which is more remote from said cath-

ode and laterally displaced with respect to said spades, each of said target electrodes having a beam receiving surface and one side member angularly disposed therewith, the side member of each of said target electrodes extending inwardly into the troughs of said spades and interleaving with an adjacent side of an adjoining spade, the sides of said target electrodes being spaced from the sides of the spades with which they are interleaved, and a further structural member disposed at the opposite side of the target electrodes to said side member tending to provide an electric field confining the beam to the beam receiving section of the target.

2. A tube as defined in claim 1 wherein the further structural member is a rod-like electrode disposed in line with at least one side of each spade electrode in the space separating the spade electrode from the adjacent target electrode.

3. An electron tube as defined in claim 1 wherein said target electrodes are trough shaped anodes having two angularly disposed surfaces with the closed portion of each target electrode providing said beam receiving surface and enveloping the passageway between two adjacent spade electrodes, and with the two angularly disposed surfaces of the anode overlapping the open ends of the two spade electrodes whereby the further structural member is one of the angularly disposed surfaces.

4. The combination defined in claim 3 wherein the closed portion of such trough shaped anode is positioned radially away from the open ends of the two adjacent spades which it envelopes a distance at least that of the spacing between the open ends of the two spades with the open ends of the anode overlapping the open ends of the two adjacent spades.

5. A tube as defined in claim 3 including beam switching elements spaced between the open ends of said spade electrodes and the closed ends of said anodes for changing the locked-in position of the electron beam on one anode to a locked-in position on an adjacent anode.

6. A multi-position beam tube for operation under the influence of crossed magnetic and electric fields comprising a cathode, a plurality of electron beam locking elements concentrically arranged about said cathode to form the beam and hold it in one of a plurality of selectable stable locked in positions, a plurality of target electrodes concentrically arranged about said beam locking elements, and beam switching elements interspersed between said target electrodes and said beam locking elements in a position at one side of the stable locked in positions of the beam to deflect the beam to a new position upon application of a switching pulse whereby switching occurs without substantially diminishing beam current.

7. The combination of a multi-position beam tube for operation under the influence of crossed magnetic and electric fields comprising a cathode, a plurality of target electrodes, a plurality of beam holding electrodes each adapted to hold the beam on a respective one of said target electrodes, and a plurality of beam switching electrodes positioned at one side of the stable locked-in beam path to deflect the beam position upon application of a switching pulse, each of said beam switching electrodes being associated with a particular target lead means connecting to said switching electrodes, a switching signal source, and circuit means interconnecting said lead means and said switching signal source to provide for controlled switching of the beam in response to switching signals from said source.

8. The combination defined in claim 7 wherein alternate ones of said switching electrodes are commonly connected through said lead means into two sets, and said switching signal source is connected through said circuit means for raising the potential of one commonly connected set of switching electrodes while lowering the potential of the other commonly connected set of switching electrodes, whereby alternative changing of the potential of the two sets of electrodes steps the beam along from target to target.

9. The combination defined in claim 7, wherein said circuit means connect said switching signal source to all said lead means in common to lower the potential of all switching electrodes simultaneously with each successive switching pulse for a period of time chosen to cause the beam to step from one target electrode to the next target electrode.

10. An electron discharge device for operation under the influence of crossed magnetic and electric fields comprising an elongated substantially evacuated envelope, an indirectly heated thermionic cathode centrally disposed therein, a concentric and coaxial array of similar spades symmetrically disposed with respect to said cathode, each of said spades having a trough-shaped transverse cross section, the sides of said spades extending away from the center portion of said envelope, a concentric and coaxial array of at least two target electrodes radially disposed with respect to said cathode displaced to receive beam current flowing between two adjacent spades, each of said targets having a target area and at least one radially extending side, said side of each of said target electrodes extending inwardly and interleaving in the trough of the adjoining spade, a rod-like electrode disposed in line with at least one side of each spade in the space separating said spade from the target near which said spade is disposed, and lead means connecting said cathode, said spades and target electrodes, and said rod like electrodes with the exterior of said envelope, said lead means to said spades including a separate impedance member connected in series with each spade.

11. A magnetron type multiple position beam switching tube comprising an elongated thermionic cathode, an inner circular array of beam forming and directing spade electrodes, a middle circular array of beam switching electrodes, and an outer circular array of electron receiving output target electrodes, each of said arrays being substantially concentrically disposed about the cathode, the electrodes of each array being symmetrically spaced one from another, there being an equal number of electrodes in each array, each of said spade electrodes having a substantially U-shaped cross-sectional configuration with the open side of the electrode facing generally outwardly from the cathode, each of the target electrodes having a substantially L-shaped cross-sectional configuration, one section of the L of each target electrode extending into the space between the outwardly extending portions of an adjacent one of said spade electrodes, and each of said beam switching electrodes being associated with a separate one of said target electrodes and being disposed between the other section of the L-shaped configuration of its associated target electrode and one of said spade electrodes other than that spade electrode into which the first mentioned section of the target electrode extends.

12. A magnetron type multiple position beam switching tube comprising an elongated thermionic cathode, an inner circular array of beam forming and directing spade electrodes, an intermeiate circular array of rod-like beam switching electrodes, and an outer circular array of electron receiving output target electrodes, each of said arrays being concentrically disposed with respect to the cathode, the electrodes of at least the two inner arrays being symmetrically spaced one from another, there being an equal number of electrodes in each of the two inner arrays, each of the spade electrodes having a substantially U-shaped cross-sectional configuration with the closed end of the U disposed nearest to the cathode, each of the target electrodes presenting at least two angularly related surface portions toward the cathode, one surface portion of each target electrode extending crosswise to the space between an adjoining pair of said spade electrodes to intercept an electron beam from the cathode passing therethrough, another of said surface portions of each target electrode extending substantially into the open end of one

of the adjoining pair of spade electrodes with which the target electrode is associated, each of said beam switching electrodes being disposed between the beam intercepting surface portion of each target electrode and the other of the pair of adjoining spade electrodes with which the target electrode is associated.

13. Electron discharge apparatus comprising, in combination, an elongated cathode, an inner circular row of spaced apart electron beam forming and directing spade electrodes concentrically disposed around the cathode, each of said spade electrodes being generally U-shaped in cross section and positioned with the closed end of the U nearest to the cathode, an outer circular row of spaced apart output target electrodes concentrically surrounding the circular row of spade electrodes in radial spaced relation thereto and positioned in substantial alignment with the spaces between the spade electrodes, each of said target electrodes presenting a surface portion crosswise to the space with which it is aligned to receive an electron beam passing therethrough from the cathode, magnetic means arranged for producing a magnetic field permeating the electron discharge area defined by the target electrodes with the field lines thereof extending substantially parallel to the cathode, the polarity of the magnetic field lines determining the direction of rotation of the electron beam around the cathode, a beam switching electrode in each of said spaces and located on the side thereof in the direction the electron beam is urged by the polarity of the magnetic field, and means for changing the potential of the beam switching electrodes to cause the electron beam to shift from space to space.

14. Electron discharge apparatus comprising, a cathode, an inner row of spaced apart beam forming spade electrodes each being generally U-shaped in cross section and forming a trough with the closed end oriented toward the cathode, an outer array of spaced apart target electrodes, each with a surface disposed beyond and in line with the space between two adjacent spade electrodes and having a span greater than said space to receive an electron beam passing therethrough from the cathode, one side member extending from said surface toward the trough of the adjacent spade member on one side of the surface, a further structural member associated with the opposite side of said surface from said side member and positioned closely adjacent to the adjacent spade on the other side of the surface, and magnetic means producing a magnetic field permeating the electron discharge area defined by the target electrodes and the cathode with the field lines extending substantially perpendicular to the electric field established by potential sources when connected to the cathode and the spade and target electrodes.

15. The combination of a multi-position beam tube as defined in claim 14, means coupling into separate sets a plurality of alternately disposed electrodes for switching the beam from one target electrode position to another in said tube, and means for alternately applying switching signals to said sets of beam switching electrodes to step the beam from one position to another.

16. Electron discharge apparatus comprising, in combination, an elongated cathode, an inner circular row of spaced apart electron beam forming and directing spade electrodes concentrically disposed around the cathode, each of said spade electrodes being generally U-shaped in cross section and positioned with the closed end of the U nearest to the cathode, an outer circular row of spaced apart output target electrodes concentrically surrounding the circular row of spade electrodes in radial spaced relation thereto and positioned in substantial radial alignment with the spaces between the spade electrodes, each of said target electrodes presenting a surface portion crosswise to the space with which it is aligned to receive an electron beam passing therethrough from the cathode, said spade electrodes and said target electrodes forming a plurality of locked-in positions for an electron beam and adapted to form an electric field upon connection to operating potentials such that one spade is lower in potential than the remaining spades at operating potential and will hold the beam in a stable locked-in position impinging on the lowered spade electrode and its associated target electrode, magnetic means arranged for producing a magnetic field permeating the electron discharge area defined by the target electrodes with the field lines thereof extending substantially parallel to the cathode, the polarity of the magnetic field lines determining the direction of rotation of the electron beam around the cathode, and a beam switching electrode in each of said spaces and positioned on the side of the stable locked in positions of the electron beam in the direction of rotation the electron beam is urged by the polarity of the magnetic field to deflect the beam to a new position upon application of a switching pulse whereby switching occurs without substantially diminishing beam current.

References Cited in the file of this patent

UNITED STATES PATENTS

2,395,299	Skellett	Feb. 19, 1946
2,536,150	Backmark et al.	Jan. 2, 1951
2,553,735	Adler	May 22, 1951
2,563,807	Alfven et al.	Aug. 14, 1951
2,591,997	Backmark	Apr. 8, 1952
2,599,949	Skellett	June 10, 1952
2,620,454	Skellett	Dec. 2, 1952
2,659,814	Sternbeck	Nov. 17, 1953