

Nov. 20, 1951

J. R. PIERCE ET AL

2,576,040

CATHODE-RAY DEVICE

Filed March 10, 1948

3 Sheets-Sheet 1

FIG. 1

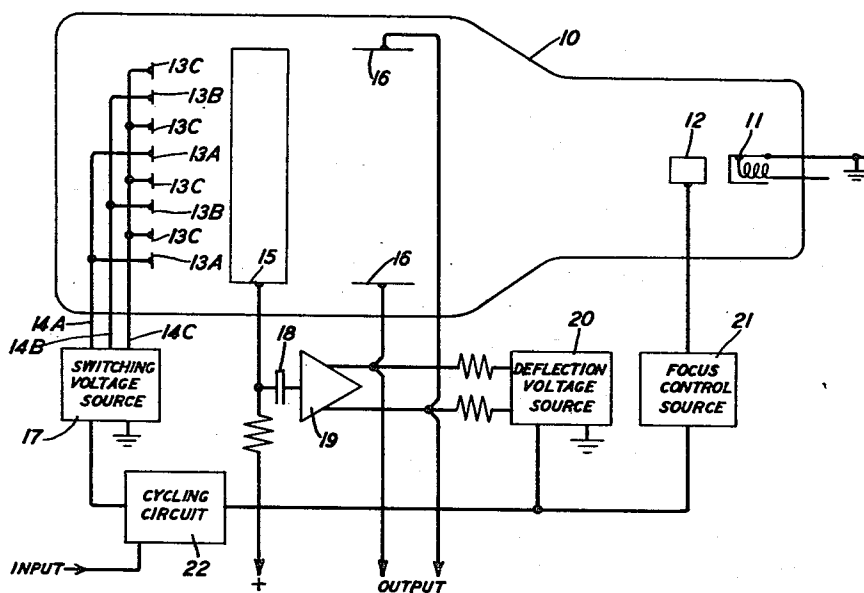


FIG. 2

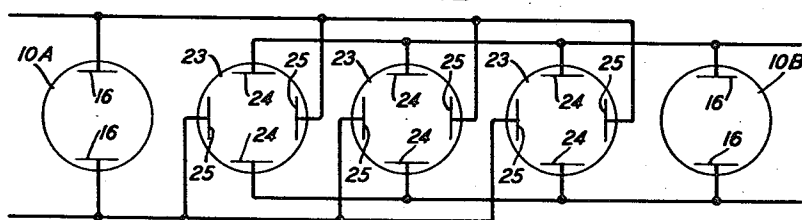
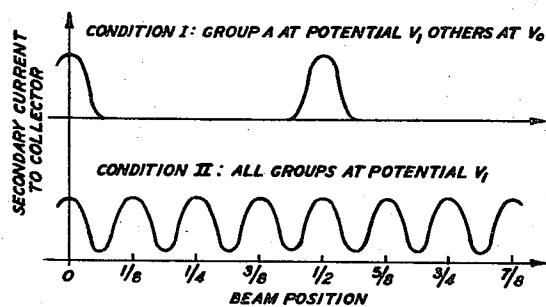


FIG. 3



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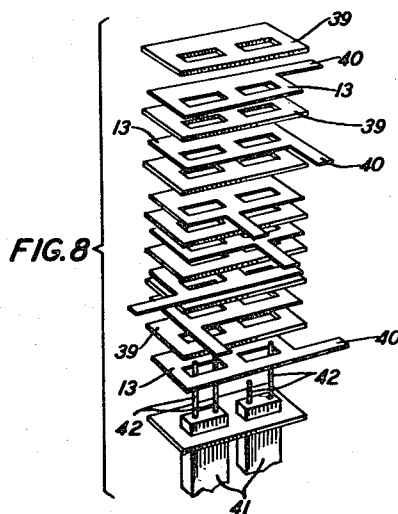
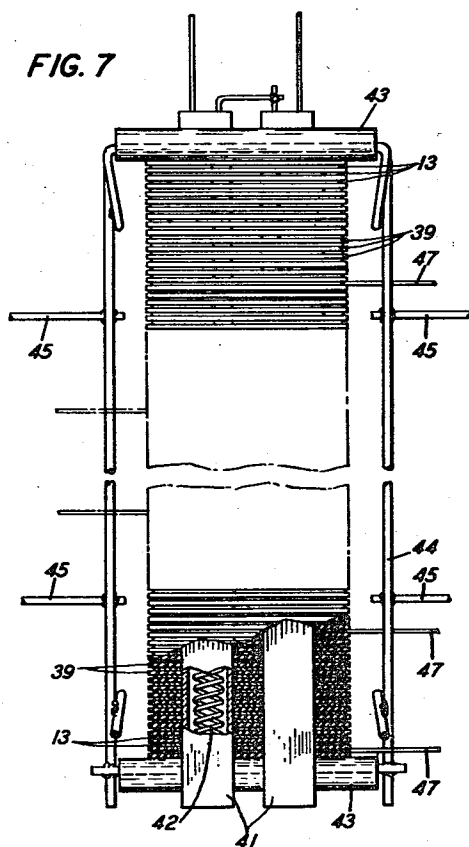
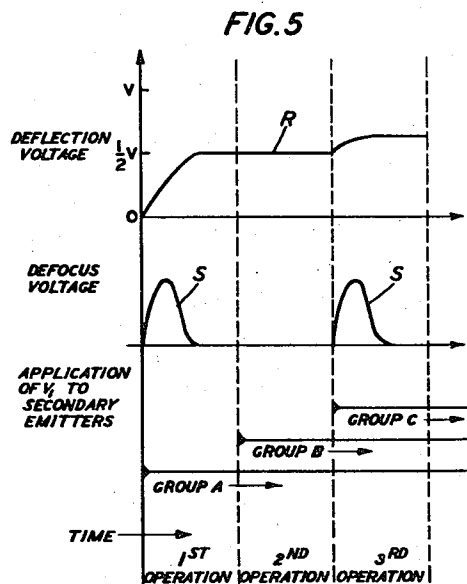
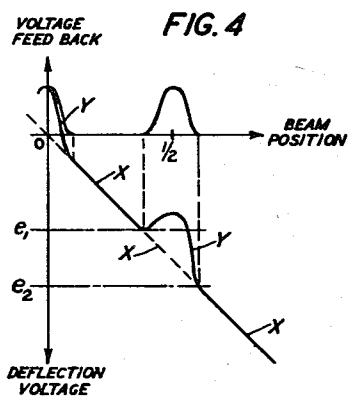
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CATHODE-RAY DEVICE

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3 Sheets-Sheet 2



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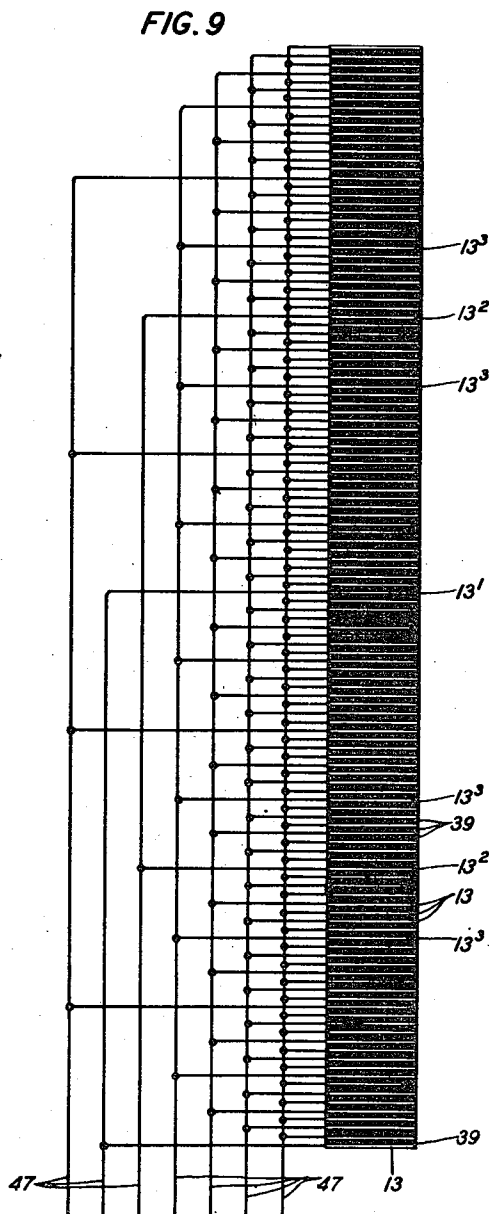
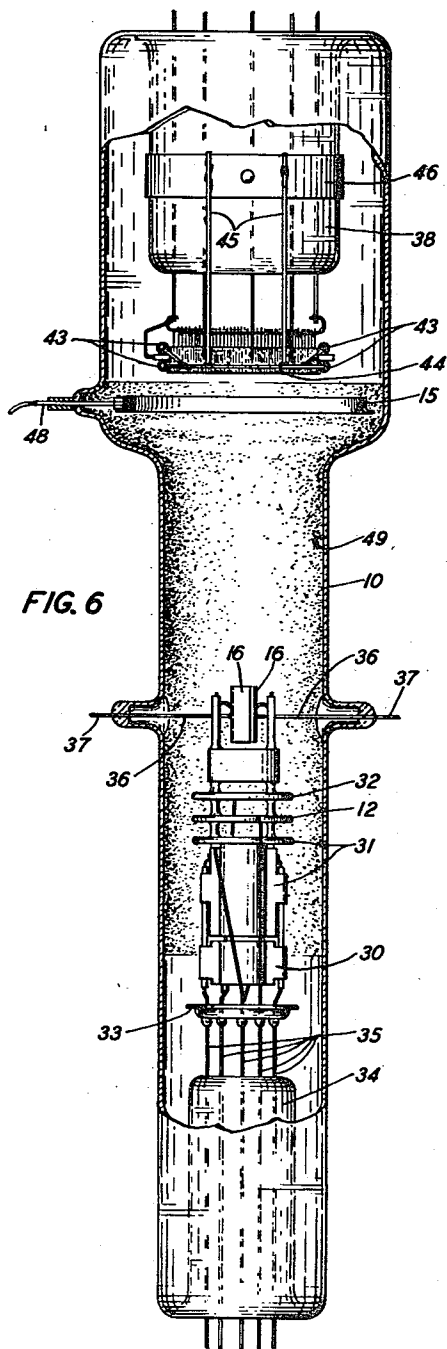
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CATHODE-RAY DEVICE

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,576,040

CATHODE-RAY DEVICE

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14 Claims. (Cl. 315-21)

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This invention relates to electron discharge apparatus and more particularly to cathode ray devices comprising a plurality of target electrodes.

One object of this invention is to facilitate the production of a potential of any one of a multiplicity of precisely accurate prescribed magnitudes between a pair of terminal points, such as, for example, a pair of deflector plates of a cathode ray device.

Another object of this invention is to enable the ready and rapid translation of one or a series of voltage pulses of approximately a prescribed magnitude into a corresponding potential of a precisely preassigned magnitude.

A further object of this invention is to achieve accurately reproducible electron beam deflections in one or more cathode ray devices.

Still another object of this invention is to facilitate the realization of such accurately reproducible beam deflections.

A still further object of this invention is to simplify the construction of multi-target cathode ray devices and especially of the target assembly and the leading-in system therefor.

In one illustrative embodiment of this invention, a cathode ray device comprises a plurality of targets, an electron gun for projecting a concentrated electron beam to the targets and a deflection system for deflecting the beam in one direction to pass over the targets in succession. In one construction, the targets are mounted in a row and the deflection system comprises a pair of deflector plates effective when energized to deflect the beam in one direction along the row. A feedback coupling is provided between the targets and the deflection system such that when the electron beam is deflected to impinge upon any prescribed target, the deflecting voltage is adjusted automatically to hold the beam in a preassigned position corresponding to that target. Thus, each beam position corresponds to a precise adjusted or final deflecting voltage and any one of a multiplicity of preassigned potentials may be produced precisely across the deflection system by the application of a corresponding voltage approximating the potential to the deflection system.

The targets are constructed to have a secondary emission coefficient greater than unity and have in cooperative relation therewith a collector electrode for receiving secondary electrons emanating from the targets. The collector electrode serves as the input element for the feedback cou-

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pling and is connected to the deflection system through a suitable circuit such as an amplifier.

In accordance with one feature of this invention, the targets are connected in groups in accordance with a prescribed number system and the deflection system is energized selectively by groups of pulses such that increments of deflecting voltage of amplitudes related in accordance with the same number system are applied to the deflecting system, the application of such increments and the feedback coupling being controlled so that the beam is deflected to the position represented by the applied group of pulses. In a specific embodiment, the targets are connected in interleaved groups in accordance with a binary number system and the increments of deflecting voltage are related in the same manner whereby in response to any pulse group the beam is stepped according to the binary expansion of the number represented by that pulse group, to the respective target.

In accordance with another feature of this invention, in a device comprising secondary electron emissive targets, the several groups of targets are brought successively into emitting condition relative to the collector electrode whereby in each step of its deflection in response to a pulse group the beam encounters only one emitting target.

The potentials produced across the deflection system may be utilized to control the beam deflection in one or more cathode ray devices. Two devices constructed in accordance with this invention may be utilized to produce coordinate deflecting potentials for one or more cathode ray devices.

The invention and the above noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a diagram showing the components, and relation thereof, of a cathode ray device and associated circuit illustrative of one embodiment of this invention;

Fig. 2 is a diagram illustrating one manner in which devices as shown in Fig. 1 may be utilized to produce coordinate deflecting voltages for a plurality of cathode ray devices;

Figs. 3, 4 and 5 are diagrams illustrating various relations and principles involved in the operation of the device shown in Fig. 1;

Fig. 6 is an elevational view, partly in section,

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of a cathode ray device constructed in accordance with this invention;

Fig. 7 is a plan view, partly in section, of the target electrode assembly included in the cathode ray device shown in Fig. 6;

Fig. 8 is an exploded perspective view of a portion of the assembly illustrated in Fig. 7, showing details of the target electrodes and the spacers therebetween; and

Fig. 9 is a diagram illustrating the electrical grouping of the target electrodes in the assembly shown in Fig. 7.

Referring now to the drawing, the cathode ray device illustrated in Fig. 1 comprises an evacuated enclosing vessel 10 at one end of which an electron gun, shown for simplicity of illustration as comprising a cathode 11 and a cylindrical control electrode 12, is mounted. Opposite the gun and adjacent the other end of the vessel 10 are a plurality of secondary electron emissive targets 13A, 13B and 13C which are mounted in a row aligned with the electron gun and are electrically connected in three groups, as shown, by conductors 14A, 14B and 14C. In cooperative relation with the targets 13 to receive secondary electrons emanating therefrom is a cylindrical collector electrode 15. Parallel deflector plates 16 are positioned between the electron gun and the targets, the plates being effective in response to the application of a potential therebetween to deflect the electron beam projected by the gun, along the row of targets.

The conductors 14 are connected to a switching voltage source 17 such that the three groups of target electrodes may be biased selectively at a potential requisite for the flow of secondary electrons therefrom to the collector electrode 15, which is operated at a potential positive relative to the cathode 11. The collector electrode 15 is connected to the deflector plates 16 by way of a condenser 18 and amplifier 19 so that whenever the electron beam impinges upon a target at a potential such that secondary electrons flow therefrom to the collector electrode, a component of deflecting potential is impressed between the deflector plates. Pulses of deflecting voltage are impressed between the plates 16 from a source 20. Another source 21 serves to focus or defocus the beam upon the targets. The several sources 17, 20 and 21 are controlled by a cycling circuit 22 to produce concomitant operations as described hereinafter.

As has been noted heretofore, whenever the electron beam is incident upon a target 13 at a proper potential, secondary electrons flow from this target to the collector electrode 15. Assume that the potential requisite for such flow is V_1 and that for a potential V_0 such flow cannot obtain. If the beam is deflected along the row of targets 13 and group A of the targets, i. e. the targets 13A, are at the potential V_1 and the other targets are at potential V_0 , the current to the collector electrode 15 will vary as illustrated in the upper portion of Fig. 3. That is, as the beam crosses the targets 13A, which correspond to abscissae 0 and $\frac{1}{2}$ in Fig. 3 as will be explained hereinafter, current flows to the collector electrode, whereas no current flows to this electrode when the beam crosses the other targets. The component of voltage impressed between the deflector plates 16 from the amplifier varies in like manner. If all of the targets were at the potential V_1 , the current to the collector electrode would vary as illustrated by the lower curve in

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Fig. 3, each crest in this curve corresponding to a respective target. It will be noted that the current is substantially the same for each target electrode.

The position of the electron beam is linearly dependent upon the deflecting voltage effective between the deflector plates 16, as illustrated by the straight portions X of the graph line in Fig. 4. Assume that the targets 13A are at the potential V_1 , the other targets are at the potential V_0 and a deflecting voltage of amplitude between e_1 and e_2 is impressed between the deflector plates 16 from the source 20. Assume further that the amplifier 19 is so poled that the component of deflecting voltage due thereto opposes the voltage due to source 20. Then, upon application of the voltage, between e_1 and e_2 , corresponding to deflection of the beam to the upper target 13A, the beam will move along the row of targets. As the beam impinges upon either target 13A and moves along it, a component of potential in opposition to the applied deflecting potential is produced so that the deflecting potential effective between the plates 16, for these positions of the beam is of the amplitude indicated by the portions Y of the graph in Fig. 4.

It can be shown readily that for all deflecting potentials of amplitude between e_1 and e_2 applied from the source 20 the beam will come to rest at a position within a narrow range just to the left of the position marked $\frac{1}{2}$ in Fig. 4, that is it will come to rest at a position within a narrow range just below the center of the upper target 13A in Fig. 1. At this position or restricted range of positions, a definite voltage obtains across the deflector plates. Thus, for a range of potentials which will deflect the beam to strike the target corresponding to the $\frac{1}{2}$ abscissae in Fig. 4, by virtue of the feedback from the collector electrode 15 and the motion of the beam to establish a condition of equilibrium, a substantially fixed potential results across the deflector plates 16.

Similarly, for applied deflecting voltages which deflect the beam to any other of the targets, a conversion of the applied voltage to a substantially fixed potential between the deflector plates 16 occurs.

The accuracy of resolution of applied deflecting voltages into a corresponding fixed potential across the deflector plates will be dependent upon the amplitude of the feedback voltage. In general, the deflection sensitivity is reduced the greater the feedback. Hence, the accuracy of resolution may be varied by control of the feedback, for example, by adjustment of the amplification of the amplifier. In a typical case of 128 targets, resolution of voltages applied from the source 20, in a range of ± 10 per cent, can be resolved into a resultant potential across the deflector plates 16 varying no more than $\pm \frac{1}{2}$ per cent of the voltage required to deflect the beam across all targets.

Thus, the device illustrated in Fig. 1 is effective to produce voltages of prescribed amplitudes in response to signal voltages applied from the source 20. Such voltages may be utilized to effect accurately reproducible beam deflections in one or more cathode ray devices, for example, as illustrated in Fig. 2. In this figure, two devices 10A and 10B of the type shown in Fig. 1 and heretofore described serve to provide coordinate deflecting potentials for a series of cathode ray devices 23 each having pairs of deflecting plates 24 and 25 in space quadrature. The deflector plates 24 are connected in parallel with the deflector plates

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16 of the device 10B; the plates 25 are similarly connected with respect to the plates 16 of the device 10A. Hence, the deflecting potential across any pair of deflector plates 24 or 25 will be the same as that across the respective deflector plates 16 and inasmuch as, as has been pointed out above, the voltages across the plates 16 are accurately representative of signal voltages impressed upon either device 10, accurately reproducible deflections of the beams in the devices 23 are obtainable. Viewed in one way, the combination illustrated in Fig. 2 functions to produce prescribed beam positions in each of the devices 23 in response to signals applied to the devices 10A and 10B so that for each pair of signals, within certain ranges, applied to the devices 10A and 10B, the beam in each of the devices 23 will be deflected to a definite corresponding position.

It will be appreciated that the voltage required across the deflecting plates 16 of Fig. 1 to deflect the electron beam to some particular target, say 13A, will depend on the accelerating voltage which governs the speed of the electrons in the electron beam. Thus, the accurate reproduction of a voltage requires the accurate control of the voltage supply for the coordinate tube. However, when several controlled tubes 23 are coupled to the coordinate tubes 10A and 10B as in Fig. 2, an accurate reproduction of beam position in the tubes 23 is achieved despite fluctuations in supply voltage if the same voltage supply is used for the tubes 23 as for the tubes 10A and 10B, since the fluctuations in supply voltage will then affect the deflection sensitivities of the tubes 10A, 10B and 23 in a like manner.

The number of different fixed potentials which can be produced across the deflector plates 16 in a device of the type illustrated in Fig. 1 is dependent, of course, upon the number of targets 13. In many cases, it is eminently desirable that this number of potentials be large. For example, in one instance 128 different potentials are desirable. The provision of this order of number of targets entails obvious difficulties and complexities, particularly from the standpoints of establishing leading-in connections to the targets and of control of the beam deflection.

In accordance with one feature of this invention, a structure including a multiplicity of targets with a readily fabricable leading-in system is realized. Basically, viewed in one way, this involves interconnecting the targets in accordance with a binary number system. The principles involved will be understood from the following analysis with reference to the eight target structure illustrated in Fig. 1. As has been pointed out heretofore, the eight targets are connected in three groups. Inasmuch as the beam deflection is linearly proportional to the deflecting voltage and as the targets are equally spaced, it is evident that each deflection voltage may be designated by a respective target

$$\frac{n}{8}$$

where n is 0 or an integer from 1 to 7, n being zero for the lowest target in Fig. 1 and 7 for the uppermost target.

The targets, then, may be indicated by fractions of a deflection voltage, V , requisite to deflect the beam from the lowest target 13A to the uppermost target 13C. Thus indicated, it is evident that the lower target 13A corresponds to 0 and the upper target 13C corresponds to $\frac{7}{8}$; the lower target 13B corresponds to $\frac{1}{4}$ and the upper

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target 13B to $\frac{3}{4}$; and the targets 13C in order from bottom to top correspond to $\frac{1}{8}$, $\frac{3}{8}$, $\frac{5}{8}$ and $\frac{7}{8}$, respectively. In general, if there are 2^p beam positions or targets, any group k of targets would comprise targets corresponding to

$$\frac{1}{2^k}, \frac{3}{2^k}, \frac{5}{2^k}, \dots, \frac{2^k-1}{2^k}$$

where $2 < k < p$. The first group would contain the additional electrode zero. In the particular case illustrated in Fig. 1, it is evident that $p=3$.

For the structure including eight targets connected in three groups, it will be seen that any deflection voltage corresponds to a binary expansion and the corresponding deflection may be produced by a permutation of three pulses and no pulses between the deflector plates 16. Forgetting for the moment the amplitude of the pulses, fractions of a voltage V correspond to the following pulse groups, 0 indicating no pulse and 1 indicating a pulse.

Fraction of V	Pulse Group
0	000
$\frac{1}{8}$	001
$\frac{1}{4}$	010
$\frac{3}{8}$	011
$\frac{1}{2}$	100
$\frac{5}{8}$	101
$\frac{3}{4}$	110
$\frac{7}{8}$	111

A specific example will illustrate the operating principle involved. Assume that it is desired to produce across the deflecting plates 16 a voltage of amplitude $\frac{5}{8} V$. The corresponding beam position is that for which the beam impinges upon the next to the top target 13C in Fig. 1. Now, the binary expansion of the number $\frac{5}{8}$ is $\frac{1}{2} + \frac{1}{4} + \frac{1}{8}$ and the corresponding pulse group is 101, as set forth in the above table. Hence, the requisite deflection and the desired voltage across the deflector plates can be produced by applying between the deflector plates a pulse of amplitude $\frac{1}{2} V$ and then adding a second pulse of amplitude $\frac{1}{8} V$.

Actually, in order to minimize transient effects in the feedback circuit through the amplifier 19 when the beam moves off of any target emitting secondary electrons to the collector electrode 15, the operation is somewhat more involved than above indicated. Specifically, the operation proceeds in a series of steps in each of which the beam is focussed or defocussed. Consider again the specific example referred to above, i. e. the case where a voltage of amplitude $\frac{5}{8} V$ is desired across the deflector plates 16. The sequence of steps is as illustrated in Fig. 5.

The targets of group A, that is the two targets 13A, are connected to the source 17 so that they are permanently at the potential V_1 . Initially all the other targets, 13B and 13C, are at the potential V_0 . Hence, at the start of the cycle the beam impinges upon the lower target 13A in Fig. 1. The first step or operation in the cycle is the application of a voltage pulse of $\frac{1}{2} V$ from the source 20 to the deflector plates 16 as indicated by curve R in Fig. 5. Simultaneously, a defocussing pulse, indicated by curve S in Fig. 5 is applied to the electrode 12 from the source 21. The defocussing pulse is of such form as to allow the beam to refocus and transients in the feedback circuit to die out before the second step is initiated.

As a consequence of the first step, the beam

will impinge upon, and be held upon the upper target 13A, which corresponds to the potential $\frac{1}{2}$ V.

In the next step, targets 13B are placed at the potential V_1 and an appropriate increment of deflecting potential is applied to the deflector plates 16 from the source 20. Inasmuch as, in the specific example under consideration, the second term in the binary expansion is zero, no deflecting pulse or defocussing voltage is called for or applied. Thus, as indicated in Fig. 5, during the second step or operation, the deflection voltage remains at substantially $\frac{1}{2}$ V.

In the third step or operation, the targets of group C, i. e. the targets 13C are brought to the potential V_1 by the source 17. Simultaneously a deflection pulse increment of $\frac{1}{8}$ V is applied to the deflector plates 16 from the source 20 and a defocussing voltage pulse is applied to the electrode 12 from the source 21. As a result, the beam is deflected to the next from the top target 13C. By virtue of the feedback it will come to rest at the position corresponding precisely to the potential $\frac{5}{8}$ V, which is the desired one.

It may be remarked that because of the feedback action the applied deflecting pulses need only roughly equal the amplitudes $\frac{1}{2}$ V and $\frac{1}{8}$ V to produce precisely the desired potential $\frac{5}{8}$ V. For example, variations of the order of ± 10 per cent in applied pulses may be tolerated.

In the specific example above discussed, inasmuch as the second term of the binary expansion of $\frac{5}{8}$ is zero ($\frac{0}{8}$), no defocussing or stepping pulse is applied during the second step. It will be evident, of course, that if the second term of the expansion were $\frac{1}{4}$, as in the cases where a final potential of $\frac{3}{4}$ or $\frac{7}{8}$ V were desired, a pulse increment of approximately $\frac{1}{4}$ V would be applied to the deflector plates 16 and simultaneously a defocussing pulse would be applied to the electrode 12, in the second step or operation of the cycle.

As has been pointed out heretofore, the several sources are under control of the cycling circuit whereby the sequential and concomitant functioning of these sources is effected. The sources and circuit 22 may be generally of known configuration. For example, the source 17 may comprise a battery and a switch. The deflecting source 20 may comprise a pulser and a resistance-condenser network of such constants that upon application of a series of pulses of substantially equal amplitude to the input side of the circuit, the voltage across the output side of the network is successively of relative amplitudes 1, $\frac{1}{2}$, $\frac{1}{4}$, ..., $\frac{1}{n}$ at the end of each input pulse cycle. If any input pulse in a series is omitted, as would be the case during the second step for the example above given, the potential at the output of the network remains at the value corresponding to that of the preceding pulse, if any. The focus control 21 may comprise a pulsing circuit of constants such as to produce pulses of the form heretofore described and illustrated at S in Fig. 5. The cycling circuit may comprise a multivibrator responsive to groups of pulses, e. g. groups of three pulse and no pulse combinations in accordance with the table heretofore presented, for cycling the sources controlled by this circuit.

The times requisite for deflection and defocussing and refocussing of the beam and response of the feedback circuit are extremely small. In an illustrative case, the total time for each of

the steps or operations in the sequence heretofore described and illustrated in Fig. 5 may be of the order of 1 microsecond. Hence, very high speed translation of input pulse groups to the cycling circuit 22 into corresponding potentials across the deflector plate 16 can be realized.

For the structure illustrated in Fig. 1 including eight (2^3) targets, the exponent p for the binary series is 3 and three steps are required to translate an input pulse group into a corresponding potential across the deflector plates 16. Similarly, for any device having 2^p targets, and therefore 2^p possible beam positions and corresponding output voltages, p steps are necessary to effect the translation. For example, in device having 128 targets, i. e. 2^7 targets, seven steps are required, so that groups of pulses and no pulses of seven would be applied to the input of the device.

The construction of a cathode ray device for producing 128 different potentials is illustrated in Figs. 6 to 9 inclusive. The device comprises, within the evacuated enclosing vessel 10, an electron gun of known construction including a cathode, not shown, an intensity control electrode 30, a two part accelerating anode 31, 32 and a focussing electrode 12 between the two parts of the anode. The several electrodes of the electron gun, together with the deflector electrodes 16, are mounted from a vitreous disc 33 which in turn is supported from the stem 34 by the leading-in conductors 35 for the gun electrodes. The leading-in conductors 36 for the deflector plates 16 extend through and are sealed to tubulatures 37 on the vessel 10.

Supported from a second stem 38 is a target assembly which, as illustrated in Figs. 7, 8 and 9, comprises 128 targets 13 separated by insulating, e. g. mica, sheet spacers 39. The edges of the targets toward the electron gun advantageously are outward of the corresponding edges of the mica spacers. The targets may be stampings of sheet material having a secondary electron emission coefficient greater than unity, each target being provided with a finger or tab 40. In a specific construction the targets may be of a silver magnesium alloy having a secondary electron emission coefficient of about 3.

The targets 13 and spacers 39 are assembled in stacked relation and fitted upon a pair of hollow rectangular ceramic rods 41 which enclose heater filaments 42 that facilitate heating of the targets during the processing thereof and the evacuation treatment of the device. The two rods 41 are clamped adjacent their ends between two pairs of ceramic tubes 43 carried by a rigid frame 44 which is mounted, by supports 45, from a collar or band 46 clamped about the stem 38.

As illustrated in Fig. 9, the 128 targets 13 are connected in binary relation by conductors joined to respective tabs 40, and lead-in wires 47 sealed in the stem 38. Specifically, the targets are connected in seven interleaved groups composed of 2, 2, 4, 8, 16, 32 and 64 targets respectively which correspond to the terms of the expansion of 2^7 with the first term or group including an additional target. It will be noted from an analysis of Fig. 9 that neglecting the first or zero target each target of each group is midway between two targets of the next higher term of the progression. That is to say, referring to Fig. 9, the target 13¹, corresponding to the term 2^1 is midway between the two targets 13², each of the latter is midway between two targets 13³ and so on. Thus, the beam may be stepped

in the same direction from any target corresponding to one term of the binary expansion to a target corresponding to a succeeding or higher order term.

The collector electrode 15 may be circular or rectangular in form and is supported by a leading-in conductor 48 sealed to the vessel 10. The vessel 10 has on a part of its inner wall a conductive coating 49 which may be connected electrically to the collector electrode.

It will be understood that the beam projected to the targets should be of such transverse dimensions that it can strike only one target at a time. In a specific construction wherein the targets were 4 mils thick and the mica spacers were 10 mils thick, a circular beam of approximately 5 mils diameter at the target electrodes has been found satisfactory.

It will be appreciated that the connection of the targets into groups in accordance with a binary number system enables use of a large number of targets while necessitating use of only relatively few leading-in conductors for the target assembly. Thus the structure of the cathode ray device is simplified and manufacture thereof is facilitated. Furthermore, such connection of the targets in groups simplifies the controls necessary to effect deflection of the beam to the position requisite to result in a desired potential across the deflector plates 16. It will be appreciated also that the construction enables attainment precisely of any one of a multiplicity of different potentials by the application of one or more voltage increments which need be of only moderately accurate amplitudes. Finally, it is to be noted that by virtue of the successive switching of the target groups to bring them to the potential, relative to the collector electrode, requisite for flow of secondary electrons from the targets to the collector electrode, the beam in each step of its motion encounters only one emitting target so that feedback and, hence, precise adjustment of the beam position is effective only when desired and the control of the feedback circuit is simplified.

Although a specific embodiment of the invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims. For example, although in the embodiment shown and described a binary grouping of the targets is employed, grouping in accordance with a different progression may be utilized.

What is claimed is:

1. Electron discharge apparatus comprising a plurality of targets arranged in a row, means opposite said targets for projecting an electron beam thereto, means for deflecting said beam along the row of targets, and means for resolving voltages applied to said deflecting means into respective potentials of preassigned amplitude at said deflecting means, said resolving means comprising means connecting said targets in interleaved groups of different and respective number related in accordance with a prescribed number system, means connected to said deflecting means for applying to said deflecting means groups of voltage increments of amplitudes related in accordance with said number system and a feedback coupling between said targets and said deflecting means.

2. Electron discharge apparatus in accordance with claim 1 wherein said targets are secondary

electron emissive and said feedback coupling includes a collector electrode opposite said targets.

3. Electron discharge apparatus in accordance with claim 2 comprising means connected to said targets for successively biasing the groups of targets at an emitting potential relative to said collector electrode concomitantly with the application of each group of voltage increments to said deflecting means.

4. Electron discharge apparatus comprising a plurality of targets arranged in a row, means opposite said targets for projecting an electron beam thereto, means for deflecting said beam along the row of targets, means connected to said deflecting means for impressing upon said deflecting means groups of voltage increments, each group being representative of a respective value in accordance with a binary number system, means connecting said targets in interleaved groups of respective numbers in accordance with said binary system, a feedback coupling between said targets and said deflecting means, and utilization means connected to said deflection means.

5. Electron discharge apparatus comprising a plurality of targets mounted in a row, means opposite said targets for projecting an electron beam thereto, means for deflecting said beam along the row of targets, means connecting said targets in interleaved groups of respective number increasing in accordance with a certain geometric progression, means connected to said deflecting means for applying to said deflecting means groups of signal increments, each group being composed of any number of increments in a preassigned number equal to the terms of said progression and wherein successive increments decrease in accordance with said progression, and a feedback coupling between said target electrodes and said deflection means.

6. Electron discharge apparatus in accordance with claim 5 wherein said targets have a secondary electron emission coefficient greater than unity and wherein said feedback coupling comprises a collector electrode in electron receiving relation to said targets.

7. Electron discharge apparatus in accordance with claim 6 comprising means connected to said targets for successively biasing successive groups of targets at an emitting potential relative to said collector electrode concomitantly with the application of each group of signal increments to said deflection means.

8. Electron discharge apparatus comprising a plurality of secondary electron emissive targets mounted in a row, means opposite said targets for projecting an electron beam thereto, a collector electrode opposite said targets, a pair of deflector plates effective when energized to deflect said beam along the row of targets, means for impressing between said deflector plates groups of voltage increments, each group corresponding to a potential effective to deflect said beam to impinge upon a respective one of said targets and representing a value in accordance with a prescribed number system, a feedback coupling between said collector electrode and said deflector plates, and means connecting said targets in interleaved groups of respective number related in accordance with said number system.

9. Electron discharge apparatus comprising a plurality of targets mounted in a row, means opposite said targets for projecting an electron beam thereto, means for deflecting said beam along the row of targets, means connecting said targets in groups of respective number in accord-

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ance with the relation a^n , where a is a preassigned integer and n is zero or a whole number, each target of each group except the largest being disposed between two targets of the next larger group, and means for applying to said deflecting means permutations of n signal pulse increments and zero pulse increments, successive pulse increments in each permutation being of relative amplitudes in accordance with the respective term of the progression $1/a^n$.

10. Electron discharge apparatus in accordance with claim 9 comprising means connected to said targets for coupling said groups of targets successively, according to increasing number, in feedback relation to said deflecting means concomitantly with the application of each of said permutations.

11. Electron discharge apparatus comprising a row of targets, means opposite said targets for projecting an electron beam thereto, means for deflecting said beam along the row of targets, a feedback coupling between said targets and said deflecting means, and means connecting said targets in interleaved groups of different and respective number related in accordance with a preassigned number system.

12. Electron discharge apparatus in accordance with claim 11 wherein said targets have a secondary electron emission coefficient greater than unity and said feedback coupling comprises a collector electrode opposite said targets.

13. Electron discharge apparatus comprising a plurality of targets in a row and having a secondary electron emission coefficient greater than unity, said targets being of sheet form, having their faces substantially parallel and being separated by sheet insulating spacers, means opposite said targets for projecting an electron beam thereto, a pair of deflector plates between said targets and said means for deflecting said beam along the row of targets, means connecting said targets in groups of respective number increas-

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ing in accordance with a prescribed geometric progression, each target of each but the largest group being between two targets of the next larger group, a collector electrode opposite said target, a feedback coupling between said collector electrode and said deflector plates, means for impressing between said deflector plates groups of voltage increments, each group being representative of a corresponding beam deflection amplitude in accordance with a numbering system corresponding to said progression and the amplitude of successive increments in each group decreasing in the relation of the respective terms in said progression, means for successively biasing said groups of targets in the order of increasing group number at an emitting potential relative to said collector electrode, and means for effecting such successive biasing concomitantly with the impressing of said groups of increments such that each group of targets is biased at emitting potential relative to said collector electrode simultaneously with the application of the corresponding order voltage increment to said deflector plate.

14. Electron discharge apparatus in accordance with claim 13 comprising means for defocussing said beam during an initial portion of the period of application of each of said voltage increments.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,417,450	Sears	Mar. 18, 1947
2,436,677	Snyder	Feb. 24, 1948
2,477,008	Rosen	July 26, 1949