Jan. 11, 1949. R. W. SEARS 2,458,652

ELECTRON DISCHARGE APPARATUS

Filed Dec. 13, 1946 4 Sheets-Sheet 1

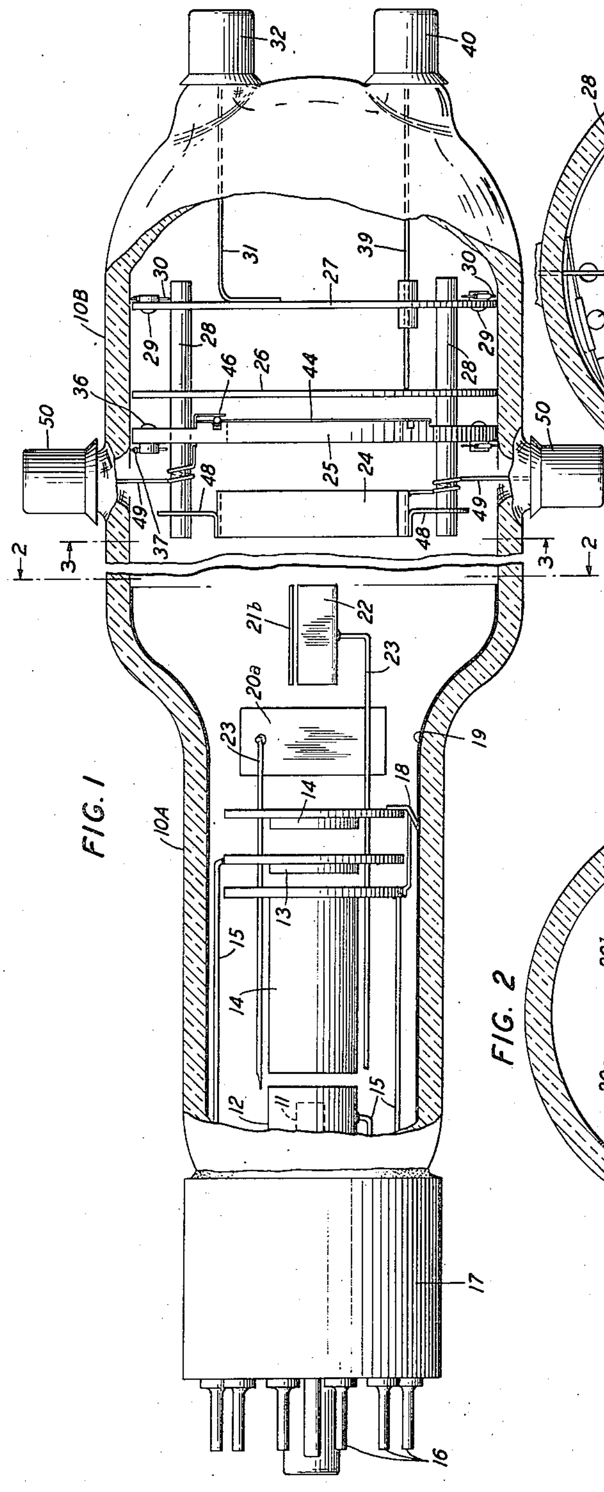

FIG. 1

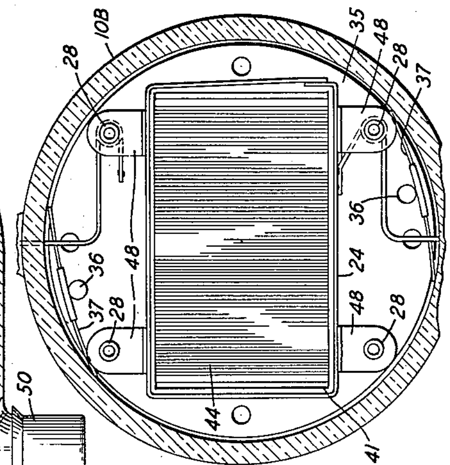

FIG. 3

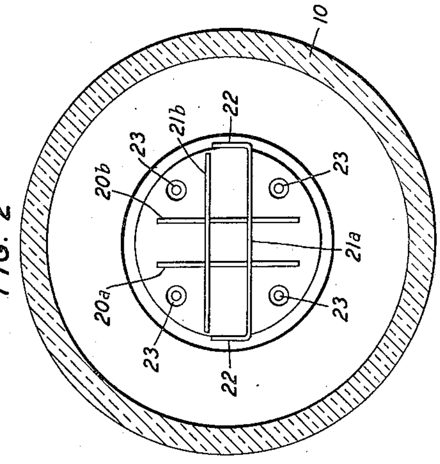

FIG. 2

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ELECTRON DISCHARGE APPARATUS

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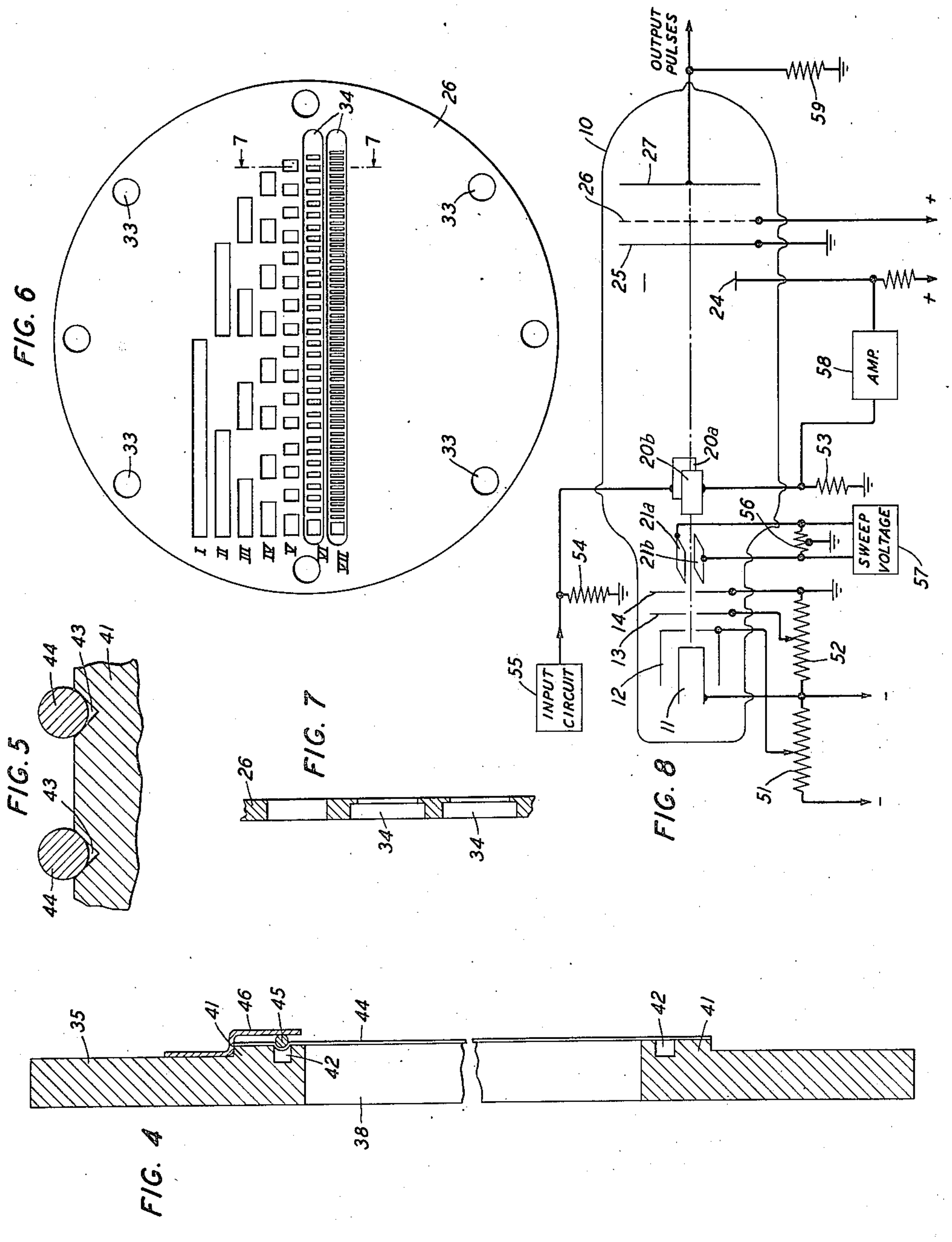

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ELECTRON DISCHARGE APPARATUS

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FIG. 9

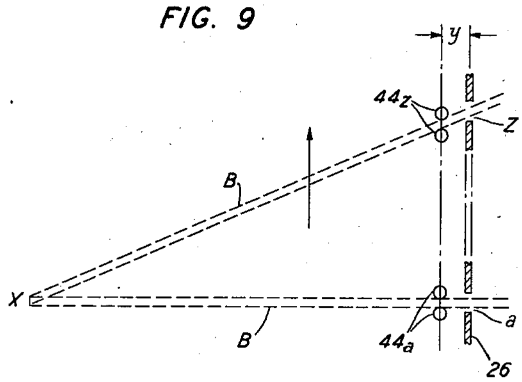


FIG. 10

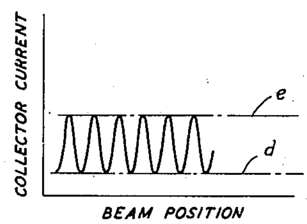
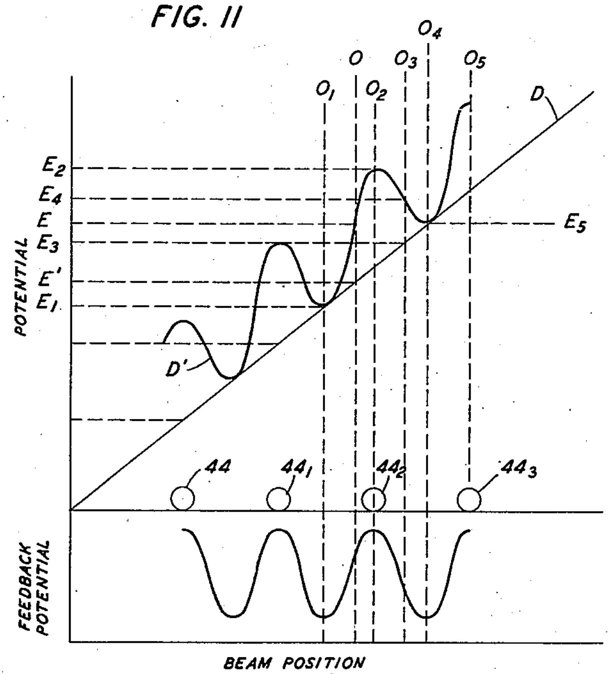


FIG. 11



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ELECTRON DISCHARGE APPARATUS

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FIG. 11A

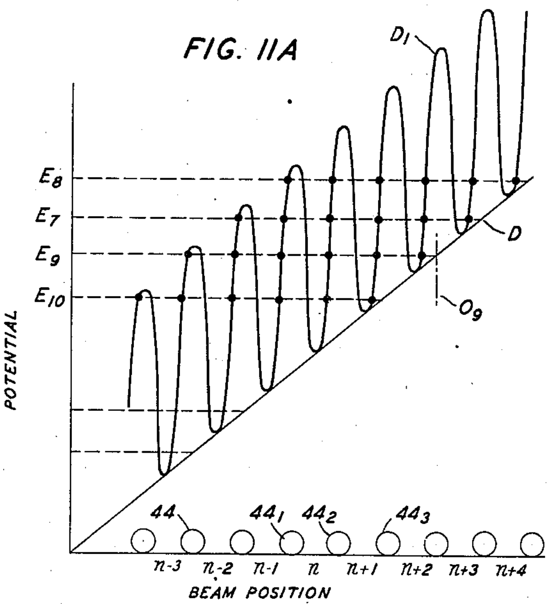


FIG. 11B

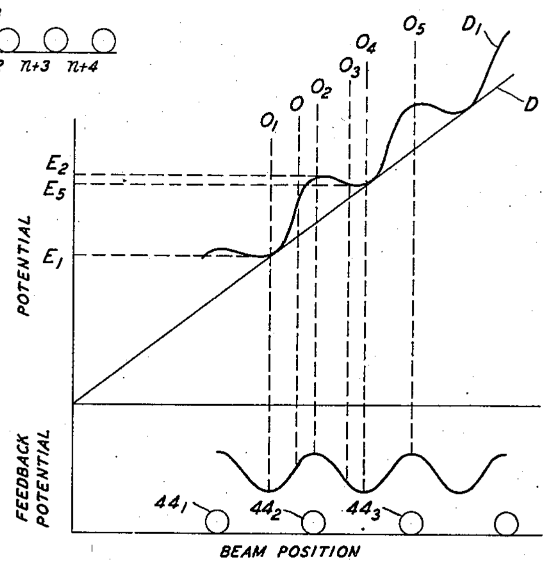
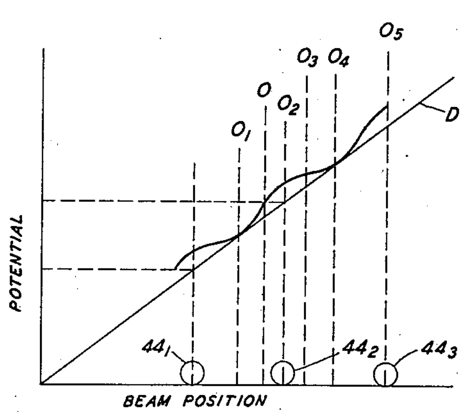


FIG. 11C



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Patented Jan. 11, 1949

2,458,652

UNITED STATES PATENT OFFICE

2,458,652

ELECTRON DISCHARGE APPARATUS

Raymond W. Sears, West Orange, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application December 13, 1946, Serial No. 715,900

11 Claims. (Cl. 250—164)

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This invention relates to electron discharge devices and more particularly to cathode ray devices of the type disclosed in the application Serial No. 715,999, filed December 13, 1946, of George Hecht and especially suitable for use in signal translating systems wherein speech or other complex waves are sampled at successive intervals and the samples are resolved into code pulse groups each corresponding to a respective sample amplitude.

Cathode ray devices of the type disclosed in the above-identified application comprise, in general, a coding mask or electrode having a plurality of rows of apertures therein, the apertures being arranged in predetermined relation so that an electron beam swept across the several rows will produce pulse groups, the character of each group being determined by the position of the sweep. The position of the sweep is determined, in turn, by the amplitude of the speech or other wave sample at the time of the sweep.

As disclosed in the application, improved performance for such a device may be realized by providing an auxiliary electrode or grid which functions to hold the beam in the prescribed code position during each sweep of the beam across the coding electrode or mask.

One object of this invention is to improve the signal resolution in cathode ray devices of the type above described.

Another object of this invention is to simplify the construction of such devices and of systems including them.

A further object of this invention is to reduce the size of cathode ray devices for use in signal coding systems.

Still another object of this invention is to facilitate exact alignment of the auxiliary and coding electrodes.

A still further object of this invention is to assure exact parallelism of the elements or wires of the auxiliary electrode and maintenance of such relation of the elements or wires during the operation of the device.

Still another object of this invention is to obtain faster quantizing.

In accordance with one feature of this invention, the auxiliary electrode, hereinafter referred to as the quantizing electrode or grid, comprises a plurality of elements or wires having a secondary electron emission coefficient greater than unity. A collector electrode is provided in cooperative relation with the quantizing electrode and in use of the device is connected to the beam deflection system through a feedback circuit.

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The elements or wires are parallel and closely adjacent, for example spaced a distance comparable to the diameter of the beam in the vicinity of the quantizing electrode, so that a substantial current of instantaneous amplitude determined by the position of the beam relative to two adjacent elements or wires, flows to the collector electrode. This current is a maximum when the beam is centered upon any element or wire and is a minimum when the beam is centered upon the space between two adjacent elements or wires.

In accordance with another feature of this invention, the quantizing electrode or grid is constructed so that the elements or wires are maintained continually under tension and in exact parallel relation. In one illustrative construction, this electrode comprises a foundation or frame across the opening in which the grid wires extend, the foundation or frame having therein a groove beneath the wires. A rigid rod or bar, in engagement with the wires, overlies the wires and groove and is constantly urged toward the groove by a resilient member mounted by the foundation or frame.

In accordance with a further feature of this invention, the coding and quantizing electrodes are fabricated in a unitary assembly wherein the grid openings are positioned in accurate alignment with certain of the openings in the coding electrode and are maintained in such relation during operation of the device.

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 an elevational view of an electron discharge device illustrative of one embodiment of the invention, a portion of the enclosing vessel being broken away to show the electrodes more clearly;

Fig. 2 is a sectional view, taken along plane 2—2 of Fig. 1, showing the form and relation of the deflector plates;

Fig. 3 is a sectional view, taken along plane 3—3 of Fig. 1, showing the configuration and relation of the grid and collector electrodes;

Fig. 4 is a view in cross-section and to an enlarged scale of the grid electrode assembly;

Fig. 5 is a fragmentary view in section and to an enlarged scale, showing details of the assembly illustrated in Fig. 4;

Fig. 6 is a face view of the apertured plate or coding electrode included in the device illustrated in Fig. 1;

Fig. 7 is a fragmentary sectional view to an enlarged scale taken along line 7—7 of Fig. 6;

Fig. 8 is a circuit diagram showing one manner in which the device may be operated;

Fig. 9 is a diagram illustrating the relation of the grid openings and the apertures in the coding electrode in the device illustrated in Fig. 1;

Fig. 10 is a graph showing the relationship of the current to the collector electrode and the beam position in the direction of the plane of and transverse to the grid wires; and

Figs. 11 to 11C are diagrams illustrating the relation of the signal and feedback potentials for various beam positions and for several relative amplitudes of the two potentials.

Referring now to the drawing, the electron discharge device shown in Fig. 1 comprises a highly evacuated cylindrical enclosing vessel formed in two parts 10A and 10B of vitreous material and having mounted therein, adjacent one end of the part 10A, an electrode system constituting an electron gun for producing a highly concentrated electron beam, for example a circular beam of the order of 0.008 to 0.012 inch in diameter. The electron gun may be of any one of a number of known constructions and comprises, generally, a cathode 11, a concentrating and control electrode 12 and focussing and accelerating electrodes 13 and 14, the latter comprising two parts as shown in Fig. 1. Electrical connection to the cathode 11 and electrodes 12 and 13 may be established by way of leading-in conductors 15 connected to terminal prongs 16 on the base 17 secured to the vessel 10. The electrode 14 is provided with one or more metallic fingers 18 which firmly engage a cylindrical conductive coating 19 upon the inner wall of the part 10A enclosing vessel, which coating serves primarily as a shield. Electrical connection to this coating and, hence, to the electrode 14 may be established by way of a leading-in conductor (not shown) connected to one of the prongs 16 or alternatively by way of a conductor (not shown) sealed in the side wall of the vessel portion 10A.

Mounted opposite the electron gun and at right angles to each other are two pairs of parallel deflector plates 20*a*, 20*b* and 21*a*, 21*b* respectively, the plate 21*a* having side flanges 22 at right angles to the body thereof, as shown clearly in Fig. 2. Leading-in conductors 23 connect the several deflector plates to respective terminal prongs 16.

Mounted within the part 10B of the enclosing vessel and supported thereby is an electrode unit all of the electrodes in which are in axial alignment with the electron gun and the deflection system defined by the plates 20 and 21. This unit comprises a collector electrode 24, a quantizing grid 25, a coding electrode 26 and a target or output electrode 27 arranged in the order named, as illustrated in Fig. 1, and held in position relative to one another by four ceramic rods or tubes 28 to which they are firmly affixed, as by a suitable cement.

The target or output electrode 27 may be a circular metallic plate having a secondary emission coefficient other than unity, for example of nickel or carbonized nickel, of slightly less diameter than the internal diameter of the portion 10B of the enclosing vessel and has affixed thereto, as by rivets 29, two or more spacers, for example, flexible wires 30 of tungsten, the ends of which engage the inner wall of the vessel part 10B. Electrical connection to the output electrode 27 may be established by way of a rigid leading-in conductor 31 connected thereto and to a cap terminal 32 sealed to the vessel part 10B.

The coding electrode 26, shown in detail in Figs. 6 and 7, also may be a circular metallic plate, for example of nickel or carbonized nickel, of a diameter slightly less than that of the internal cylindrical wall of the vessel part 10B, and provided with apertures 33 into which the ceramic rods or tubes 28 are fitted, the plate being affixed to the rods or tubes as noted heretofore. The plate is provided with an elongated rectangular aperture I and a plurality of rows II to VII inclusive, of rectangular apertures, the rows being parallel to one another and to the aperture I and all the apertures in rows II to VII having their corresponding sides parallel. The aperture I and those in rows II to V inclusive, may be formed by punching alone; the apertures in rows VI and VII may be formed, as illustrated in Fig. 7, by first milling grooves or recesses 34 in the plate and then punching to produce the apertures.

The number of apertures in rows II to VII are 2, 4, 8, 16, 32 and 64 respectively. Although the operation of the device will be described in detail hereinafter, it may be noted here that the beam is deflected selectively in one direction, horizontally in Figs. 1 and 6, in the direction of and outside row VII by the deflector plates 20*a* and 20*b* so that it is opposite either one of the apertures in row VII of the coding electrode or an area between two apertures or just beyond the last aperture, i. e. the rightmost aperture in Fig. 6. The beam then is swept across the coding electrode in the direction normal to the rows of apertures, i. e. vertically in Figs. 1 and 6. The apertures in the several rows are so arranged that for each position to which the beam is stepped it sweeps across a different combination of apertures and solid areas in the coding electrode whereby 128 different pulse or code groups may be produced at the target or output electrode 27.

In the particular construction illustrated, in each of rows III to VII the apertures are equally spaced and, with the exception of the first aperture, i. e. the leftmost aperture in Fig. 6, are of the same width, i. e. the horizontal dimension thereof in Fig. 6. The width of the apertures in row VII is of the same order of magnitude as the beam diameter. The first aperture in each of rows II to VII is somewhat wider than the other apertures in that row for reasons which will appear presently. Advantageously, all of the apertures are of the same height, i. e. the vertical dimension in Fig. 6. The leftmost edges of the first apertures in the several rows are in line with one another and the leftmost edge of the aperture I. Also each left side of each aperture in rows II to VI is aligned with a corresponding side of an aperture in each of the succeeding rows III to VII. Connection to the coding electrode is made by way of a leading-in conductor 39 connected to a cap terminal 40.

The quantizing electrode 25 comprises a circular metal plate 35, for example of nickel, of a diameter slightly smaller than that of the internal cylindrical wall of the vessel portion 10B and having affixed thereto, as by rivets 36, resilient wire spacers 37, similar to the spacers 30, the ends of which engage the inner wall of the vessel portion 10B. The plate 35 is provided with a rectangular aperture 38 of somewhat larger dimensions than those of a rectangle sufficiently large to encompass the aperture I and rows II to VII in the coding electrode 26. As illustrated in Figs. 3 and 4, the plate 35 has thereon parallel rails or raised portions 41 adjacent the longer sides of the aperture 38 and one or both of these portions is provided with a longitudinally extending groove 42. Both of these portions 41 are provided also with parallel, transverse V-shaped grooves or slots 43 (see Fig. 5), each groove 43 in one portion 41 being an alignment with a corresponding groove in the other portion.

Seated in the grooves 43 and affixed, as by brazing, to the raised portions 41 adjacent the outer sides thereof are fine parallel grid wires 44 which, in a particularly advantageous construction, are of a material having a thermal coefficient of expansion substantially equal to or greater than that of the plate 35 and having also a secondary electron emission coefficient greater than unity. In a specific construction, the plate 35 may be of nickel and the wires 44 of the copper-nickel alloy known as "Monel," the latter having a secondary electron emission coefficient of approximately 3.5. Aligned with one of the grooves 42 and bearing against all the wires 44 is a rigid rod or wire 45, for example of tungsten, which is forced partially into the groove by a spring strip 46, for example of beryllium-copper, coextensive with the rod or wire 45 and secured to the plate 35.

In the fabrication of the quantizing electrode, the grid wires 44 are stretched uniformly in place on the plate 35 and secured to the latter, after which the rod or wire 45 and spring 46 are mounted in place. The rod and spring serve to tension the grid wires and to maintain a tension therein during the evacuation treatment and operation of the device, so that the parallel relation of the grid wires is preserved. During the evacuation treatment of the device, the quantizing electrode is subject to substantial temperature changes and the grid wires may bow. However, because of the equality or difference in the thermal coefficients of the plate 35 and wires 44, the latter always are held under tension during operation of the device and, hence, the parallel relation thereof is maintained.

The quantizing electrode is mounted parallel to the coding electrode 26 by the rods or tubes 28 so that the aperture 38 is opposite the coding apertures in the electrode 26 and the grid wires 44 are exactly parallel to the vertical edges (in Fig. 6) of the apertures I and in the rows II to VII. The grid wires 44 are spaced so that there is a grid opening opposite each of the smaller apertures in row VII in the coding electrode. In a specific construction, the apertures mentioned may be 0.010 inch wide, spaced 0.024 inch center to center, and there may be 129 grid wires 0.004 inch in diameter and spaced 0.0116 inch center to center. The leftmost aperture (in Fig. 6) of row VII may be 0.054 inch wide. One of the grid wires is positioned opposite the left-hand (in Fig. 6) edge of this aperture. An additional pair of grid wires 44 is positioned just beyond the rightmost aperture in row VII.

The quantizing grid is aligned with the coding electrode, i. e. the vertical axes (in Figs. 3 and 6) of the two are in the same plane. Hence, the central grid openings are aligned, or essentially so, with the central apertures in row VII of the coding electrode. However, as indicated above, the center-to-center spacing of the apertures in row VII is greater than twice the center-to-center spacing of the grid wires 44 so that the apertures to either side of the center in row VII are offset relative to the corresponding grid opening and the offset increases as the distance from the center of the row increases. The reason for this construction will be understood from the following considerations with reference to Fig. 9.

Operation of the device requires that each aperture in row VII in the coding electrode have a corresponding grid opening associated therewith. Consider now an electron beam B which is deflected in the direction indicated by the arrow in Fig. 9 about the pivot point X in line with a central aperture *a* in row VII in the coding electrode 26. It will be noted that for this aperture *a* the grid opening between wires 44A is centrally aligned with the aperture. However, if the beam is deflected to pass through an aperture *z* to one side of the central aperture *a*, because of the distance between the grid and the plate 26, it is necessary that the corresponding grid wires 44*z* be offset relative to the aperture *z* in order that the beam will pass through and be centered relative to the grid opening corresponding to the aperture *z*. That is to say, each grid opening must be aligned with the corresponding aperture when viewed from the point X. It will be noted that the amount of offset necessary increases as the distance between openings *a* and *z* increases. The offset between grid wire openings and apertures in the coding electrode 26 will be determined in any particular case by the distance *y* between the grid 44 and the coding plate 26 and the distance between the point X and the grid plane, and, of course, can be calculated from the geometric relations involved. The particular dimensions for grid opening and apertures set forth hereinabove have been found satisfactory for a spacing *y* of 0.142 inch between the grid 44 and the plate 26 and a distance of 4.126 inches from the point X and the grid plane. The point X is located, in an actual system, between the deflector plates 20*a* and 20*b*, as is known in the art.

The collector electrode 24 is rectangular as shown in Fig. 3, of dimensions slightly greater than the corresponding dimensions of the aperture 38 and is centrally aligned with the aperture 38. It may be formed of a suitable metal, such as nickel, and is mounted from the rods or tubes 28 by metal brackets 48.

Electrical connection to the quantizing and collector electrodes may be made by way of leading-in conductors 49 connected to cap terminals 50 affixed to the vessel portion 10B.

In the fabrication of the device, the electron gun and the deflector plates are mounted in the vessel portion 10A and the collector, quantizing, coding and output electrodes are mounted in the vessel portion 10B. The two assemblies are joined by fusing the two vessel portions together and in such relation that the grid wires 44 are accurately parallel to the deflector plates 20*a* and 20*b* and the vertical (in Fig. 3.) axis of the grid is accurately aligned with the median plane between these deflector plates.

One manner in which the device shown in Figs. 1 to 7 and described hereinabove may be operated for pulse code modulation is illustrated in Fig. 8. The focussing and accelerating electrode 14 and the quantizing electrode 25 are connected directly to ground as shown. The cathode is held at a high negative potential, for example 1000 volts, relative to ground and the electrode 12 is held at a negative potential, for example, of less than 100 volts, relative to the cathode by way of the potentiometer resistance 51. The potential of the electrode may be varied to adjust the beam current. The focussing electrode 13 is biased positive relative to the cathode, for example, of the order of 250 volts, by way of the poteniometer resistance 52.

The deflector plates 20a and 20b are connected to ground through resistors 53 and 54 and the input signal samples are applied to the deflector plate 20a from a suitable circuit 55. The other deflector plates 21a and 21b are balanced to ground by the resistor 56 and have a sweep voltage to provide a linear sweep, impressed therebetween from the source 57.

The coding electrode 26 is held positive relative to ground, for example, of the order of 90 volts. The collector electrode 24 is biased positive relative to ground at a potential equal to or higher than that of the coding electrode, for example 90 volts, and is connected to the deflector plate 20a by an amplifier 58, the electrode 24 being connected to the input side of the amplifier.

The target or output electrode 27 is connected to ground through a resistor 59.

The resistance 53 is made relatively small, for example of the order of 220,000 ohms and the deflector plates are constructed and arranged so that the capacitance therebetween is small, for example of the order of one micromicrofared, whereby the time constant of the resistance-capacitance circuit defined thereby also is very small so that high frequency input signal pulses may be distinguished.

The operation of a device of the type herein described and illustrated, in a pulse code modulating system, is briefly, as follows: A signal, for example of audio frequency, is amplitude sampled at high frequency and the amplitude samples are impressed across the deflector plates 20a and 20b. The beam is deflected accordingly, horizontally in Figs. 1 and 6, to be opposite one of the apertures in row VII in the coding electrode or opposite a space between two apertures or beyond the last (rightmost in Fig. 6) aperture in the row. It is then swept across the coding electrode, i. e. in the vertical direction in Figs. 1 and 6, whereby current pulses, or no current for the beam position beyond the last aperture in row VII, are produced at the target or output electrode 27. As noted heretofore, the pulse group produced by sweeping of the beam in any position to which it is deflected is different from the pulse group for any other position. The deflection position, as has been noted, is determined by the amplitude of the input signal sample; hence, each pulse group corresponds to or represents a respective signal amplitude so that each input sample is coded. Inasmuch as, as noted heretofore, in the device shown and described one hundred and twenty-eight different pulse groups may be obtained, one hundred and twenty-eight different amplitude samples may be distinguished and coded.

The beam position, for no input signal, may be such that it passes to the center of row VII of apertures in the coding electrode 26, so that for positive input signals the beam is stepped in one direction, e. g. to the left in Fig. 6 and for negative signals it is stepped in the opposite direction, e. g., to the right in Fig. 6. Alternatively, the no signal position may be at either end of row VII.

As noted heretofore, the first (leftmost in Fig. 6) aperture in each of rows II to VII in the coding electrode is somewhat larger than the remaining apertures in the respective row. This allows recognition of input samples of somewhat greater amplitude than if the first apertures were of the same size as the remainder and, in effect, provides a peak limiting effect. A similar limiting effect obtains at the other end (rightmost in Fig. 6) of the coding system.

It will be appreciated that in order to realize proper coding of the input signals, once the beam is deflected to any code position it must remain in that position while it is swept across the coding electrode, i. e. it must follow the path (vertical in Figs. 1 and 6) corresponding to the amplitude of the input sample. Each path, except the leftmost one in Fig. 6 is between a respective pair of grid wires. If, due, for example, to slight misalignment of the electrodes or electrical disturbances, the beam departed from the requisite path during a sweep, a false pulse group might be produced at the output or target electrode and incorrect coding of the input signal would result. The quantizing electrode 25 prevents such incorrect coding as will be understood from the following considerations with reference to Figs. 10 and 11 to 11C inclusive.

If the beam were swept across the grid wires 44, i. e., horizontally in Figs. 1 and 3, the beam current to the quantizing electrode would vary periodically, being a maximum when the beam is centered on any grid wire 44 and a minimum when the beam is centered on the opening between two adjacent grid wires. The secondary electron current from the grid wires varies in like manner so that the current to the collector electrode 24 varies in similar wise. If the beam diameter were less than the width of the grid openings, the current to the collector electrode would vary between zero and a maximum; however, when the beam diameter is somewhat greater than the width of the grid openings, the collector current does not fall to zero but varies between a minimum of amplitude d illustrated in Fig. 10 and a maximum e. The absolute values of the maximum and minimum collector currents in any device will be determined, of course, primarily by the beam current and the secondary emission coefficient of the grid wires. The minimum value is dependent also upon the relative magnitudes of the beam diameter and the grid opening width and, additionally, the transverse current distribution in the beam. As is known, the current density adjacent the beam boundary is less than that at and near the center of the beam. Although the specific form of the collector current-beam position characteristic thus is dependent upon a number of factors, nevertheless the general relation is as illustrated in Fig. 10 and the collector current is a maximum when the beam is centered upon a grid wire and is a minimum when the beam is centered upon a grid opening.

The collector current is fed to the amplifier 58 and converted into a voltage between the deflector plates 20a and 20b. Thus, for any position of the beam, in the horizontal dimension in Figs. 1 and 8, the effective potential between the deflector plates 20a and 20b is the sum of the potential due to the input signal and the feedback potential due to the collector current. The feedback potential is dependent, of course, upon the position of the beam relative to the grid wires 44.

As illustrated by the line D in Fig. 11, the beam position in the direction normal to the grid wires 44 varies linearly with the deflecting potential effective between the deflector plates

20*a* and 20*b*. The effective deflecting potential for any beam position is the resultant of the signal potential due to the input circuit 55 and the feedback potential. For the condition of negative feedback, i. e., the condition where the potential of the feedback potential is such that the latter opposes the signal potential, the signal potential-beam position relation is as illustrated by the curve D'. For simplicity of illustration, in Figs. 11 to 11C, the signal curve is shown for the condition when the minimum feedback potential is zero, which condition obtains for a beam diameter less than the width of the grid openings. It will be apparent from what follows that the same analysis follows for conditions where the minimum feedback potential is other than zero, as for the case where the beam diameter is somewhat greater than the grid opening width.

Consider now the conditions extant when the beam is at the position O (Fig.11). In order to be at this position, the effective deflecting potential must be of the magnitude E'. The feedback potential is of the amplitude E—E' so that the signal potential is of the value E. If now the beam is subjected to a disturbance, for example because the signal amplitude increases slightly, the beam tends to move to the right, i. e. toward the grid wire 44_2. However, any such movement would result in an increase in the feedback potential and, consequently, a decrease in the effective deflecting potential. Similarly, if there is a disturbance such that the signal amplitude decreases slightly, the beam tends to move to the left, i. e. toward the grid wire 44_1. Such motion would result in a decrease in the feedback potential and, consequently, an increase in the effective deflecting potential.

Hence, for the position O, the conditions are such that the beam is in equilibrium or stable. Similar analysis will show that for any beam position between substantially O_1 and O_2, the conditions are such that the beam will be held in that position or, stated in another way, the beam will be held in the opening between grid wires 44_1 and 44_2 and against the grid wire 44_2.

Consider, now, the conditions extant for the beam position O_3. For this position, the signal voltage is of amplitude E_4, the feedback voltage is E_4—E_3 and the effective deflecting potential is E_3. If for any reason the beam is disturbed, for example if the signal voltage increases slightly, the beam moves to the right. As it so moves the feedback voltage decreases. Consequently, the effective deflecting voltage increases and the beam is deflected further to the right. The action is cumulative and continuous so that the beam continues moving to the right until it reaches a position between O_4 and O_5, the beam is not in equilibrium. If, at position O_3, the signal voltage decreases, the beam tends to move to the left. However, such motion results in an increase in the feedback voltage and a further decrease in the effective deflecting potential so that the beam moves to the left until it reaches a position between O_1 and O_2.

Similar analysis will show that for any condition resulting in a beam position between O_2 and O_4 the beam will be deflected to a position either between O_1 and O_2 or between O_4 and O_5, the direction of deflection being dependent upon the direction from which the position O_3 is approached. Thus, for positions between O_2 and O_4 the beam is not in equilibrium and if the beam reaches such a position it is deflected automatically to a stable position, i. e. between O_4 and O_5 or O_1 and O_2.

Viewed in another way, if the feedback circuit is closed while the beam is deflected in response to application of a signal from the circuit 55, of amplitude between E_2 and E_5, the beam would come to rest at a position between either O_1 and O_2 or O_4 and O_5 depending upon whether the direction of deflection due to this signal were to the right or to the left respectively. Thus, it is possible that for signals between the amplitudes noted two different pulse groups or codes could be produced.

For the particular amplitude of feedback voltage illustrated in Fig. 11, substantially equal to the voltage increment corresponding to E_5—E_1, i. e. substantially equal to that corresponding to a beam deflection from the center of one grid opening to the next adjacent one, two different pulse groups or codes could be produced for the range of signal voltages between E_5 and E_2. The two codes would be successive ones. That is, if the pulse group associated with the opening between grid wires 44_1 and 44_2 is identified as code *n*, that corresponding to the grid opening between wires 44_2 and 44_3 could be designated as $n+1$.

If the amplitude of the feedback voltage is increased and the feedback circuit is closed as the beam is deflected in response to an input signal, the separation between the two possible pulse groups increases. This may be seen from Fig. 11A wherein stable beam positions for several input signals are indicated by points on the curve D_1 and several codes are designated for the respective grid openings, the feedback potential being of maximum amplitude several times the deflection voltage movement requisite to swing the beam from one grid opening to the next adjacent one. For the signal E_7, under the conditions postulated, it will be seen that codes $n+3$ or $n-2$ may be produced; for an input signal E_8, codes $n+4$ or $n-1$ may be produced; for an input signal E_9, codes $n+2$ or $n-3$ are possible; and for an input signal E_{10}, codes $n+1$ or $n-4$ are possible.

For maximum amplitudes of feedback potential less than that equal to the deflection voltage increment corresponding to the center-to-center spacing of the grid openings, the conditions possible may be seen from Fig. 11B. In this figure, the feedback voltage amplitude is approximately one-half that of the deflection voltage increment and such that the curve D_1 has a slightly negative slope for beam positions between O_2 and O_4 and corresponding positions relative to other grid openings. From what has been said heretofore it will be appreciated that for the conditions illustrated in Fig. 11B, the equilibrium or stable positions of the beam fall between O_1 and O_2, between O_4 and O_5, etc., and that positions, such as between O_2 and O_4, for which the curve D_1 has negative slope are unstable beam positions. For such positions, or more accurately for the signal voltages corresponding thereto, two codes are possible. However, it will be noted that the range of signal voltages, e. g. between E_5 and E_2, for which such double coding is possible is considerably smaller than that for the condition or feedback potential amplitude resulting in the curve D_1 in Fig. 11.

If the amplitude of the feed back potential is decreased still further, i. e. if the maximum amplitude thereof is less than one-half the potential increment corresponding to a beam deflection equal to the center-to-center spacing of adjacent grid openings, the conditions possible will be understood with reference to Fig. 11C. For such amplitude of feedback potential, all portions of the curve D_1 have a positive slope; for points between O_1 and O_2, between O_4 and O_5 and similar regions, the slope is greater than that of line D; for other points, e. g. between O_2 and O_4, the slope is less than that of line D. Beam positions corresponding to the first points noted, e. g. position O, are equilibrium or stable positions, as is apparent from what has been said heretofore. Additionally, beam positions at the other points noted, say the position O_3 or other position between O_2 and O_4, also are equilibrium or stable positions because of the small positive slope of the curve D_1 at these points. That is to say, the change in effective deflecting potential associated with departure from the beam in either direction from position O_3 is insufficient to drive the beam further in that direction. Consequently, for the feedback potential amplitude-deflection potential amplitude relation illustrated in Fig. 11C, every beam position is an equilibrium or stable one.

From the conditions and relationships illustrated in Figs. 11 and 11C and pointed out hereinabove, certain characteristics of devices including a quantizing electrode or grid will be apparent. First, it will be noted that in such a device, once the beam has been deflected to any code position, by the application of a potential between the deflector plates **20**, it will be held in a stable position by the action of the grid as the beam is swept across the coding electrode by the potential applied between the deflector plates **21**. If, for example, any two adjacent grid wires **44** are misaligned relative to the direction of the beam sweep, once the beam is deflected to a stable position to pass between these two wires it will be held between them during the sweep cycle by virtue of the feedback potential due to secondary emission from these wires. Thus, once the beam reaches a stable or equilibrium position between two wires, when it is swept, the code pulse group obtained is that corresponding to the beam position between these two wires.

Furthermore, it will be noted that the beam will remain in any stable position it reaches despite variations in the applied signal, i. e., that applied between the deflector plates **20** from the input circuit **55**, during the sweeping cycle. The magnitude of variation for which this will obtain is determined, of course, by the amplitude of the feedback potential and will be greater the larger the feedback potential. Thus, for the condition illustrated in Fig. 11, if the beam reaches a stable position, e. g., between O_1 and O_2, it will remain between the wires $\mathbf{44}_1$ and $\mathbf{44}_2$ during the sweeping cycle and produce the corresponding code pulse group for variations in input signal, during the sweeping period, resulting in effective deflecting potentials between about E_1 and E_2. For the conditions illustrated in Fig. 11A, the range of voltage variations for which the beam will remain in a stable position between two grid wires obviously is greater than that for the conditions illustrated in Fig. 11, and for the conditions illustrated in Fig. 11B, this range is smaller than that for the relations illustrated in Figs. 11 and 11A.

From this standpoint, therefore, it is advantageous that the feedback potential be large, specifically several times as great as the deflecting potential increment necessary to displace the beam from one grid wire to the next in the absence of feedback. Although, as has been noted heretofore, for such large amplitude of feedback potential the possibility of ambiguity in coding is present in the case where two directional displacement of the beam in response to signal pulses applied to the deflector plates **20** is utilized, such ambiguity may be avoided by effectively blanking the beam or by opening the feedback circuit until the potential across the deflector plates **20** is raised or lowered by an input signal pulse to the value requisite to deflect the beam to the code position corresponding to the amplitude of the signal pulse. For example, referring to Fig. 11A, if the signal voltage is E_9 corresponding to the beam position O_9, and the beam is blanked or the feedback circuit effectively opened until the voltage reaches this value and the beam is then turned on or the feedback circuit closed, the beam will be held in a stable position to produce the code pulse group $n+2$.

A further important function of the electrode or grid **25**, which leads to its designation as a quantizing electrode or grid, is to be noted. As is apparent, there is a range of effective deflecting potentials between the deflector electrodes **20** corresponding to a beam position such that it passes between a pair of grid wires. For example, referring to Fig. 11, it will be seen that for all input signals of values such that the beam passes between grid wires $\mathbf{44}_1$ and $\mathbf{44}_2$, the beam will reach a stable position between O_1 and O_2, remain there during the sweeping cycle and result in the corresponding code pulse group. Stated in another way, all input pulses effective to deflect the beam to a position between wires $\mathbf{44}_1$ and $\mathbf{44}_2$ result in the code pulse group corresponding to this position. Similarly, all input pulses effective to deflect the beam to a position between O_2 and O_5 result in the code pulse group associated with the opening between the wires $\mathbf{44}_2$ and $\mathbf{44}_3$.

Thus, the quantizing electrode or grid in effect, divides the range of input signals into a multiplicity of discrete bands each of which corresponds to a respective code pulse group.

The electrode or grid **25**, therefore, performs the dual functions of quantizing the input signal and of holding the beam in the proper code position during each sweeping cycle.

As has been noted heretofore, advantageously the feedback potential is relatively large. The provision of the electrode or grid **25** having a secondary electron emission coefficient greater than unity facilitates attainment of this desideratum in that it not only provides an initially greater feedback current but also reduces the amplification requisite to produce a given feedback potential, and thus simplifies the amplifier design.

Additionally, the provision of such a grid has other advantages. Secondary emission from the coding electrode **26** cannot be entirely eliminated, at least not readily. However, in the case where the electrode **25** has a secondary emission coefficient greater than unity, the secondary current from the coding electrode to the collector electrode **24** is but a very small fraction, in any event, of the total current to the collector electrode so that the feedback potential is accurately determined by and representative of the beam position.

Further, the provision of such a grid enables a substantial reduction in the size of the device and particularly of the quantizing electrode or grid for any desired number of code groups, whereby very closely spaced grid wires may be employed and high resolution of input signals thus attained, and, additionally, problems attendant upon beam deflection and focussing are minimized.

Additionally, the collector electrode 24 has a small capacitance to the other electrodes whereby fast quantizing action is obtained.

Although, a specific embodiment of this 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.

What is claimed is:

1. An electron discharge device comprising a member having a plurality of rows of apertures therein, means opposite thereto for projecting an electron beam toward said member, means for deflecting said beam in the direction along one of said rows, means for deflecting said beam in a direction different from said first direction, and means for guiding said beam along a path of preassigned configuration while it is deflected by said second deflecting means, said guiding means comprising an auxiliary electrode between said beam projecting means and said member and having therein apertures conforming to said preassigned configuration, said auxiliary electrode having a coefficient of secondary electron emission greater than unity, a collector electrode opposite said auxiliary electrode and a feedback coupling between said collector electrode and said first deflecting means.

2. An electron discharge device comprising a member having a plurality of rectilinear rows of apertures therein, means opposite thereto for projecting an electron beam to said member, means for deflecting said beam in the direction parallel to one of said rows, means for sweeping said beam across said member at an angle to said direction, and means for holding said beam to a substantially rectilinear path while it is deflected by said sweeping means, said holding means comprising an auxiliary electrode between said beam projecting means and said member, extending across the beam paths therebetween and having a plurality of restilinear openings therein, the face of said auxiliary electrode toward said beam projecting means having a coefficient of secondary emission greater than unity, a collector electrode opposite said auxiliary electrode and a feedback coupling between said collector electrode and said deflecting means.

3. An electron discharge device comprising a member having a plurality of parallel rows of targets therein, means opposite thereto for projecting an electron beam to said member, means for deflecting said beam in the direction parallel to said rows, means for sweeping said beam across said member in the direction at right angles to said rows, an auxiliary electrode between said beam projecting means and said member and comprising a plurality of parallel elements extending normal to said rows and in the direction of the beam sweep, said elements having a coefficient of secondary emission greater than unity, and a collector electrode opposite said auxiliary electrode.

4. An electron discharge device comprising a member having a plurality of adjacent rows of targets therein, means opposite thereto for projecting an electron beam to said member, a first deflecting means for deflecting said beam in the direction parallel to one of said rows, a second deflecting means for deflecting said beam in a direction across said rows, an auxiliary electrode between said beam projecting means and said member and having therein a plurality of openings extending transversely of the beam paths between said beam projecting means and said member, there being one opening for each target in said one row and in alignment therewith, said auxiliary electrode having a coefficient of secondary emission greater than unity, and a collector electrode adjacent said auxiliary electrode.

5. An electron discharge device comprising a member having a plurality of substantially parallel rows of targets therein, an auxiliary electrode opposite one face of said member and having therein a plurality of parallel rectilinear openings extending across said rows, there being one opening in alignment with each target in one of said rows, said auxiliary electrode having a coefficient of secondary electron emission greater than unity, a collector electrode opposite said auxiliary electrode, a first deflection means for deflecting said beam in the direction parallel to said rows, and a second deflection means for deflecting said beam in the direction parallel to said openings.

6. An electrode for electron discharge devices, comprising a foundation member having an aperture therein and having also a groove therein to one side of said aperture, a plurality of wires extending across said aperture and groove and affixed to said foundation member beyond said groove, and means for applying tension to said wires comprising a member overlying said groove and in engagement with said wires and means urging said second member toward said groove.

7. An electrode for electron discharge devices, comprising a foundation member having an aperture therein and having also a groove therein to one side of said aperture, a plurality of wires extending across said aperture and groove and affixed to said foundation member beyond said groove, a rigid rod overlying said wires and in alignment with said groove, and resilient means mounted by said foundation member and bearing against said rod to force it toward said groove.

8. An electrode for electron discharge devices, comprising a foundation member having an aperture therein and having also a groove therein to one side of said aperture, a plurality of wires extending across said aperture and groove and affixed to said foundation member beyond said groove, a rigid wire overlying said groove and said wires and engaging said wires, and a resilient strip substantially coextensive with said rigid wire, secured to said foundation member and bearing against said rigid wire to face it toward said groove.

9. An electrode for electron discharge devices, comprising a foundation plate having an aperture therein and having raised portions on opposite sides of said aperture, both of said raised portions being provided with a plurality of transverse parallel slots and one of said portions being provided with a longitudinal groove, a plurality of wires extending across said aperture, seated in said slots and secured adjacent their ends to said plate, a rigid wire overlying said wires and groove and in alignment with said groove, and a resilient strip mounted by said plate, substantially coextensive with said rigid wire and bearing against said rigid wire to urge it into said groove.

10. An electron discharge device comprising an

enclosing vessel, an electron gun mounted at one end of the enclosing vessel, a unitary assembly supported adjacent the other end of said vessel, said assembly comprising a coding plate having a plurality of rows of apertures therein and having also aligning openings therein, an auxiliary electrode opposite said plate and having openings therein in alignment with said rows of apertures, said auxiliary electrode comprising a foundation member having aligning openings therein one opposite each of said openings in said plate and rigid insulating rods each fitted in respective aligning openings in said plate and said foundation member, and deflecting means between said gun and said assembly.

11. An electron discharge device comprising an enclosing vessel having two opposed cylindrical portions sealed together at their opposing edges, an electron gun mounted in one of said portions, deflector means including a pair of parallel deflector plates supported in said one portion, and a unitary assembly mounted within the other of said portions, said assembly comprising a coding electrode having a plurality of parallel rows of apertures therein, a grid including a plurality of parallel wires extending over one face of said coding electrode and at right angles to said rows, said wires being parallel to said pair of deflector plates, and means joined thereto fixing said grid in relation to said coding electrode.

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

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