

June 23, 1942.

M. W. BALDWIN, JR

2,287,408

MODULATING AND COMPENSATING APPARATUS

Filed July 31, 1940

FIG. 1

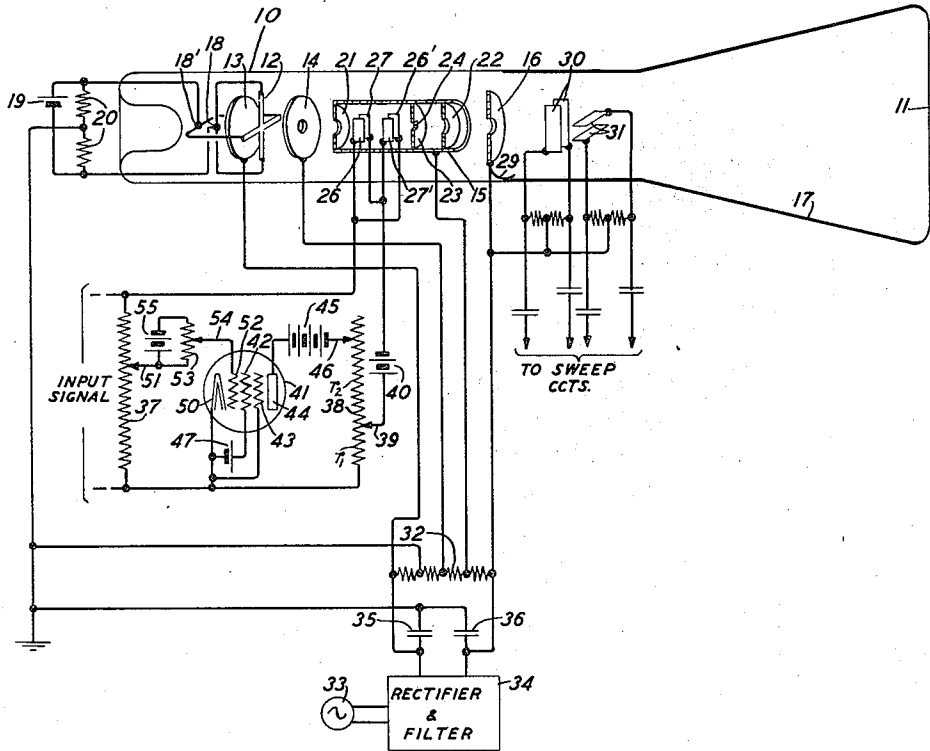


FIG. 2

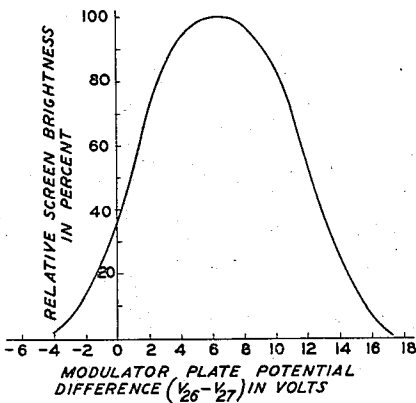
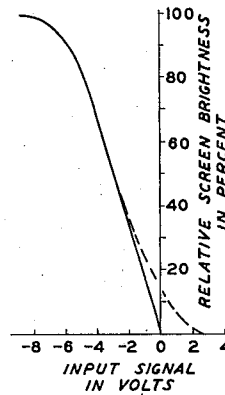


FIG. 3



INVENTOR
M. W. BALDWIN, JR.
BY
Chas. Sprague
ATTORNEY

UNITED STATES PATENT OFFICE

2,287,408

MODULATING AND COMPENSATING
APPARATUS

Millard W. Baldwin, Jr., Glen Ridge, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application July 31, 1940, Serial No. 348,604

7 Claims. (Cl. 178—7.5)

This invention relates to cathode ray devices and more particularly to modulating systems therefor.

It is a related object of the invention to provide a novel system by means of which, in the course of modulation of the beam of a cathode ray device by a signal, compensation for a non-linear characteristic of said device is secured.

It is an object of the invention to provide an improved system for modulating the strength of the cathode beam of a cathode ray device.

In application Serial No. 118,277 of C. J. Davisson, filed December 30, 1936, now Patent 2,217,197, issued Oct. 8, 1940, there is described a cathode ray television receiver tube in which modulation is achieved by laterally shifting an electron beam of uneven density with respect to an aperture by means of a signal applied between a pair of modulating electrodes or plates arranged on opposite sides of the axis of the tube. After passing through the aperture the beam is directed upon and focused in the plane of a luminescent screen to produce a spot of light whose intensity depends upon the electron density in that part of the beam which impinges on the aperture and, therefore, upon the signal applied to the modulating plates.

The uneven distribution of electrons over the cross-section of the original beam at the plane of the aperture falls off from the center of the original beam toward either side in accordance with a probability curve, so that the rate of change of electron density in the emerging beam as it is shifted over the aperture is not uniform. This makes for a non-linear relation between screen brightness and modulating signal which, expressed graphically, takes the form of a probability curve.

A tube of the type above described is operated on one side only of its two-sided characteristic curve between a point somewhat removed from the peak of the curve and its toe. The working part of the characteristic is thus upwardly curved throughout about one-half of its length and the curvature is most severe at the toe, or for low light values. This results in faulty reproduction of the picture or scene being transmitted inasmuch as a given signal change at a low level of brightness will produce a much smaller brightness change than will the same signal change at a higher level. In other words, the contrast is not uniform over the brightness range, being high for high brightness levels and low for low brightness levels. This condition gives

rise to an image of displeasing character, commonly described as "muddy."

Recognizing the limitations of the tube of the aforementioned application, C. J. Davisson has gone to great lengths to overcome them by an ingenious but elaborate construction internal to the cathode ray tube itself. Application Serial No. 169,423 of C. J. Davisson, filed October 16, 1937, now Patent 2,217,198, issued Oct. 8, 1940, describes this construction. According to the teaching of Patent 2,217,198, among other novel and advantageous features, beam modulation is achieved according to a modified plan. A small part of the original beam of electrons from the cathode is first passed through a slit so narrow that the distribution of electrons over it is, in theory, substantially uniform. The beam from this slit is then laterally shifted past the aperture by application of the signal voltage to the modulating electrodes. Since the cross-section of the beam from the narrow slit is ideally a strip of uniform density and perfectly sharp edges, the arrangement of this last-mentioned application provides, ideally, a system in which the relation between screen brightness and modulating signal is strictly linear. However, whether due to the imperfections of present manufacturing technique or otherwise, actual results obtained with a tube made as nearly as possible in accordance with the teachings of the aforementioned Patent 2,217,198, reveal a residual non-linear relation between screen brightness and modulating signal which still takes the form of a probability distribution curve.

The non-linear character of the response of the tube of either of the above-mentioned applications can be rendered unnoticeable by restricting operation to signals of sufficiently small magnitude; but this, of course, constitutes an inefficient use of the possibilities afforded by the tubes. Correct reconstitution of an image from received signals is to be efficiently secured, if possible, by making the over-all characteristic of the receiver apparatus as a whole linear throughout a working range of substantial extent.

Accordingly, it is a primary object of this invention to provide apparatus by means of which a linear characteristic for a television receiver employing a cathode ray tube is secured over a working range of substantial extent; and a specific object is to correct or compensate for the non-linearity of the signal brightness characteristic of a television receiver tube of the type in which modulation is accomplished by shifting the cathode beam with respect to an aperture.

To these ends there is provided, in accordance with the invention, a simple and inexpensive circuit arrangement which serves to predistort the modulating signal in just the manner and in just the amount required to overcome the distortion introduced by the cathode ray tube itself. In accordance with a preferred modification, a distortion signal of proper type is derived from the image signal through the use of an auxiliary circuit arrangement, and this distortion signal is applied, along with the image signal proper, to the modulating electrodes of the cathode ray tube in such a way that the screen brightness is linearly related to the image signals over the full working range of the tube. Still more specifically, an impedance element, for example, a resistor, is connected with at least a portion thereof in series between a network carrying the image signals and a modulating electrode of the cathode ray tube; and at the same time the image signals are supplied to the input circuit of an auxiliary discharge device whose output circuit is directly connected to the terminals of the resistor. The preferred auxiliary discharge device is a vacuum tube whose electrode configuration adapts it to operation without substantial phase shifts at image signal frequencies and whose characteristic is complementary to the non-linear characteristic of the cathode ray tube to be corrected. The ohm value of the resistor and the volt value of the auxiliary tube bias are chosen in such a manner as to make the output voltage of the auxiliary tube substantially equal to the departure of the cathode ray tube characteristic from linearity for all brightness values.

The invention will be more readily understood by reference to the following description of a preferred embodiment, taken in connection with the accompanying drawing which forms a part thereof. This description and the drawing illustrates the application of the invention to a cathode ray television tube of the type disclosed and claimed in the aforementioned Patent 2,217,197 but it is to be understood that this application is selected by way of illustration only, since the invention is equally applicable to cathode ray tubes of other types in which the non-linear behavior above described exists; for example, the tube described and claimed in the aforementioned Patent 2,217,198.

In the drawing:

Fig. 1 shows schematically a cathode ray television receiver tube in which modulation is achieved by lateral shift of the cathode beam past an aperture, and an associated characteristic correcting circuit in accordance with the invention;

Fig. 2 shows a curve illustrating the non-linear relations of a tube to which the invention may be applied; and

Fig. 3 shows curves illustrating the manner and extent of the characteristic correction in accordance with the invention.

Referring more specifically to the drawing, Fig. 1 shows a cathode ray tube and its associated circuit, including the distortion correcting circuit of the invention, for use as a television receiving device. The tube itself comprises a gas-tight envelope 10 containing an electron gun assembly for generating, focusing and accelerating a beam of electrons, means for modulating the beam, and means for deflecting the beam so that it traverses every elemental area of a field of view on a fluorescent screen 11 located at one end of the envelope.

The electron gun arrangement comprises a cathode 12, a back plate or electrode 13, a first accelerating anode 14, a second accelerating anode 15 and a third accelerating anode 16 which is connected through a conductor 29 to a conductive coating 17 located on the interior walls of the tube. Broadly speaking, the electron gun arrangement comprises two electron focusing or lens systems of the electrostatic type, the first a condensing lens system for concentrating a beam of electrons generated by the cathode 12 upon a modulation aperture, the second a projection lens system for projecting electrons of this beam which pass through the aperture upon the screen or target 11.

The cathode 12 is preferably formed in the shape of a cross from a single sheet of tungsten of the order of 0.001 inch thick. Opposite ends of this cross are electrically connected together to form two terminals 18 and 18' which are in turn preferably connected to a suitable source of current 19. A resistance 20 may also be connected across the terminals 18 and 18', and the mid-point of this resistor 20 may be connected to ground to minimize stray fields, improve stability, and provide a point from which the various potentials of the system may be measured. For a more complete description of a cross-shaped cathode element, reference may be made to United States Patent 2,117,709, issued May 17, 1938.

The back electrode 13 may consist of a circular plate spaced a short distance behind the cathode 12 and parallel with the arms of the cross. It is preferably connected to a source of potential somewhat below the cathode potential and serves to direct electrons emitted from the cathode in paths substantially parallel with the axis of the tube 10.

The first accelerating electrode 14 may consist of a circular plate having a circular aperture in the center thereof and located on the side of the cathode remote from the back electrode 13. It is preferably supplied with a potential which is positive with respect to the cathode and serves to produce convergence of the electrons emanating from the cathode upon the modulating aperture.

The next element in line between cathode and beam receiving screen is the second anode 15 which may consist of a metallic cylinder placed axially of the tube 10 and terminated at either end by circular plates 21 and 22. Except for an aperture in the center of each of these plates 21 and 22, they completely close the cylinder anode 15 so that the region interior thereto is bounded on all sides by an equipotential surface, with the result that this interior region is a substantially field-free space.

Within the field-free region defined by the second anode 15 is a circular plate 23 having centrally thereof a small aperture 24 preferably rectangular or square. This aperture 24 constitutes the scanning aperture to which reference has already been made. Between the first circular plate 21 and the apertured plate 23 are mounted two pairs of modulator electrodes 26, 27, 26' and 27'. They are preferably cross-connected as shown so that application of the modulating signal to their terminals will operate merely to shift the electron beam laterally without deflecting it through any uncompensated angle. This arrangement, which is known per se, is not included in the aforementioned Patent 2,217,197 but is

fully described in the aforementioned Patent 2,217,198.

The next electrode in line is the third accelerating anode which preferably consists of a circular metallic plate 16 having an aperture in the center thereof and is preferably connected to a source of positive potential with respect to the second anode 15. This third electrode 16 serves to gather electrons which, having passed through the aperture 24, emerge from the second anode 15, and to direct them upon and focus them in the plane of the screen 11 which may be of any suitable luminescent material, for example, willemitite.

The axial position of the apertured plate 23 within the cylinder of the second anode 15, and the axial positions and electric potentials of the back plate 13, the first accelerating anode 14, the second anode 15, and the third anode 16 are preferably so chosen and adjusted that an electron beam originating at the cathode 12 is brought to a focus in the plane of the aperture 24 and an electron image of the aperture 24 is formed on the screen 11. These choices of spacing and potentials may be in accordance with the principles disclosed in the aforementioned Patent 2,217,197.

The interior wall of the beam receiving end of the tube 10 is preferably lined with a conductive coating 17 which, being connected to the third accelerating anode 16, serves to provide a substantially field-free space between the anode 16 and the fluorescent screen and at the same time serves as a collector for secondary electrons which may be emitted from the material of the screen 11 when the latter is bombarded by the primary electrons of the cathode beam.

Horizontal beam deflecting plates 30 and vertical beam deflecting plates 31 are mounted between the third accelerating anode 16 and the screen 11. Suitable sources of horizontal and vertical saw-toothed scanning voltages may be connected to them. These scanning voltages cause the electron beam projected by the electron gun apparatus described above to scan every elemental area of the field of view of the screen or target 11 in turn, in well-known manner. For a complete description of preferred sweep circuit arrangements for generating suitable scanning voltages of saw-toothed wave form, reference may be made to United States Patent 2,178,464, issued Oct. 31, 1939 and to United States Patent 2,209,199, issued July 23, 1940.

Correct operating potentials for the electrodes described above may be obtained in a manner well known per se by connecting each electrode to a suitable point of a resistor 32 to which is supplied a direct current from any suitable direct current source, for example, generator 33 and rectifier-filter 34. A low impedance alternating current path to ground is provided for each of the external terminals of the resistor 32 by means of condensers 35 and 36 which are connected between these terminals and ground.

With a tube having the general construction above described, modulation of the electron beam generated by the cathode is achieved by shifting the beam with respect to the aperture 24 by a signal voltage applied to the modulator plates 26, 26', 27 and 27' so that for one value of the signal a part of the beam cross-section which is relatively dense is focused on the aperture 24 and for a signal of a different value a relatively tenuous part of the cathode beam is focused on the aperture. If the electron density in the beam

were in direct proportion to distance, for example, the distance measured from the center of the beam, the characteristic of the tube would be linear, at least in so far as the effects and phenomena with which this application deals are concerned. It is a fact, however, that the density of the original beam follows substantially a probability distribution curve, being greatest and fairly uniform at its center and falling off with distance measured in any radial direction from the center, the rate of density decrease being greatest about half-way from the center to the periphery and decreasing with less and less rapidity as the periphery of the beam is more and more nearly approached. Therefore, a small deflection of the original beam in the plane of the aperture 24 may produce a change in electron density of the emerging beam of one value when the aperture intercepts a part of the beam close to its center, and a density change of a very different value when the aperture intercepts a part of the beam close to the periphery. Thus the density of the beam emerging from the aperture 24 is related to the amount of beam deflection and, therefore, to the potential difference impressed on the modulating plates in a non-linear manner; and since, except for certain spurious reflection and scattering effects which are of minor importance and have no bearing on the invention, brightness of the spot on the receiving screen 11 is in general proportional to the density of the impinging beam, the non-linear relation holds between modulator plate potential difference and screen brightness.

This non-linear relation is illustrated by the characteristic curve of Fig. 2 which embodies results of measurements actually made with a tube of the type described in the aforementioned Patent 2,217,198 although it is generally representative of similar results obtainable with a tube of the type described in the aforementioned Patent 2,217,197. As shown by the curve, in which the abscissa represents modulator plate potential difference and the ordinate shows relative brightness of the screen in per cent, the tube employed was such that maximum screen brightness occurred with a potential difference of about 7 volts between the modulator plates, measured positively from plate 27 to plate 26. From this point the brightness decreases progressively both for greater potential differences up to 17 volts for substantially zero brightness, and for lesser potential differences down to zero and past it to about 4 volts negative.

It will be observed that while a part of each side of this characteristic curve, roughly from 30 per cent to 75 per cent of maximum brightness, is fairly straight, the lower part of each side has a pronounced toe of progressively decreasing slope over which the relation of brightness to plate potential difference is far from linear.

A simple circuit may be provided in accordance with the invention to correct or compensate for this non-linearity. A preferred form of such a correcting circuit is shown in Fig. 1 below the cathode end of the tube 10. Referring to this part of the figure, image signals are to be considered as flowing in the resistor 37. Without the contribution of this invention, this resistor 37 would normally be coupled, either directly or following any appropriate amount of amplification, to the modulator plates of the cathode ray tube. In accordance with the invention, however, one terminal of this resistor 37 may be

directly connected to one modulating plate 26 of a pair and the other terminal may be connected through a portion r_1 of a resistor 38, a movable contact 39 and a source of direct current potential, for example, a battery 40, to the other modulating plate 27 of the pair. The potential source 40 serves to adjust the initial shift of the original cathode beam with respect to the aperture 24 in order that the cathode ray tube shall work over the desired portion of its characteristic. The portion r_1 of the resistor 38 is added in series with the modulator plates in accordance with the invention and provides a compensating voltage drop in a manner to be described.

In accordance with the invention there is provided a compensating discharge device 41 which is preferably a vacuum tube of the pentode class, and still more specifically may be a tube of the type known as "310A." The second or screen grid 42 of this tube is maintained at a potential somewhat higher than that of the cathode 50, as by a battery 47, whereas the third or suppressor grid 43 is directly connected to the cathode 50. The potentials at which these two grids are maintained and their geometrical disposition and arrangement assist in giving this tube the characteristics which render it suitable for the purposes of this invention.

The anode 44 of this tube 41 is supplied with operating potential from a suitable source 45 whose low potential end may be connected to an adjustable contact 46 arranged to slide over the surface of the plate loading resistor 38, to whose fixed terminal the cathode 50 of the tube 41 is directly connected.

One terminal of the resistor 37 is connected to the cathode 50, and a portion of the signal voltage appearing in the resistor 37, namely, that portion between the cathode terminal of the resistor and the movable tap 51, is applied to the control grid 52 of the tube 41 through a resistor 53 and a movable tap 54. A battery 55 connected to the end terminals of the resistor 53 serves to adjust the grid bias of the tube 41 and, therefore, the point of operation on its characteristic.

The operation and effect of the compensating circuit of the invention will be understood from a consideration of Fig. 3, in which the dashed curve is the right-hand part of the curve of Fig. 2, redrawn to show the relation of screen brightness to impressed signal voltage and the solid curve shows the over-all characteristic of the apparatus including the compensating circuit.

The circuit adjustments which result in placing the curves in the positions shown may be made by altering the positions of the taps 39, 46, 51 and 54. Such possibility of adjustment is of advantage because the characteristic curve of one cathode ray tube to be corrected may differ somewhat from that of another. In the arrangement which gave the excellent results illustrated they were:

Resistor 38, 5000 ohms;

Full output voltage of compensator tube applied to modulator plates;

Full input signal voltage applied to compensator tube;

Modulator plate battery bias, 14.8 volts;

Compensator grid battery bias, 3.5 volts.

The manner of operation of the compensating circuit above described will now be explained as applied to a negative signal, that is, a signal whose voltage excursions in the negative direc-

tion correspond to bright parts of the picture. The arrangements of the invention may, of course, be employed with a positive signal by appropriate changes in biases and polarities; or, if preferred, a positive signal may be translated into a negative one by the simple expedient of increasing or decreasing the number of amplification stages by one.

Referring now to Fig. 3, assume, for example, that the image signal applied at a certain instant to the resistor 37 has a large negative value, for example, -4 volts, representing a bright portion of the picture being transmitted, this will be impressed on the modulator plates in a sense opposite to the voltage of the battery 40 so that a part of the original cathode beam near the center thereof and, therefore, having high electron density will be focused on the aperture 24 to give a high electron density in the beam following the aperture and, therefore, a high degree of brightness on the screen 11. At the same time, this large signal will operate to bias the control grid 52 of the tube 41 below the cut-off point of the tube so that no plate current flows from this tube through the resistor 38 and no voltage drop across the portion r_1 of this resistor is added to the signal voltage on the modulating plates of the cathode ray tube. Under these conditions, the cathode ray tube works on the straight portion of its characteristic curve and the compensating circuit has no effect.

On the other hand, assume that the signal impressed on the resistor 37 is of a small value corresponding to a dark portion of the picture being transmitted. By way of numerical example, assume a signal voltage of -1 volt, corresponding to a relative screen brightness for the uncompensated cathode ray tube of 25 per cent. This small signal voltage allows the grid 52 of the tube 41 to rise in potential past its cut-off point and the tube 41 becomes conductive, producing a substantial voltage drop through the resistor 38. A fraction of this voltage drop which appears across the part r_1 of the resistor 38 adds to the voltage drop due to the signal across the modulating plates 26, 27 to produce a still further deflection of the original beam away from the aperture, corresponding to a relative screen brightness of 17 per cent instead of 25.

It will be observed that whereas the value 25 per cent lies on the dashed curve of Fig. 3, the value 17 per cent lies below it on the solid line which continues the straight portion of the over-all characteristic. Other points along this line, substantially to the zero brightness axis, have been obtained with the apparatus of the invention. Since this line represents a linear relation between signal input and screen brightness, the system whose operation it depicts serves to compensate for the non-linearity of the cathode ray tube and provide a linear over-all characteristic.

It should be understood that auxiliary tubes other than the type 310A may, by particular choice of the load resistor, bias voltage and other ancillary factors, be adapted to serve in a compensating circuit in accordance with the invention. The compensating circuit arrangement itself may be altered. Either an altered compensating circuit or the particular compensating circuit described may be employed to compensate for non-linearity in the characteristic of a different type of cathode ray tube, for example, one whose characteristic curve falls off at its upper or high brightness end. In any case, whether any of these variations be employed or

not, the compensation may be employed only in part, and the cathode ray tube characteristic modified without being rendered linear. Such variations and modifications may be within the spirit of the invention and the scope of the claims.

What is claimed is:

1. In combination with a device having control means and being characterized by a partly non-linear relation between input signals applied to said control means and output signals of said device, an impedance element having at least two terminals, one of said terminals being connected to said control means, a discharge device having input terminals and output terminals, said output terminals being connected to two terminals of said impedance element, said discharge device and impedance element constituting together means for compensating for distortion in said output signals due to said non-linear relation, said last-mentioned means having a characteristic related to the departure of the characteristic of said first-named device from linearity, means for applying said input signals to said input terminals to produce a voltage drop across said impedance element, means for applying said input signals to said impedance element and said control means in series in a sense such that the control means voltage due to said last-named voltage stands in additive relation to the control means voltage due to said input signals, and means for biasing said discharge device to be operative over a portion of the input signal range in which the characteristic of said first-named device is non-linear and inoperative over another portion of said range in which said characteristic is linear, whereby the over-all characteristic of said first-named device and said compensating circuit, taken together, is linear.

2. Apparatus for correcting the non-linear portion of the input-output characteristic of translating apparatus, which characteristic is non-linear over one portion of its range and substantially linear over the remaining portion of its range, which comprises an electron discharge device having main electrodes for supplying an output voltage, and additional discharge control means in its input circuit, said device being characterized by an input-output relation which is complementary to that of said non-linear portion, means for applying signals both to said translating apparatus and to said device together, means for combining output signals of said device with input signals of said translating apparatus, and means for disabling said device upon the application thereto of signals of magnitude corresponding to the linear range of said translating apparatus.

3. In combination with translating apparatus having input terminals and characterized by a non-linear input-output relation, an impedance connected to said input terminals, means for applying signals to a part of said impedance, means connected to another part of said impedance comprising a device characterized by an input-output relation which is complementary to said non-linear relation, the output terminals of said device being connected to a portion of said impedance so that the input signals to said translating apparatus and the output of said device are combined.

4. Apparatus for correcting the non-linear characteristic of a cathode ray tube having a

cathode, a pair of control electrodes, an anode and a target electrode, which comprises means to supply control voltage to said control electrodes through a series resistance, a thermionic tube having a cathode, a grid and an anode, and connections from one of said control electrodes of said cathode ray tube to the grid and from the other of said control electrodes of said cathode ray tube to the anode of said thermionic tube.

5. Apparatus for correcting the non-linear portion of the input-output characteristic of a translating device characterized by substantial non-linearity at low outputs and comparative linearity at high outputs and having control electrodes which comprises an impedance element divided into two portions, one of which is connected in circuit with said control electrodes and a source of signals destined to actuate said device, an auxiliary electric discharge device connected to a portion of said impedance element and having a characteristic complementary to the low-output portion of said characteristic to be corrected, the output terminals of said auxiliary device being connected to the other portion of said impedance element and the input terminals of said auxiliary device being connected to said source, said input and output terminals being so poled with respect to said source and said impedance element as to produce across said control electrodes a correcting voltage in series and in phase with the voltage of said signal.

6. Apparatus for correcting the non-linear portion of the input-output characteristic of a translating device characterized by substantial non-linearity at low outputs and substantial linearity at high outputs and having control electrodes which comprises an impedance element divided into two portions, one of which is connected in circuit with said control electrodes and a source of signals destined to actuate said device, an auxiliary electric discharge device connected to a portion of said impedance element and having a characteristic complementary to the low-output portion of said characteristic to be corrected, the output terminals of said auxiliary device being connected to the other portion of said impedance element and the input terminals of said auxiliary device being connected to said source, said input and output terminals being so poled with respect to said source and said impedance element as to produce across said control electrodes a correcting voltage whose values are greatest for the signal voltage values producing the smallest outputs of said translating device and zero for signal voltage values corresponding to the substantially linear portions of said translating device characteristic.

7. Apparatus for correcting the non-linear portion of the input-output characteristic of a translating device characterized by substantial non-linearity at low outputs and substantial linearity at high outputs and having control electrodes which comprises an impedance element divided into two portions, one of which is connected in circuit with said control electrodes and a source of signals destined to actuate said device, an auxiliary electric discharge device connected to a portion of said impedance element and having a characteristic complementary to the low output portion of said characteristic to be corrected, the output terminals of said auxiliary device being connected to the other portion of said impedance element and the input terminals

of said auxiliary device being connected to said source, said input and output terminals being so poled with respect to said source and said impedance element as to produce across said control electrodes a correcting voltage in series and in phase with the voltage of said signal and hav-

ing values which are greatest for signal voltage values producing the smallest outputs of said translating device, and zero for signal voltage values corresponding to the substantially linear portions of said translating device characteristic.

MILLARD W. BALDWIN, JR.