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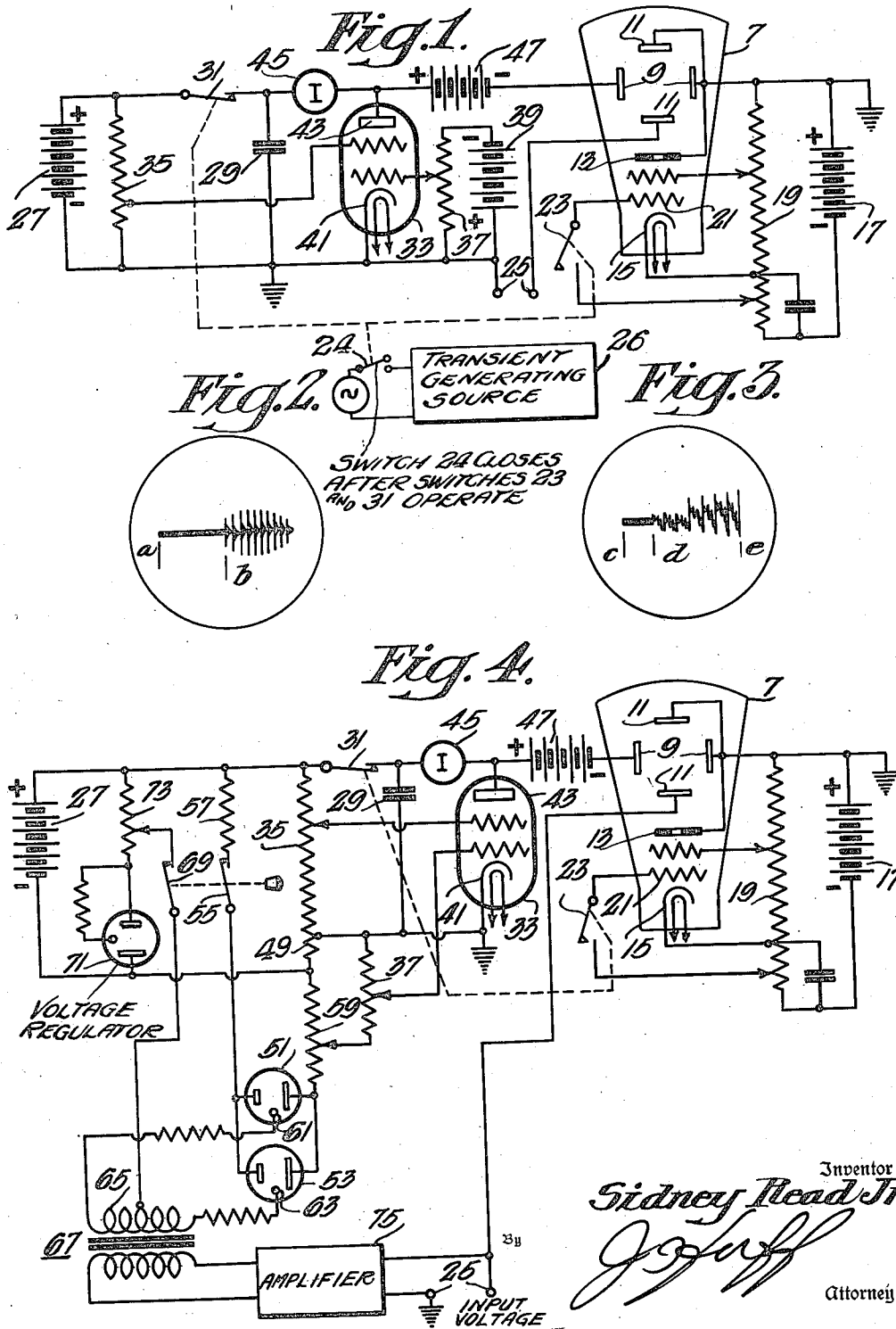
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CATHODE RAY OSCILLOGRAPH FOR RECORDING TRANSIENTS

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CATHODE RAY OSCILLOGRAPH FOR
RECORDING TRANSIENTS

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This invention relates to apparatus for visually indicating and photographing high speed transients, and particularly to an improved cathode ray oscillograph for studying non-recurrent controlled or uncontrolled high speed electrical transient phenomena.

I am aware of a system designed to accomplish similar objects in which the beam of a cathode ray tube is caused to make an excursion across the fluorescent screen at a time which coincides with the application of a transient to be studied by means of a spark discharge. Such a system is described in an article entitled "The use of the high vacuum cathode ray tube for recording high speed transient phenomena," by D. I. McGillewie, published in the October, 1938, number of "Electrical Communication." The single horizontal movement of the beam may be made to occur in a time varying between one microsecond and one millisecond. However, since the horizontal deflecting voltage is proportional to the voltage across a capacitor which is discharging through a resistor, the instantaneous position of the beam with respect to time is not linear. It is the primary object of this invention, therefore, to provide a deflecting voltage which is linear with respect to time, which provides a single horizontal sweep of the cathode ray beam, and the time duration of which may be selected at will.

In studying controlled transients, that is, transients which are produced as the result of an operation which may be made to occur at any given time, it is desirable to initiate the cathode ray horizontal deflection before the application of the transient to the vertical deflecting plates. Where high speed transients are involved, that is, where the time required for the single excursion of the beam is measured in microseconds, it becomes exceedingly difficult to apply the transient at the correct instant. As a result, the indication of the transient may appear at one edge of the cathode ray screen, or it may even arrive after the horizontal scanning operation has been completed. It is a further object of this invention, therefore, to provide means for initiating the horizontal scanning operation, or sweep, in a first direction at a first rate of speed, preferably at a relatively low speed so that the controlled transient may be applied to the vertical deflecting electrodes to deflect the beam in a second or trace indicating direction at a time when the beam has traversed but a small portion of its scanning path. At the same time, in accordance with this invention, an impulse derived from the

transient is utilized to change said rate of speed in said first direction, specifically to accelerate the horizontal deflection of the beam to any desired degree so that the transient itself may be photographed or viewed on an enlarged time scale.

A further disadvantage common to all known devices of the prior art is that the unit intensity of the light produced by the cathode ray beam is inversely proportional to the speed of the beam. That is, a brilliant trace is produced when the beam is moving slowly and a faint trace is produced when the beam is moving rapidly. Transient phenomena usually include widely varying rates of change. As a result, the trace produced by such transient phenomena varies in amplitude in like manner. This makes visual observation difficult, and likewise produces photographic reproductions which are difficult to analyze. Unfortunately, it is usually the high speed transients that are of the greatest importance, and it is these which are the most difficult to reproduce, since they have the least amplitude. It is a further object of this invention, therefore, to provide means for varying the beam intensity in proportion to the speed of vertical and horizontal deflection so that the illumination of the trace produced by the transient to be studied is constant throughout the curve.

Other objects, as well as a description of the nature and operation of this invention, will appear from a consideration of the following specification and the appended drawings.

Referring to the drawings, Figure 1 is a circuit diagram of a cathode ray oscillograph for indicating transient phenomena the occurrence of which can be controlled; Figures 2 and 3 are sketches illustrating the appearance of transients on a cathode ray screen; Figure 4 is the circuit diagram of an embodiment of this invention in which the horizontal deflection is accelerated by the applied transient; and Figure 5 is the schematic diagram of an embodiment of this invention in which the beam intensity is varied in proportion to the speed of the vertical and horizontal deflecting voltages; and Figures 5a and 5b are modifications of the invention of Figure 5. Similar reference numerals refer to similar parts throughout the several drawings.

Referring to Fig. 1, reference numeral 7 indicates a conventional cathode ray tube having pairs of mutually perpendicular deflecting electrodes 9 and 11. One horizontal and one vertical deflecting electrode and the No. 2 anode 13 are connected to ground. The cathode 15 is con-

connected to a suitable source of potential, supplied, for example, by means of a battery 17 and a shunt connected resistor 19. The potential of the cathode is highly negative with respect to ground. A slightly greater negative potential is applied to the grid 21 through a switch 23. It will be recognized that these connections are entirely conventional.

The transient voltage which is to be studied is connected between a pair of input terminals 25, one of which is grounded, and the other of which is connected to the ungrounded vertical deflecting electrode 11.

The horizontal deflecting voltage is derived from a system which includes a battery 27 which is connected across a capacitor 29 by a circuit which includes a normally closed switch 31. A pentode tube 33 is connected across capacitor 29. Screen grid voltage for the tube is derived from any suitable source, such as a resistor 35 connected across battery 27, and its grid potential is determined by means of a potentiometer 37 connected across a source of voltage such as battery 39 or the like. The cathode 41 of the pentode 33 is grounded, while the anode 43 is connected, preferably through a milliammeter 45, to the ungrounded terminal of capacitor 29. The anode 43 of tube 33 is also connected to the remaining horizontal deflecting electrode 9 through a battery 47, which has its negative terminal connected to the deflecting electrode.

The operation of this device will now be described. The battery potential is normally applied across capacitor 29 and the pentode 33. In order to prevent this positive voltage from deflecting the cathode ray beam off the screen, the series connected battery 47 is interposed in the circuit to reduce the effective voltage on the deflecting electrode to such a value that the beam is normally located at a point near one edge of the fluorescent screen. When the switch 31 is opened, the charging voltage is removed from capacitor 29, which immediately begins to discharge through the pentode 33. It is known that the current through a pentode is substantially constant over that range of its plate current-plate voltage characteristic in which the plate voltage exceeds the screen voltage. The tube voltages are, therefore, selected to provide for its operation in this constant current region. As a result, the condenser discharges at a rate which is linear with respect to time. The reduced voltage across the capacitor changes the potential of the horizontal deflecting electrode, thus causing the beam to move in a horizontal direction. When the condenser has discharged the cycle is completed and the beam remains stationary. The beam therefore makes one excursion across the fluorescent screen at a linear rate.

The speed of deflection is determined by the bias which is applied to the control grid of the pentode 33. This may be adjusted to any desired value by means of the grid potentiometer 37. As indicated above, the plate and screen voltages should be made such that the beam velocity is linear with time over the useful portion of the fluorescent screen. This is accomplished by making the plate voltage sufficiently high so that the beam traverses the screen before the plate voltage has been reduced to a value comparable to that of the screen. The usual capacitance-resistance circuit has an exponential discharge curve, since a resistor is not a constant current

device in the presence of a varying terminal voltage.

The function of switch 23, connected in series with the cathode ray grid tube, is to shut off the beam during periods of preparation before the transient is applied. When the switch is open, a high negative voltage is built up on the grid which effectually cuts off the beam. It has been found insufficient merely to deflect the beam off the screen since there is a certain amount of reflected illumination, due to reflection from the tube sidewalls, which tends to fog the photographic negative which is used to record the transient. Preferably the two switches 23 and 31 are operatively connected so that the proper bias is applied to the cathode ray grid not later than the time at which the deflecting operation is begun. A third switch 24, electrically connected to a transient source 26, may also be operatively connected to the first named switches by means of which the transient phenomena may be instituted immediately after switches 31 and 23 have opened and closed, respectively.

One difficulty with this arrangement is best illustrated by reference to Fig. 2, which represents a photograph of the sound track of the beginning of the letter "I." This voltage was obtained by connecting a microphone and audio frequency amplifier to the input terminals 25. It will be observed that a portion of the screen between *a* and *b* has not been utilized. This is because of the difficulty of initiating the transient which is to be studied immediately after the beam deflection has been instituted. The faster the occurrence of the transient, the more rapid the necessary beam deflection, and the more pronounced this difficulty becomes. A system for overcoming this disadvantage is illustrated in Fig. 4, to which reference is now made.

That portion of the device illustrated in Fig. 4 which includes the cathode ray tube 7 and its associated equipment, charging battery 27, capacitor 29, and the pentode 33, is identical to the corresponding portion of the device illustrated in Fig. 1. The change which is provided relates to an automatic means for accelerating the deflection of the beam upon the application of the transient by causing the discharge of a pair of gas tubes to change the bias on the grid of the pentode 33. It will be noted that a resistor 49 has been connected in series with resistor 35, between ground and the negative terminal of battery 27. This resistor provides a source of negative potential with respect to ground for the normal bias of the pentode grid. A pair of gas discharge tubes 51 and 53, of the cold cathode type, are connected in parallel and have their anode electrodes connected through a switch 55 and a resistor 57 to the positive terminal of battery 27, and their cathode electrodes connected to the negative terminal of battery 27 through a potentiometer 59. The gas tubes 51 and 53 are provided with control electrodes which are used to cause the breakdown of the tubes upon the application of a suitable voltage. The tubes 51 and 53 used by me in this arrangement are known as gas triodes, type OA4-G, described on page 45 of RCA Receiving Tube Manual RC-14. The control electrodes 61 and 63 are connected, respectively, to the outer terminals of the secondary 65 of a transformer 67. The secondary center tap is connected through a switch 69 to a suitable source of positive potential, which may be supplied, for example, by means of a voltage regulator tube 71 and a potentiometer 73 se-

rially connected across battery 27. The primary of transformer 67 is energized by the applied transient through a circuit which may include an amplifier 75.

The amplitude of the positive potential derived from potentiometer 73 which is applied to the two control electrodes 61 and 63 is adjusted to such a value that the tubes 51 and 53 are just below their breakdown point. This permits one, or eventually both, of the gas tubes to become conductive when potentials of the proper polarity, which are derived from the applied transient, are applied to the respective control electrodes. In the absence of such a voltage, and prior to the breakdown of the tubes 51 and 53, there is no voltage drop in potentiometer 59 so that the normal operating potential of the grid of pentode 33 is determined by the adjustment of potentiometer 37. This potential will be negative with respect to ground and will be selected to provide any desired initial rate of horizontal deflection for the cathode ray tube 7. Upon the application of a transient voltage, the subsequent breakdown of at least one of the gas tubes 51 and 53 produces a voltage drop in potentiometer 59 which causes the grid of pentode 33 to become more positive with respect to ground. The current flowing in potentiometer 59 is practically the same whether one or both tubes breakdown, as gas tubes maintain essentially a constant voltage. The amplitude of the grid potential is suitably selected to provide any desired rate of deflection for the remainder of the cycle. Switches 69 and 55 are included in the circuits shown to remove the potentials from the gas tubes 51 and 53 after the observation or recording has been made, to extinguish the tubes and to prepare the device for a subsequent observation.

The method of using this device is similar to that of the embodiment described in Fig. 1. Switch 31 is opened and the cathode ray beam permitted to begin its horizontal deflection at a low rate, and then at the proper instant the transient is applied and the observation made with the desired accelerated time displacement of the beam.

By means of the meter 45, which indicates the amplitude of the discharge current, it is possible to predetermine the velocity of the beam deflection. The beam velocity V in inches per second is expressed by the equation

$$V = \frac{I}{SC} \times 10^3$$

where

I =current in milliamperes,

C =capacitance of capacitor 29 in microfarads, and

S =volts required to deflect the beam one inch across the screen.

Fig. 3 illustrates the improved operation of the system which has been described immediately above. The distance $c-d$ illustrated in the figure is that distance through which the beam moves at the initial slow rate of speed, prior to the application of the transient voltage. The transient voltage itself, however, by accelerating the horizontal deflection of the beam, is viewed on an accelerated time base covering the region $d-e$. It is no longer necessary to view the transient voltage with a low horizontal deflecting speed, since by the arrangement shown the transient voltage may readily be applied at the prop-

er instant after the horizontal deflection has been initiated.

It will be realized that the photographic image of that section of the horizontal trace $c-d$ which is made prior to the application of the transient voltage is very dense. This density is caused by two factors. The amount of light emitted per unit area from a fluorescent screen is a function of the beam velocity, so that more light is produced in the initial region in which the beam moves comparatively slowly. In addition, the exposure of a photographic negative is a function of the amount of light falling thereon. These factors heretofore have caused considerable difficulty in recording oscillograms. When the intensity of the beam is sufficiently great for a proper illumination during the time of rapid beam deflection, a decrease in deflection rate results in overexposure and in some cases in burning of the screen.

A modification of this invention is illustrated in Fig. 5 which completely overcomes this objection by providing means for varying the beam intensity in proportion to the horizontal and vertical deflecting speed. This part of my invention has wide application to all types of mechanical as well as cathode ray oscillographs. It may be utilized in connection with oscillographs which are used to study recurrent electrical phenomena where the scanning voltage is synchronized with the frequency of recurrence. The uniform unit illumination produced by this means greatly assists visual observation of voltage peaks which are usually indistinctly reproduced by reason of the high velocity of the beam.

Referring to Fig. 5, a cathode ray tube 7 is utilized, as before. Operating potentials for the tube are supplied by a source of voltage 17 and a voltage divider 19. An initial operating grid bias is supplied by an adjustable connection 77 to the voltage divider 19 through a pair of grid leak resistors 79 and 81. The amplitude of this bias is preferably sufficient to shut off the cathode ray beam.

As before, the input voltage is applied between the two vertical deflecting electrodes 11; in this case, however, the time delay network 83 is included in the input circuit for reasons which will be pointed out hereinafter.

In order to provide automatic control of the beam intensity, two control circuits have been provided which apply to the control grid 21 positive potentials which are proportional, respectively, to the rate of change of horizontal and vertical deflecting voltages. The horizontal deflecting control is obtained by connecting the primary of a transformer 85 in series with the capacitor 29 which is used, as before, to produce a linear deflection of the cathode ray beam in a horizontal direction. The secondary of transformer 85 is connected across grid leak resistor 79 so that when the transformer is energized by the discharge current of capacitor 29 through pentode 33, a positive voltage is superimposed on the initial grid bias, the amplitude of which is proportional to the rate of discharge of the capacitor. Consequently, the amplitude of the superimposed voltage is also proportional to the rate of horizontal deflection.

The control voltage for maintaining constant unit illumination during vertical displacement of the cathode ray beam is controlled by a circuit which includes a transformer 87 and push-pull rectifiers 89 and 91. The primary of trans-

former 87 is connected to the output of the time delay network 83. The transformer secondary is connected to a differentiating circuit which includes a pair of small capacitors 93 and 95 and a resistor 97, the midpoint of which is connected to the adjustable contact 77. The outputs of the two rectifiers 89 and 91 are connected to the common point of resistors 79 and 81, so that the control voltage developed in response to the applied input voltage is effectively connected in series with the normal grid bias. The rectifier circuit shown produces a unipotential output voltage from an alternating input voltage. A transient of either polarity, therefore, will cause the control grid 21 to become more positive. As a result, the cathode ray beam intensity is increased by an amount which is proportional to the rate of change of the applied transient without regard to its polarity. The unit illumination of the cathode ray trace is therefore constant as the vertical deflecting speed varies.

In order to make the device fully automatic, the switch which was previously used to initiate the horizontal beam deflection has been replaced by a resistor 99. The value of resistor 99 is preferably high with respect to the impedance of pentode 33 during any part of the useful period of conductivity of the latter. The purpose of resistor 99 is to charge capacitor 29, while pentode 33 discharges the capacitor at a linear rate, as before. It is true that the presence of the charging resistor 99 during the discharge cycle tends to make the deflecting voltage slightly non-linear. This can be overcome by replacing resistor 99 by a constant current device such as a pentode 99a of Figure 5a, or a vacuum phototube 99b of Figure 5b with suitable means for illuminating the same.

The circuit for applying a more positive bias to the control grid of pentode 33 in response to the applied transient voltage, including transformer 67 and the gas tubes 51 and 53, is the same as that described in connection with the preceding circuits and need not be explained again in detail. However, it is desirable to point out that the applied transient initiates the horizontal deflection of the cathode ray a brief interval before the same transient is applied to the vertical deflecting electrodes by reason of the interposition of the time delay network 83. The degree of the delay required depends upon the time necessary for one or both of the gas tubes to become conductive. This time is of the order of microseconds, and for any but exceptionally rapid transients, probably need not be considered. The input circuits shown include iron cored transformers; however, other coupling means may be preferable for high speed transients.

It will be recalled that in the arrangement illustrated in Fig. 4 the initial bias of the grid of tube 33 was adjusted to that value which would produce the desired initial horizontal rate of deflection. In the present arrangement, however, the initial bias is adjusted to a value which reduces the plate current of the pentode 33 to a minimum. The same amount of current flows in 99, thereby maintaining an equilibrium voltage across capacitor 29. The position of the arm of potentiometer 37 and the potential of battery 47 therefore determine the initial position of the beam along the horizontal axis. In the device illustrated in Fig. 5, it is no longer necessary to provide the initial slow deflection,

since the device is completely automatic, and the applied transient voltage itself initiates the horizontal deflecting operation at a fixed predetermined time before the application of the voltage to the vertical deflecting electrodes.

As in the preceding arrangements, the device illustrated in Fig. 5 produces but a single cycle of operation upon the application of a transient voltage. To prepare the device for a second observation, it is necessary to open circuit switches 55 and 69, thus removing the anode potential from gas tubes 51 and 53, restoring the initial potential on the grid of pentode 33, and permitting capacitor 29 to become recharged. The circuit including elements 29 and 85 inherently serves to diminish the beam on the return path in case of a resetting operation by means of opening switches 55 and 69.

With respect to the adjustment of the initial negative bias on the control grid 21 of the cathode ray tube 7, the amplitude of this voltage is adjusted to that value which extinguishes the cathode ray beam. This original bias is overcome, however, upon the application of a vertical or a horizontal deflecting voltage. Consequently, the cathode ray beam impinges on the fluorescent screen only when deflecting voltages are also present. This prevents burning of the screen during periods when no deflecting voltages are applied, and also completely removes any illumination during the same periods. This greatly facilitates photographing the effect of the transients, since there is no stray illumination to fog the negative.

I have thus described an improved cathode ray oscillograph having certain new features which are also applicable to other types of oscillographs. Of general application is the arrangement by which the beam intensity is controlled in accordance with the rates of speed of the horizontal and vertical deflections. Of particular importance to the study of high speed transient phenomena are the linear deflecting voltage arrangement, the horizontal deflection accelerating system, and the automatic system for scanning a non-recurrent transient.

I claim as my invention:

1. A device of the character described comprising a cathode ray tube having vertical and horizontal beam deflecting means and a beam intensity control electrode normally biased to shut off said beam; a source of voltage for applying a single deflecting impulse to said horizontal deflecting means, said source comprising a capacitor, circuit connections between said capacitor and said horizontal deflecting means, a source of positive potential, switching means for normally connecting said source across said capacitor for charging said capacitor, a thermionic tube having a substantially constant plate voltage-plate current characteristic connected across said capacitor for discharging said capacitor at a constant rate when said switching means is operated to disconnect said source from said capacitor, the instantaneous position of said beam being proportional to the instantaneous voltage across said capacitor; other switching means in circuit with said control electrode and operatively connected to said first switching means for applying an operating bias to said electrode, and means for applying a voltage to be indicated to said vertical deflecting means immediately after said switches have been operated.

2. In a device of the character described for 75 indicating a voltage trace, a cathode ray tube

having vertical and horizontal beam deflecting means; means for energizing said horizontal deflecting means to cause said beam to move horizontally in a given direction at a predetermined rate prior to the impression of said voltage; means for subsequently energizing said vertical beam deflecting means in accordance with said voltage to be indicated; and means responsive to said last named voltage for causing said beam to complete its movement in said direction at a different rate.

3. In a device of the character described for indicating a transient voltage trace, cathode ray beam producing means; means for initially sweep-deflecting said beam in a first direction at a first rate of speed in the absence of an impressed transient voltage; means for subsequently deflecting said beam in a second or trace indicating direction in accordance with an impressed transient voltage; and means responsive to said last named means for substantially changing the rate of speed of said beam in said first direction.

4. In a cathode ray oscillograph device having beam producing means for indicating transient voltage traces, sweep voltage responsive means for initially deflecting said beam in a given sweep direction at a predetermined rate of speed in the absence of impressed transient voltages to be indicated, voltage responsive means for subsequently deflecting said beam in a trace indicating direction in accordance with an impressed transient voltage, and means responsive to said transient voltage for causing said beam to continue in the same sweep direction at a substantially increased rate of speed.

5. In a device of the character described, a variable impedance device; cathode ray beam producing means; means for deflecting said beam in a first direction at a rate of speed determined by said variable impedance device; means for deflecting said beam in a second direction in accordance with a voltage which is to be indicated; and means responsive to said voltage for varying the impedance of said device to change the speed of deflection of said beam in said first direction.

6. In a device of the character described, a capacitor, means for charging said capacitor, a variable impedance device for discharging said capacitor; an indicating screen; cathode ray beam producing means; means for deflecting said beam across said screen in a first direction at a rate of speed determined by the initial impedance of said device; means for deflecting said beam in a second direction across said screen in accordance with a voltage which is to be indicated; and means responsive to said voltage for changing the impedance of said device to change the speed of deflection of said beam in said first direction.

7. A device of the character described comprising a cathode ray tube having vertical and horizontal beam-deflecting means and a control electrode; a voltage source for applying a deflecting impulse to said horizontal deflecting means, said source comprising a capacitor, means for charging said capacitor, and means for discharging said capacitor at a given instant and at a constant rate, the position of said beam being proportional to the instantaneous voltage across said capacitor, and circuit connections between said capacitor and said control electrode whereby the intensity of said beam is determined by the rate of discharge of said capacitor.

8. A device of the character described com-

prising a cathode ray tube having vertical and horizontal beam-deflecting means and a control electrode, a voltage source for applying a single deflecting impulse to said horizontal deflecting means, said source comprising a capacitor, means for charging said capacitor, and means for discharging said capacitor at a given instant and at a constant rate, the position of said beam being proportional to the instantaneous voltage across said capacitor, and circuit connections between said capacitor and said control electrode whereby the intensity of said beam is varied by the rate of discharge of said capacitor, means for applying a voltage to be indicated to said vertical deflecting means, and means for varying the intensity of said beam in accordance with the rate of change in said voltage to be indicated.

9. A device of the character described comprising a cathode ray tube having vertical and horizontal beam deflecting means, means for applying a deflecting impulse to said horizontal deflecting means for deflecting said beam at a first rate, means for applying a voltage to be indicated to said vertical deflecting means, means responsive to said voltage for changing the horizontal rate of deflection to a second rate, means for controlling the intensity of said beam as a function of the rate of change of said horizontal deflecting impulse, and means for also controlling the intensity of said beam as a function of the rate of change of said voltage to be indicated.

10. A device of the character described comprising a cathode ray tube having vertical and horizontal beam deflecting means, a voltage source for applying a single deflecting impulse to said horizontal deflecting means, said source comprising a capacitor, means for charging said capacitor, means including current-responsive means in circuit with said capacitor for discharging said capacitor at a substantially constant rate, said current-responsive means being coupled to said cathode ray tube so as to control the intensity of said beam, the position of said beam being proportional to the instantaneous voltage across said capacitor, and the intensity of said beam being varied by the rate of discharge of said capacitor through said current-responsive means.

11. In a device of the character described, a capacitor, a source of voltage for charging said capacitor, a constant current thermionic tube connected in parallel with said capacitor for discharging said capacitor, means for applying a grid bias to said tube for controlling the normal rate of discharge of said capacitor, a cathode ray tube having vertical and horizontal deflecting electrodes, connections from said capacitor to said horizontal deflecting electrodes, the horizontal position of said ray being proportional to the charge on said capacitor, means for applying a voltage to be observed to said vertical deflecting electrodes, and means responsive to said voltage for changing said grid bias to increase the rate of discharge of said capacitor.

12. A device of the character described in claim 11 which includes means for delaying the application of said voltage to said vertical deflecting electrodes so that said cathode ray is not deflected vertically before the rate of discharge of said capacitor has been increased.

13. In a device of the character described, a capacitor, a source of voltage for charging said capacitor, a constant current thermionic tube connected in parallel with said capacitor for discharging said capacitor, bias means for applying

a grid bias to said tube to determine the normal rate of discharge of said capacitor, a cathode ray tube having vertical and horizontal deflecting electrodes, means coupling said capacitor to said horizontal deflecting electrodes whereby the horizontal position of said ray is determined by the charge on said capacitor, input means for applying a voltage to be observed to said vertical de-

flecting electrodes, a gas-filled grid control tube coupled to said input means and in circuit with said bias means whereby said voltage to be observed causes said gas-filled tube to become conductive to change the grid bias of said constant current tube.

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