Jan. 25, 1944. W. A. KNOOP 2,339,863

CATHODE RAY SCANNING APPARATUS

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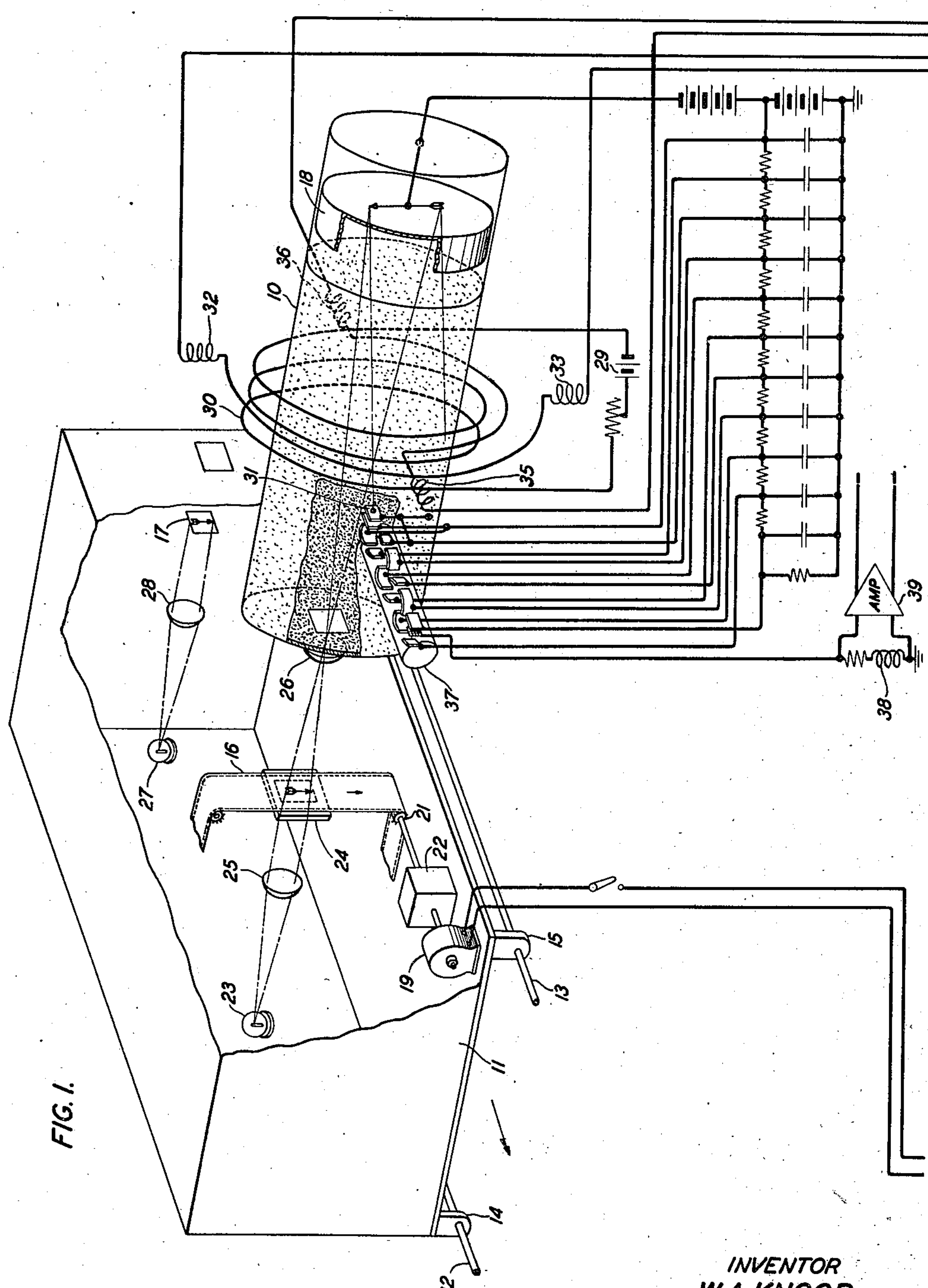

FIG. I.

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CATHODE RAY SCANNING APPARATUS

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FIG. 2.

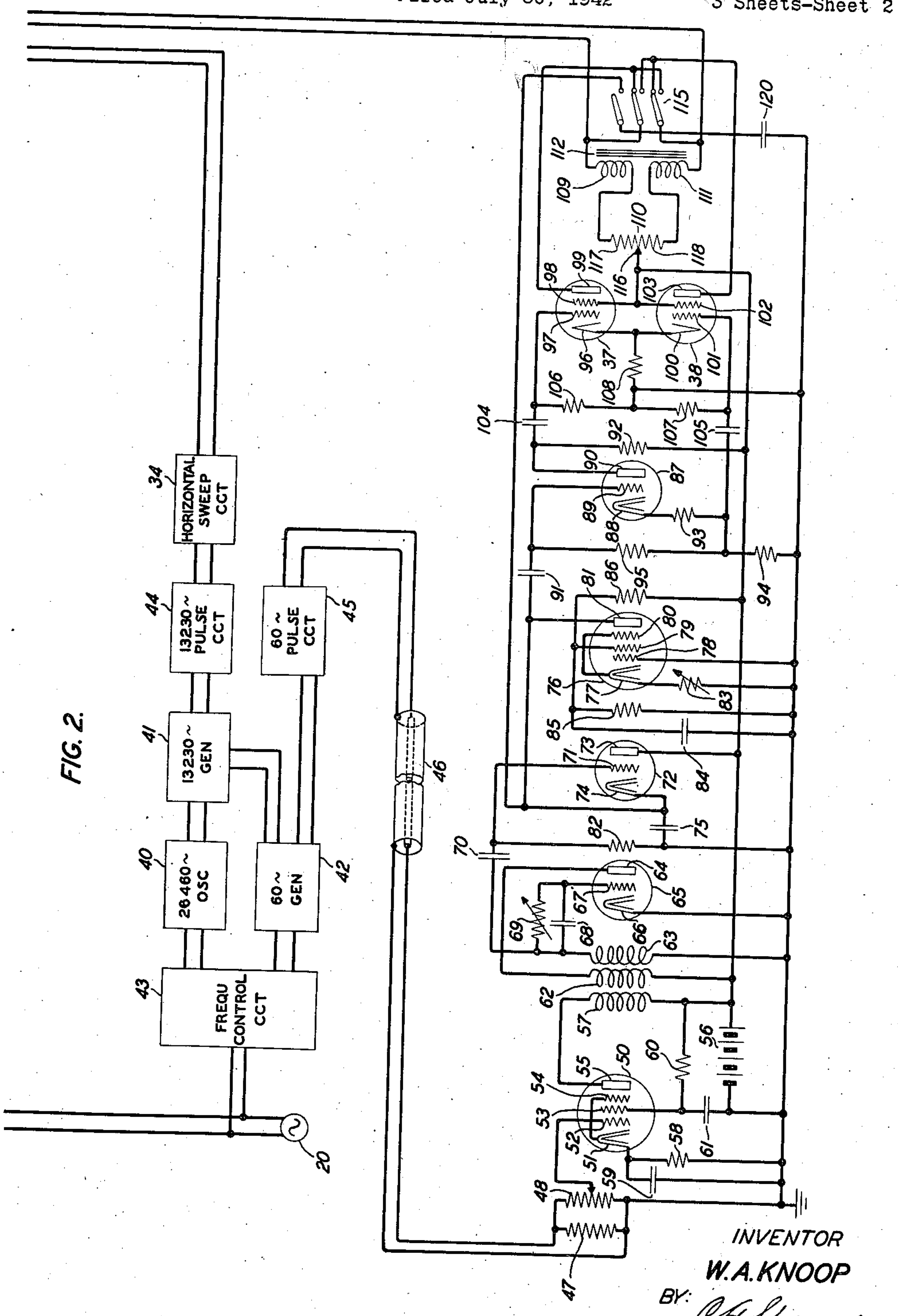

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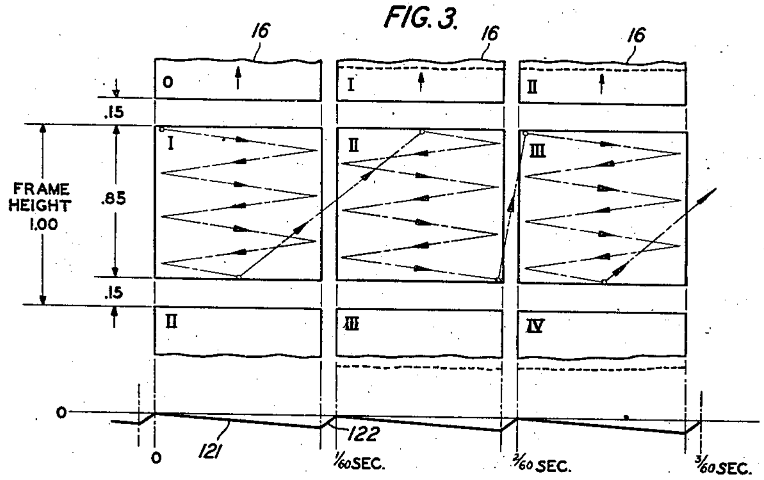
FIG. 3.



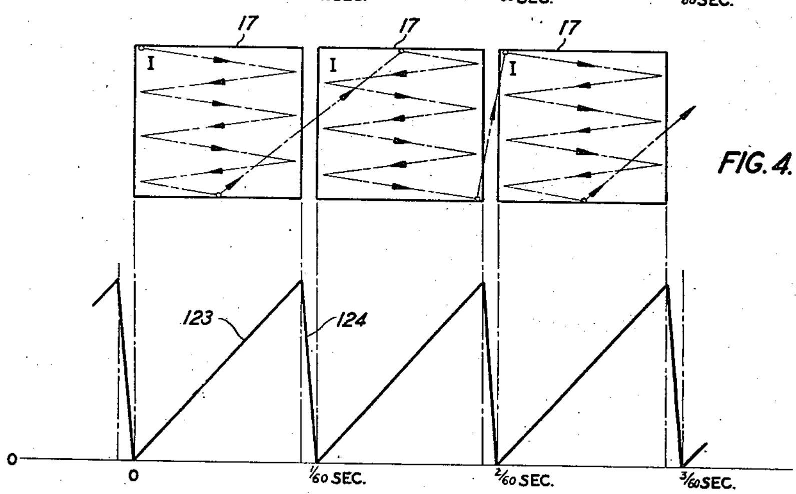


FIG. 4.

FIG. 5.

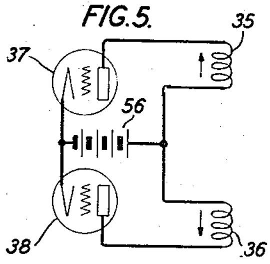
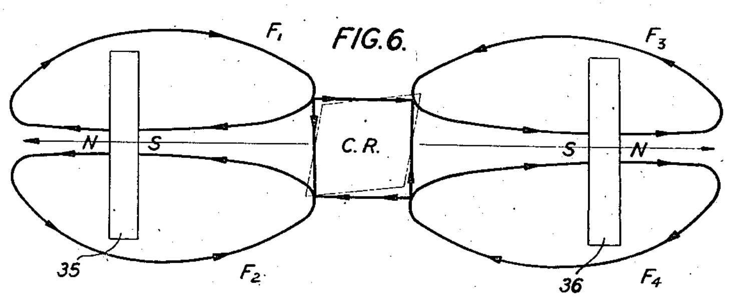


FIG. 6.



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CATHODE RAY SCANNING APPARATUS

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Application July 30, 1942, Serial No. 452,947

3 Claims. (Cl. 178—7.2)

This invention relates to cathode ray scanning apparatus and particularly to a circuit for supplying deflecting current to deflecting coils of a cathode ray scanning device from a push-pull amplifier.

For the purpose of supplying an amplified electric wave to a pair of deflecting coils of a cathode ray tube, it has been found advantageous to employ push-pull amplification in the amplifier stage which supplies energy to the coils in order to balance out second harmonic distortion. When, for example, the vertical deflecting coils on opposite sides of a cathode ray tube of the image dissector type are connected in the anode circuits of the two amplifier tubes, respectively, of the push-pull amplifier in a manner to cause the vertical deflection of the cathode ray beam in response to a deflecting electromotive force applied to the amplifier input circuit, it has been discovered that the dissector tube produced a distorted image current. This distortion was found to be due to the distortion of the electron image produced in the dissector tube as a result of the opposing electromagnetic fields set up by the vertical deflecting coils on opposite sides of the cathode ray tube, respectively, when energized by the anode currents from the push-pull amplifier.

For the purpose of avoiding distortion of the electron image in accordance with the present invention, the deflecting coils are caused to produce aiding magnetomotive forces when energized. The coils are included in a current path connecting the anodes of the push-pull amplifier tubes and there is provided a second current path connecting the anodes through different portions of which anode currents are supplied to different tubes, respectively of the push-pull amplifier. The resistance of the two portions of the second current path is such that the current flowing through said deflecting coils is reduced to zero or a low amplitude when the control grids of the push-pull amplifier tubes are at the same potential.

In accordance with the invention means are provided for scanning alternatively still pictures or continuously moving motion picture film. In order to avoid the scanning of any part of the frame lines which separate successive picture portions of the motion picture film during the picture scanning periods, that is, during the periods between successive vertical synchronizing intervals, the electron beam is deflected to cause the electron image in the dissector tube to move vertically through a short distance in the reverse direction with respect to the direction of motion due to the movement of the film while the picture area is being scanned and rapidly in the same direction during the vertical synchronizing period. To condition the apparatus for scanning a still picture which may be a single frame of a stationary motion picture film, the amplitude of the vertical sweep current is increased by reducing the capacity in the circuit of the vertical sweep generator and the direction of the deflecting current in the vertical sweep coils is simultaneously reversed.

Figs. 1 and 2 of the drawings, when Fig. 1 is placed above Fig. 2, constitute a diagrammatic view of a cathode ray scanning apparatus in accordance with the present invention; and

Figs. 3 to 6 are diagrams to which reference will be made in describing the invention.

Referring to Figs. 1 and 2 of the drawings, there is disclosed a scanning apparatus comprising a cathode ray tube 10 of the image dissector type. A motion picture projector and a still picture projector are mounted upon a carriage 11 which is slidable along the rods 12 and 13 passing through lugs 14 and 15 of the carriage so that images may be projected from the motion picture film 16 or from a still picture 17, alternatively, to the cathode 18 of the dissector tube 10. The motion picture projecting apparatus comprises a synchronous motor 19 energized from the 60-cycle source 20 for driving the film sprocket 21 through the gears in gear box 22. Light from source 23 is directed upon the portion of the picture film within the film gate 24 by condenser lens 25 and a projector lens 26 projects an image of the portion of the film within the film gate upon the cathode 18. Similarly, when the carriage is moved to bring the still picture into alignment with the image dissector tube, light from source 27 passing through condenser lens 28 illuminates the picture 17 and an image thereof is projected upon the cathode 18. Electrons emitted from the elemental areas of the cathode 18 in accordance with the illumination thereof are focussed, due to the electromagnetic field set up by current from source 29 flowing through coil 30, to form an electron image corresponding to the optical image on the cathode at the plane of a scanning aperture 31. When a motion picture film is scanned the movement of the optical image on cathode 18 due to the movement of the film causes the electron image to move vertically with respect to the scanning aperture 31. The cathode ray beam from the cathode 18 is also deflected both horizontally and vertically to cause the movement of the electron image with respect to the scanning aperture 31. To produce the horizontal deflection of the cathode ray beam, a saw-toothed wave current of line scanning frequency is supplied to the horizontal deflecting coils 32, 33 from a horizontal sweep circuit 34. To produce the vertical deflection of the cathode ray beam, a saw-toothed wave of field scanning frequency is supplied to the vertical deflecting coils 35, 36 from the push-pull amplifier 37, 38 of the vertical sweep circuit. The electrons from the elemental areas in succession of the electron image which pass through the scanning aperture 31 due to the horizontal and vertical motion of the electron image bombard the first multiplier electrode of the electron multiplier 37. As a result, an image current is set up in the terminating impedance 38 connected to the output of the electron multiplier and this image current may be amplified prior to its transmission to an image producing apparatus by the amplifier 39. Suitable potentials are applied to the electrodes of the image dissector tube and its associated electron multiplier from the circuit comprising battery 60, condensers 61 and resistors 62, as is shown and described in an application of A. G. Jensen, Serial No. 321,390, filed February 29, 1940 (Patent No. 2,291,723, granted Aug. 4, 1942).

The motion picture film 16 may be advanced at the rate of sixty picture frames per second, for example, and the electron image may be moved horizontally under control of the saw-toothed wave from sweep circuit 34 to cause successive lines of the image to be scanned at the rate of 13,230 lines per second or 220½ lines per film frame, the lines of alternate frames being interlaced. Any suitable means may be employed for supplying deflecting currents of saw-toothed wave form to the horizontal deflecting coils 32, 33 and, if desired, these coils may be energized from a push-pull amplifier in the same manner that the vertical deflecting coils 35, 36 are energized, as will be described hereinafter.

The means for energizing the horizontal deflecting coils 32, 33 shown diagrammatically in Fig. 3 comprises a 26,460-cycle controlled oscillator 40 from which is derived by successive steps the submultiple frequency sources 41 and 42 of 13,230-cycle and 60-cycle waves, respectively, of rectangular wave form. The 60-cycle wave from the power source 20 and the 60-cycle wave from the submultiple frequency generator 42 are impressed upon the frequency regulating circuit 43. There is produced by the circuit 43 as the result of beating together the waves from sources 20 and 42 a control current which is impressed upon the oscillator 40 for maintaining the frequency of the wave produced by the oscillator 40 in step with the frequency of the 60-cycle power source 20, that is, for maintaining the frequency of source 40 at the 441st multiple of the frequency of power source 20. Of course, a line scanning frequency rate other than 441 lines for two picture frames of the film 16 or for two field scannings of the still picture 17 may be used in which case the frequency of source 40 would be maintained at some harmonic of the 60-cycle power source other than the 441st. An arrangement of the type described for generating waves for controlling a sweep circuit which, in turn, controls the deflection of a cathode ray beam and for maintaining the waves in synchronism with an alternating current power source is disclosed in an article by A. V. Bedford and John Paul Smith on page 51 of "RCA Review" for July 1940, published by RCA Institute Technical Press, 75 Varick Street, New York, New York. The 13,230-cycle source 41 controls a 13,230-cycle impulse generating circuit 44 which, in turn, controls the horizontal sweep circuit 34 for supplying a 13,230-cycle saw-toothed current wave to the horizontal deflecting coils 32, 33.

Sixty cycle pulses produced by the generator 45 under control of the subharmonic generator 42 are impressed by way of the 72-ohm coaxial line 46 upon a circuit for controlling the energization of the vertical sweep coils 35, 36. The coaxial line is terminated in a 72-ohm resistor 47 across which is connected a 2,000-ohm potentiometer 48. The 60-cycle impulses from the potentiometer are impressed upon the control grid-cathode circuit of the pentode 50 having a cathode 51, control grid 52, screen grid 53, suppressor grid 54 and anode 55. The anode current path for the pentode may be traced from the positive terminal of battery 56 through transformer winding 57 to anode 55 and from cathode 51 through 1,000-ohm biasing resistor 58 shunted by 1 microfarad condenser 59 to the grounded negative terminal of battery 56. Positive battery from source 56 is also supplied to screen grid 53 through 2,000-ohm resistor 60. A by-pass condenser 61 of 1 microfarad is connected between the screen grid and ground. The suppressor grid 54 is connected to the cathode.

Transformer windings 62 and 63 are electromagnetically coupled to the winding 57. The winding 62 is connected between the positive terminal of battery 56 and the anode 64 of a three-electrode vacuum tube 65. The winding 63 is in a circuit connecting the grounded cathode 66 with the grid 67 of tube 65, the 0.1 microfarad condenser 68 shunted by 1,000-ohm variable resistor 69 being connected in this circuit between the grid 67 and the winding 63.

The impulses impressed upon the control grid 52 of the pentode 50 are of such polarity as to decrease the anode current of the tube flowing through transformer winding 57 and the winding 63 is so wound with respect to winding 57 that there are induced in winding 63, due to the impulses in winding 57, impulses of electromotive force which make the grid 67 positive with respect to the cathode 66. As a result, electrons from cathode 66 accumulate on grid 67 and the condenser 68 becomes charged, the plate connected to the grid 67 being negative. The positive impulse impressed upon the grid 67 prior to the charging of condenser 68 causes a sudden rush of anode current through transformer winding 62 to take place and, as a result, the voltage induced in winding 63 is increased to increase the positive potential on the grid 67. At the end of the impulse from the pentode 50 the grid 67 has a negative potential with respect to cathode 66 due to the charge stored in condenser 68 and, as a result, no current flows through the anode circuit of tube 65. Prior to the time that a succeeding impulse arrives from the pentode 50, the condenser 68 has partly discharged through resistor 69 and, when the succeeding impulse arrives, the action above described is repeated.

The positive impulses produced at the terminal of winding 63 which is connected to condenser 68 are also impressed through condenser 70 upon the grid 71 of three-electrode vacuum tube 72. The anode 73 of tube 72 is connected to the positive terminal of battery 56 while the cathode 74 is connected through condenser 75 of 0.25 microfarad to ground. Each impulse on grid 71 causes anode current to flow through a circuit including the sweep condenser 75 to cause the condenser to become charged. The grid 71 is connected through a grid leak resistor 82 to ground.

The pentode 76 is a constant current tube through the anode circuit of which the condenser

75 discharges at a substantially constant rate. The electrodes of this tube are a cathode 77, grid 78, screen grid 79, suppressor grid 80 and an anode 81. The anode is connected to the positive terminal of condenser 75 while the cathode 77 is connected to ground through a variable resistor 83 which may be adjusted to control the rate of discharge of condenser 75. The grid 78 is directly connected to ground. The screen grid 79 is connected through 1 microfarad condenser 84 to ground, this condenser being shunted by a 50,000-ohm resistor 85. The positive terminal of battery 56 is connected to the screen grid 79 through 200,000-ohm resistor 86. The suppressor grid 80 is connected to the cathode 77. Due to the charging of condenser 75 at a rapid rate and its slower discharging at a constant rate, a saw-toothed wave voltage is generated across the condenser.

The three-electrode vacuum tube 87 having a cathode 88, grid 89 and anode 90 is a phase inverter having less than unity gain per side. The positive terminal of condenser 75 is connected through 1 microfarad condenser 91 to the grid 89. Anode current is supplied to tube 87 through a circuit from positive terminal of battery 56, 50,000-ohm resistor 92 to anode 90 and from cathode 88 through bias resistor 93 of 3,000-ohm and 50,000-ohm resistor 94 to ground. A grid leak resistor 95 is connected between the grid 89 and the lead joining resistors 93 and 94.

The phase inverter tube circuit is connected to the input of push-pull amplifier comprising the tetrodes 37 and 38. The tube 37 has a cathode 96, a grid 97, screen grid 98 and an anode 99 and tube 38 has a cathode 100, grid 101, screen grid 102 and an anode 103. Anode 90 of tube 87 is connected to grid 97 through condenser 104 of 1 microfarad, and the lead connecting resistors 93 and 94 is connected through condenser 105 of 1 microfarad to the grid 101. Screen grids 98 and 102 are connected to the positive terminal of battery 56. A grid leak resistor 106 of 0.5 megohm is connected between grid 97 and ground and grid leak resistor 107 of 0.5 megohm is connected between grid 101 and ground. Cathodes 96 and 100 are each connected to a terminal of 200-ohm resistor 108, the other terminal of which is connected to ground. With the switch 115 in the position shown in the drawings, there is connected between anode 99 of tube 37 and anode 103 of tube 38 a current path from anode 99 through inductive winding 109 on core 112, resistor 110 and inductive winding 111 on core 112, like inductance element 109 to anode 103. The windings 109 and 111 are preferably wound on a single core to keep the magnetization of the core at a relatively low value. The resistor 110 has a variable contact 116 which is connected to the positive terminal of battery 56. Anode current is thus supplied to tube 37 through a circuit which may be traced from positive terminal of battery 56 through a portion 117 of resistor 110, winding 109 through switch 115 to anode 99 and from cathode 96 through resistor 108 to ground. The anode circuit for tube 38 may be traced from positive terminal of battery 56 through portion 118 of resistor 110, winding 111 through switch 115 to anode 103 and from cathode 100 through resistor 108 to ground. With the switch 115 in the position shown, the vertical deflecting coils 35 and 36 in series are in a second current path connecting the anodes 99 and 103, a terminal of coil 35 being connected to anode 99 and a terminal of coil 36 being connected to anode 103. With the switch 115 in the position shown a saw-toothed wave current of large amplitude as shown in the lower portion of Fig. 4 is caused to flow through the vertical sweep coils 35 and 36 and the apparatus is in condition for scanning the steady picture 17. When switch 115 is operated to close the contacts which are shown open in the drawings, the phase of the deflecting current through the vertical sweep coils is reversed because a terminal of coil 35 is then connected to anode 103 and a terminal of coil 36 is connected to anode 99. Moreover, 1 microfarad condenser 120 is connected in parallel with sweep condenser 75 so that a deflecting voltage of relatively smaller amplitude will be produced due to the charging and discharging of condensers 75 and 120 in parallel. As a result, a deflecting current, as shown at the lower portion of Fig. 3, is produced in the sweep coils 35 and 36.

As shown in Fig. 3, the picture portion of a motion picture frame occupies about 85 per cent of the frame height and a black bar which separates successive picture portions occupies about 15 per cent of the frame height. If the vertical scanning motion of the optical image on cathode 18 and the corresponding motion of the electron image were due entirely to the movement of the motion picture film, only 85 per cent of the total time would be spent in scanning the electron images corresponding to picture portions of the film. The interval allotted for transmitting vertical synchronizing signals is usually less than 15 per cent of the total time, say 10 per cent. In order to avoid loss of 5 per cent of the scanning time, for example, that is, the difference between 15 per cent and 10 per cent, the electron beam is deflected vertically in a manner to reduce the rate of movement of the electron image while a picture portion of the film is scanned by such an amount that the picture portion is scanned during 90 per cent of the time, leaving 10 per cent of the time for sending vertical synchronizing signals during which interval the electron beam is returned to its original position for commencement of scanning of the succeeding picture portion. As shown in the lower portion of Fig. 3 the vertical deflecting wave has a portion 121 of negative slope during 90 per cent of the film frame scanning period of $^1/_{60}$ second and a portion 122 of positive slope during 10 per cent of the period of $^1/_{60}$ second.

When scanning the still picture 17, the saw-toothed current applied to the vertical deflecting coils is increased in amplitude and reversed in phase with respect to the current wave shown in Fig. 3. This wave is shown in Fig. 4 and comprises a portion 123 of positive slope having a duration of 90 per cent of $^1/_{60}$ second and a portion 124 of negative slope having a duration of 10 per cent of $^1/_{60}$ second.

The advantage of the arrangement shown in Fig. 2 for supplying energy from the push-pull amplifier 37, 38 to the deflecting coils 35 and 36 which are on opposite sides of the image dissector tube may be understood from a consideration of Figs. 5 and 6. In Fig. 5, anode current is supplied to the tube 37 of the push-pull amplifier from battery 56 through deflecting coil 35 and anode current is supplied to tube 38 of the push-pull amplifier from battery 56 through deflecting coil 36. In order that a resultant deflecting field may be set up due to the currents flowing through coils 35 and 36 when a deflecting wave is applied to the input of the push-pull amplifier, as in Fig. 2, the coils 35 and 36, when connected as shown in Fig. 5, must be wound so as to set up opposing magnetomotive forces when energized by current from battery 56. Due to the steady direct current component which flows through coils 35 and 36 independently of any saw-toothed deflecting wave applied to the input circuit of push-pull amplifier 37, 38, there are set up by coils 35 and 36 fields which deflect portions of the cathode ray beam to cause the electron image produced by the cathode ray beam to be distorted in the manner shown in Fig. 6.

Consider that only steady direct current is passing through the coils 35 and 36 to produce fields as indicated by the lines F_1, F_2, F_3 and F_4 of Fig. 6. Consider also that the positive direction of the cathode ray beam current C. R. is toward the observer viewing Fig. 6, then the forces acting upon the edge portions of the cathode ray beam C. R. will be as shown by the solid arrows and the beam will be sheared into the shape shown by the dot-dash line.

To avoid this distortion of the electron image the vertical sweep coils 35 and 36 are energized from the push-pull amplifier circuit in a manner to produce aiding magnetomotive forces. Therefore steady direct current does not flow through the coils 35 and 36 except for a small amount which may be used for centering the cathode ray beam, this amount being adjustable by means of the movable contact 116, for example. When no deflecting wave is applied to the input of the push-pull amplifier 37, 38 of Fig. 2 and the control grids 97 and 101 are, therefore, at substantially the same potential, the voltage measured between contact 116 and anode 99 is substantially equal to and opposite to the voltage measured between contact 116 and anode 103 so that the voltage measured between anode 99 and anode 103, that is, the voltage across coils 35 and 36, is substantially zero. When a deflecting wave is applied to the input of the push-pull amplifier, current will flow in opposite directions alternately through coils 35 and 36, the current flow at any instant being in such direction that aiding magnetomotive forces are set up by the coils 35 and 36, thus avoiding distortion of the electron image. With switch 115 in the position shown, at an instant when the grid 97 is positive with respect to ground and grid 101 negative with respect to ground, the amplitude of the anode current for tube 37 will be greater than the anode current for tube 38 with the result that the voltage measured between contact 116 and anode 99 is greater than the voltage measured between contact 116 and anode 103. Therefore, current will flow from the positive terminal of battery 56 through portion 118 of resistor 110, winding 111, coil 36, coil 35, to anode 99 and from cathode 96 through resistor 108 to ground. At another instant when grid 101 is positive and grid 97 negative with respect to ground, current from source 56 will flow through portion 117 of resistor 110, winding 109, coil 35, coil 36 to anode 103 and from cathode 100 through resistor 108 to ground. Thus, a saw-toothed current wave supplied by the push-pull amplifier is caused to flow through coils 35 and 36 for producing an electromagnetic field for vertically deflecting the cathode ray beam while avoiding distortion of the electron image.

The impedance of the current path consisting of windings 109 and 111 and resistor 110 is high compared with the impedance of deflecting coils 35 and 36 in series so that the larger portion of the alternating component of the sweep current from amplifier 37, 38 will flow through the deflecting coils. In order to avoid distortion of the current wave through coils 35 and 36, the ratio of inductive reactance to resistance of the impedance of the current path consisting of windings 109 and 111 and resistor 110 is made equal to the ratio of inductive reactance to resistance of coils 35 and 36 so that the impedance ratio of the two current paths which are in shunt with respect to each other may be the same at all frequencies.

What is claimed is:

1. Means for energizing the sweep coil of a cathode ray tube for producing an electromagnetic field for deflecting the cathode ray beam generated in the tube comprising a first condenser, means for alternately charging and discharging said condenser to generate an electromotive force across said condenser for controlling the deflection of said cathode ray beam, a push-pull amplifier under control of said electromotive force, means for connecting the output of said amplifier to said sweep coil to cause an energizing current to flow therethrough, a second condenser, and switching means which may be operated to reverse the phase of said energizing current and to simultaneously connect said second condenser in parallel to said first condenser to decrease the amplitude of said energizing current.

2. Means for scanning alternatively a continuously moving motion picture film or a still picture, comprising a cathode ray scanning device having means for generating a cathode ray beam, means for repeatedly deflecting said beam horizontally at the line scanning rate, means for generating an electromagnetic field for repeatedly vertically deflecting said cathode ray beam at the field scanning rate when suitably energized, means for supplying to said vertical deflecting means for energizing it a saw-toothed current wave of such slope and amplitude that the period of scanning the picture portions of the continuously moving film is increased, and means for increasing the amplitude and simultaneously reversing the phase of the current supplied to said vertical deflecting means when a still picture is being scanned.

3. In combination, means for generating a cathode ray beam, a push-pull amplifier comprising a plurality of electric discharge devices each having an anode, a cathode and a control electrode, a first current path connecting said anodes having inductance and resistance, a contact to said current path the position of which may be varied, a source of direct current in a current path connecting said movable contact and said cathode, means for producing an electromagnetic field for deflecting said cathode ray beam when suitably energized, and means for connecting said last-mentioned means in a second current path connecting said anodes, the impedance of said first current path being large with respect to the impedance of said second current path and the ratio of said impedances being substantially constant over a wide range of frequencies.

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