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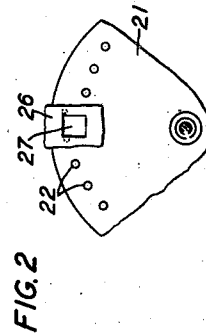
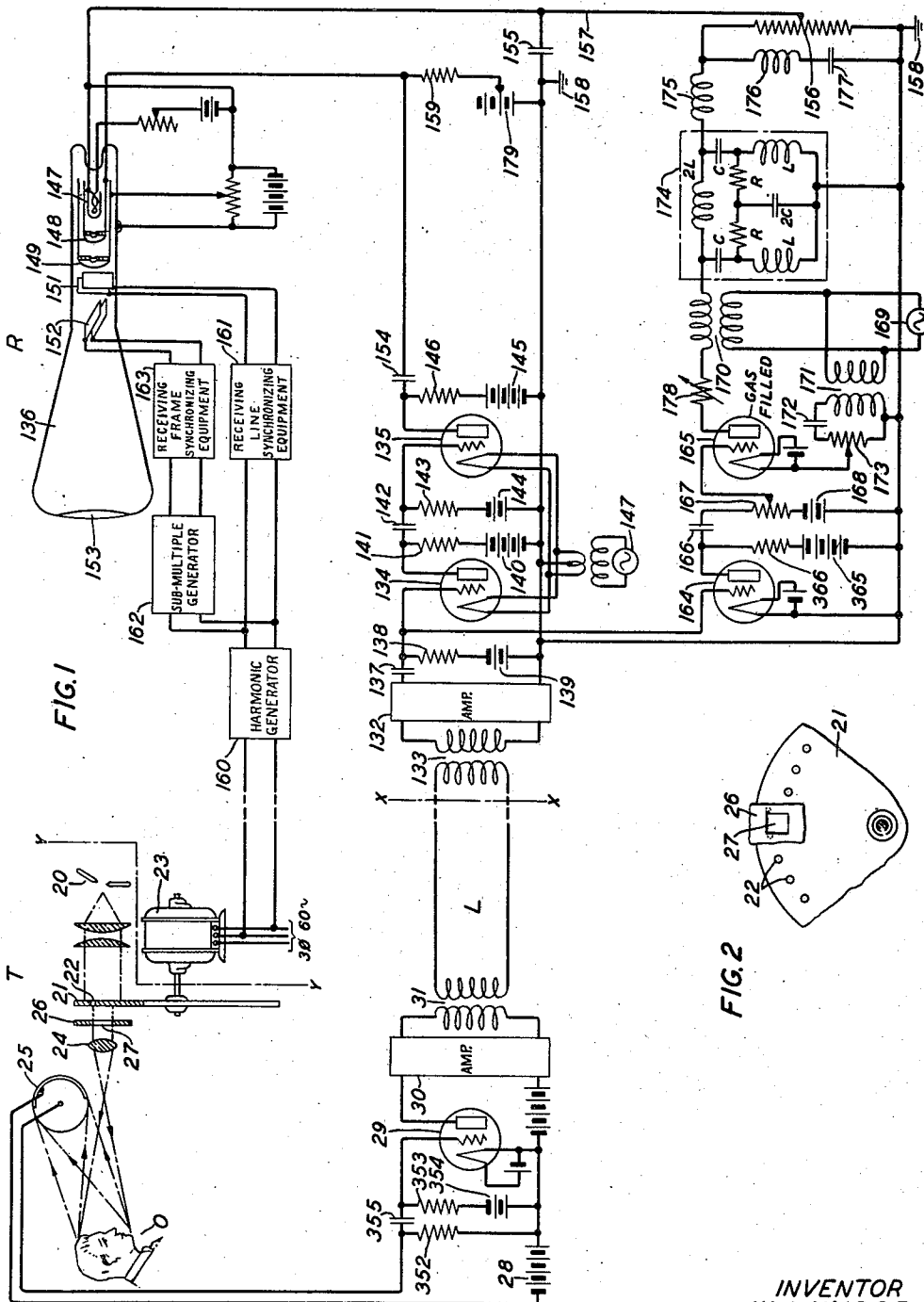
W. A. KNOOP

2,274,710

ELECTRO-OPTICAL IMAGE PRODUCTION

Filed April 28, 1939

4 Sheets-Sheet 1



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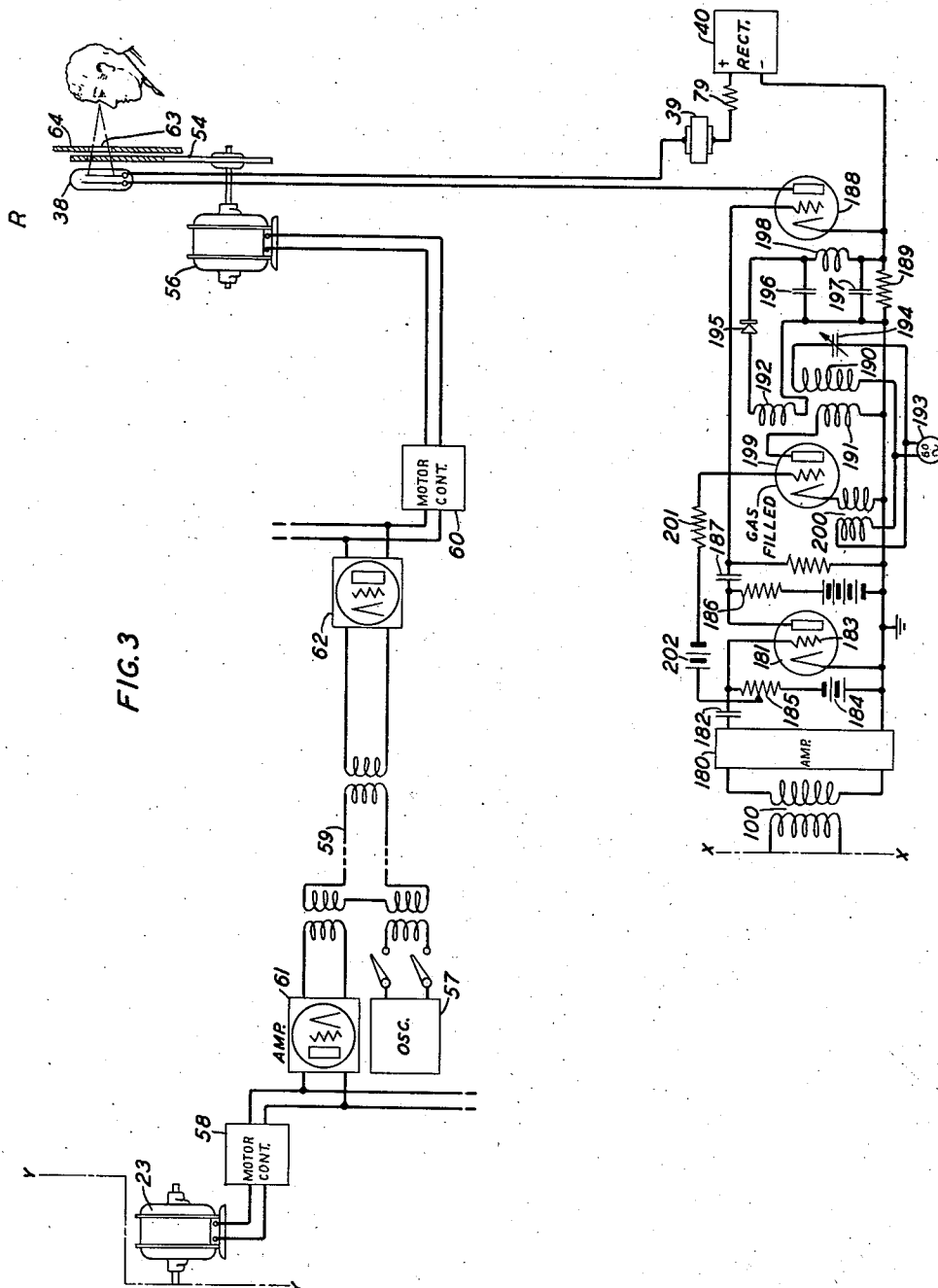
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ELECTRO-OPTICAL IMAGE PRODUCTION

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4 Sheets-Sheet 2



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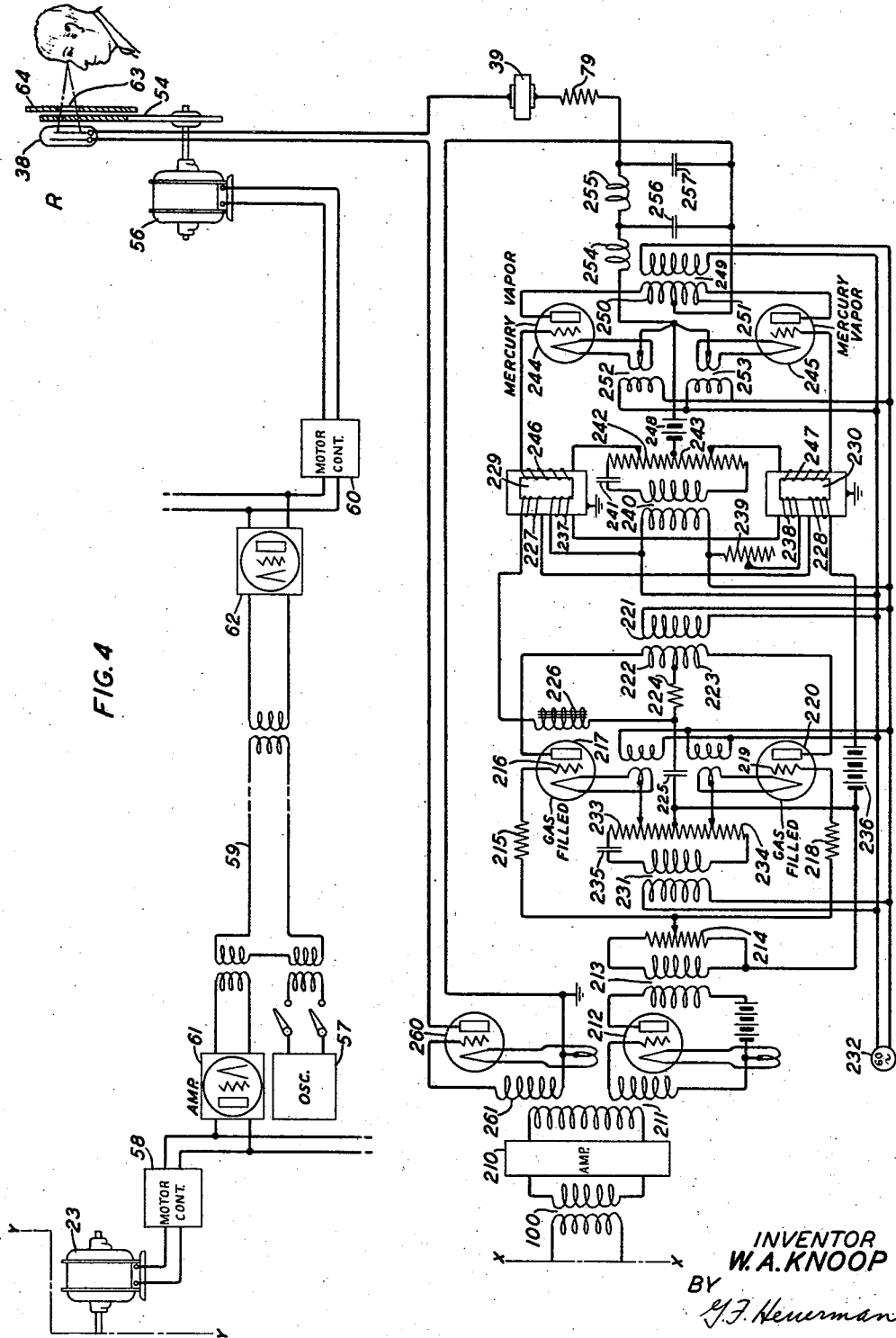
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ELECTRO-OPTICAL IMAGE PRODUCTION

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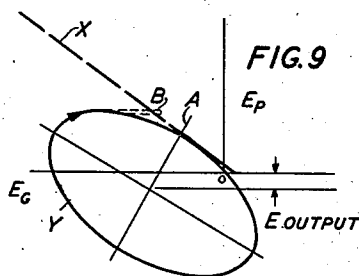
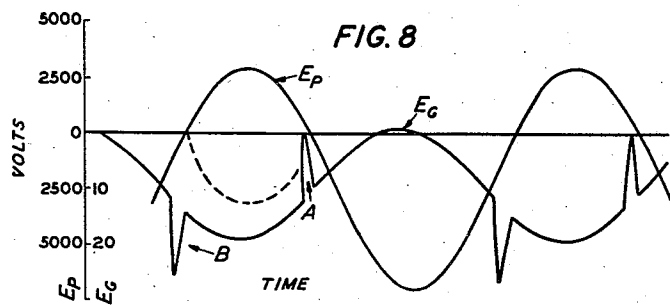
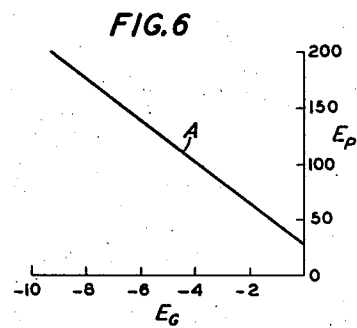
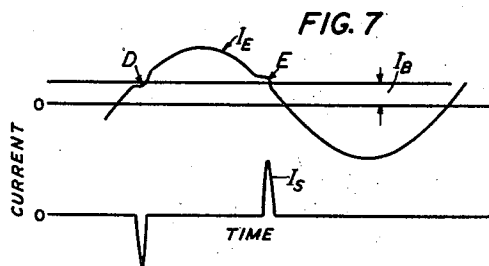
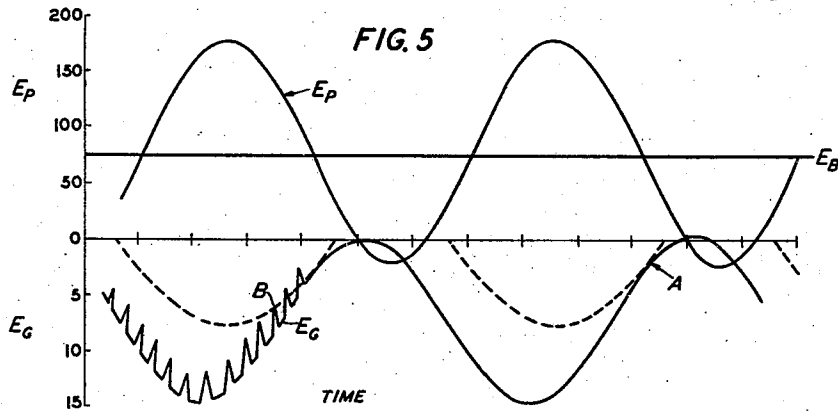
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ELECTRO-OPTICAL IMAGE PRODUCTION

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,274,710

ELECTRO-OPTICAL IMAGE PRODUCTION

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Application April 28, 1939, Serial No. 270,476

5 Claims. (Cl. 178—7.5)

This invention relates to electro-optical image production and particularly to apparatus for and methods of producing television images.

This application is a continuation in part of my application Serial No. 99,023, filed September 2, 1936.

In a television system shown and described herein for the purpose of illustrating the invention, there is produced a unidirectional image current having amplitude variations corresponding to the tone values of successively scanned elemental areas of a field of view and having other amplitude variations produced as the result of periodically reducing the current to a value equal to or preferably less than that produced when scanning an area of black tone value. Such a reduction in amplitude may be introduced at the end of each scanning line of a field of view, as, for example, by periodically interrupting the scanning of the field of view and, therefore, the light activation of the light sensitive element employed in scanning. The electrical transmitting apparatus upon which this unidirectional image current is impressed suppresses the direct component which is representative of the average tone value of the field being scanned and which varies in amplitude as the average tone value of the field changes. The amplitude of the steady component of the unidirectional image current, which component is representative of the average tone value over a given period, varies in accordance with the amplitude of the impulses set up as the result of periodically interrupting the scanning. In the alternating image current, the amplitude of the impulses produced as the result of periodically interrupting the scanning, measured between the peaks of the impulses and zero, varies in accordance with the amplitude of the suppressed direct component and, therefore, in accordance with the average tone value of the elemental areas scanned between successive interruptions of the scanning. These "black" or "correcting" impulses are utilized at the transmitter or receiver for controlling apparatus for correcting for the suppression of the direct component of the unidirectional image current.

In accordance with a preferred embodiment of the invention, the alternating image current or electromotive force including the correcting impulses is impressed upon a device which responds only to the correcting impulses to control a source of current, and current from this source is utilized in correcting for the suppression of the direct component of the image current. The

average amplitude of the current from this source varies in accordance with the amplitude of the correcting impulses. The correcting device includes one or more gas-filled tubes, commonly known as thyatrons. These tubes have the characteristic of passing current in the discharge or plate circuit when the potential on the grid is sufficiently high, for a given voltage across the plate circuit and thereafter continuing to pass current in the plate circuit independently of subsequent changes in the grid potential until the plate voltage is reduced below the ionization potential. An alternating potential of a frequency which is low compared with the frequency of recurrence of the correcting impulses is applied to the grid and anode circuits of the gas-filled tube or tubes, the voltage applied to the grid being approximately 180 degrees out of phase with respect to the potential applied to the anode. The correcting impulses are superposed upon the voltage applied to the grid circuit.

The anode current of the gas-filled tube after being filtered to suppress the alternating components flows through an output resistor across which is connected a small condenser, the current through this output resistor being a slowly varying unidirectional current. The condenser which becomes charged to a voltage corresponding to the direct component representative of average image tone value is connected in the control circuit of a cathode ray image producing tube for biasing it, the television signal also being impressed upon the control circuit of the cathode ray tube.

In another embodiment of the invention, the anode current of the gas-filled tube flows through a biasing winding of each of two impulse coils of the type disclosed in United States Patent 1,880,412 to Burton, October 4, 1932. These impulse coils have cores which are constricted in cross-section in the portions where the secondary winding is located. This portion of the core thus saturates quickly and for this reason a sharp voltage impulse of short duration and high amplitude is produced in the secondary winding every time the magnetic field in the constricted portion of the core becomes saturated or unsaturated because of the flow of alternating current in the primary of the impulse transformer. These high amplitude voltage impulses are impressed upon the input circuit of one or more three-electrode mercury vapor rectifier tubes together with a voltage from a source of alternating current. Alternating voltage from this source

may also be applied to the anodes of the rectifier tubes, the voltages upon the grid and anode circuits being approximately 180 degrees out of phase with respect to each other. The output circuit of the rectifier tubes may be connected through a filter to the output circuit of the amplifier which controls the energization of the light producing device of the image producing apparatus.

A ballast resistor of a suitable material which changes its resistance in accordance with changes in potential thereacross, a material commonly known as thyrite, for example, may be included in the circuit in series with the light producing device, a gaseous discharge lamp, for example, in order to obtain a straight line relationship between the current flowing through the lamp and the thyrite element in series and the electromotive force across the lamp and the thyrite element. A small resistance element may also be included in series with the lamp and thyrite element to help straighten out the characteristic.

The invention will be more readily understood from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a diagrammatic view of a television system including apparatus controlled by a source of image current having only alternating components for producing a slowly varying unidirectional electromotive force for use in controlling the average tone value of the reproduced image;

Fig. 2 is a detail showing of a portion of the scanning apparatus of Fig. 1;

Figs. 3 and 4 are diagrammatic views of modifications of a portion of the television system of Fig. 1; and

Figs. 5 to 9, inclusive, are curves which will be used in connection with Figs. 1 to 4 to explain the operation of the invention.

Referring now to Fig. 1, there is shown by way of example, a television transmitter T and a television receiver R connected by a suitable line L. The transmitter comprises a source of light 20 of constant intensity associated with an optical system including a disc 21 provided with a row of apertures 22 arranged in a spiral line and adapted to be rotated by a motor 23, and a lens system, shown by way of example as a lens 24. Rotation of the disc 21 causes light from the source 20 to pass through the successive apertures 22 to thereby produce a moving beam of light which is focussed by the lens system 24 to illuminate elemental areas of the field of view 0 in succession. The disc 21 is rotated at a speed such that, for one complete revolution, elemental areas of parallel adjacent lines of the complete field of view 0 are successively illuminated within the period of persistence of vision. Light reflected from the successive elemental areas of the field of view 0 reaches a light sensitive electric device 25, which is thereby activated to produce an image current varying in accordance with the tone values of such elemental areas. In front of the disc 21 is a screen 26 of opaque material provided with an opening 27 which determines the size of the field 0. The opening 27 is so dimensioned that light passes through the apertures 22, one at a time, to the field of view 0.

For the purpose of the present invention, the scanning apparatus operates in such a manner that the scanning of the field of view is periodically interrupted for a brief interval one or more times during each complete scanning period. In

a preferred arrangement for effecting this result, the lateral distance between the apertures 22 of the disc 21 is made greater than the width of the opening 27 in the screen 26, by an amount equal to the width of one or a few elemental areas, as shown in Fig. 2.

The light sensitive device 25 supplied with energizing current from the direct current source 28, will be activated, under control of the above-described optical system, to produce a unidirectional image current. This unidirectional image current consists of a slowly varying direct component the amplitude of which corresponds to the average of the tone value or brightness of the field of view and alternating components of different frequencies, respectively, the amplitudes of which are determined by the tone values of the successively scanned elemental areas of the field of view. The frequencies of these alternating components may extend from a frequency of a million cycles or more to a low frequency which is approximately the frequency of scanning of the entire field of view, i. e., around 20 cycles per second. When no light is applied to the light sensitive device, due to the interruption of the scanning light beam, for example, the amplitude of the current flowing in the circuit of the light sensitive device 25 will be reduced to a low value, substantially zero, for example.

While the major portion of the image current frequency band may be satisfactorily transmitted over well-known communication circuits including telephone lines or coaxial cables, for example, it is well known that such transmission circuits include apparatus which suppresses or greatly attenuates the direct and very low frequency components of a television signal.

The electromotive force across a resistive element 352 in circuit with the light sensitive device 25 is applied to a circuit including a coupling condenser 355 and the input circuit of an amplifier thermionic tube 29 which includes a high resistance 353 and a biasing battery 354. The coupling condenser 355 suppresses the direct current component of the unidirectional image current. The tube 29 is connected through additional stages of amplification 30 and transformer 31, to a line L. There is thus impressed upon the line L an alternating image current including the correcting impulses which are of larger amplitude than other portions of the image current and of a polarity the same as that produced by scanning black elemental areas.

At the receiving station the line L is connected through transformer 133 to a suitable amplifier 132 which may comprise a plurality of stages and the output circuit of amplifier 132 is connected through the amplifier tubes 134 and 135 to the control electrode-cathode circuit of the cathode ray image producing device 136. The amplifier 132 is coupled to the amplifier stage 134 through the coupling condenser 137, grid resistor 138 and biasing battery 139. Battery 140 supplies anode current to vacuum tube 134 through resistor 141. Vacuum tube 134 is coupled to vacuum tube 135 through coupling condenser 142, grid resistor 143 and grid biasing battery 144. Battery 145 supplies anode current to vacuum tube 135 through resistor 146. Current source 147 supplies current to the thermionic cathodes of vacuum tubes 134 and 135. The cathode ray tube 136 is of the type disclosed in United States application Serial No. 48,299 of F. Gray, filed November 5, 1935. It comprises a

cathode 147, a control electrode 148, an anode 149, deflecting electrodes 151 and 152 and a screen of fluorescent or phosphorescent material 153. The anode-cathode circuit of vacuum tube 135 is connected through coupling condenser 154 of 2 microfarads to the control electrode 148 and through a condenser 155 of .02 microfarad to the cathode 147 of the cathode ray tube, a portion of resistance element 156 (15,000 ohms) being connected across condenser 155 through lead 157 and ground 158. A grid biasing battery 179 is connected in series with resistor 159 and a portion of resistor 156 to the control electrode-cathode circuit of the cathode ray tube 136. Sixty-cycle current from the source applied to motor 23 is also supplied to the harmonic generator 160 for producing 4,800-cycle current, which is supplied to the sweep control circuit 161, the output of which is connected to the line deflecting electrodes 151. A submultiple frequency generator 162 controlled by current from the harmonic generator 160 supplies 20-cycle current to the low frequency sweep circuit 163, the output of which is connected to the frame deflecting electrodes 152. The cathode ray beam produced in the tube 136 thus scans the screen 153 in synchronism with the scanning of the image field at the transmitting station and the beam is modulated in intensity under control of the alternating components of the television image current supplied to the cathode ray tube from the output of the amplifier tube 135, thus producing a television image of the view which is scanned at the transmitter.

The television image current transmitted to the receiver R does not include a slowly varying direct component representative of the average tone value of the field of view being scanned at the transmitting station T. However, the transmitted current has recurring impulses the amplitude of which measured between the peaks of the impulses and zero varies in accordance with the average tone value of the elemental areas scanned between the times that successive correcting impulses are generated at the transmitter. These impulses may be produced at the end of each scanning line by interrupting the scanning light beam or by any other suitable means such, for example, as a separate light sensitive device associated with the transmitting circuit and means for periodically directing light from the entire field upon the device.

For the purpose of controlling the production of images having an average tone value corresponding to that of the view being scanned, there is provided a correcting circuit including vacuum tube amplifier 164 and gas-filled electric discharge device 165. The input circuit of vacuum tube 164 is connected in parallel with the input circuit of vacuum tube 134 to the output of amplifier 132. Anode current is supplied to the vacuum tube 164 from battery 365 through resistor 366. The output of vacuum tube 164 is coupled to the control circuit of the gas-filled tube 165 through a circuit comprising condenser 166 of 0.2 microfarad, potentiometer 167 and grid-biasing battery 168, the condenser being of small capacity in order to transmit efficiently the fundamental frequency of the correcting impulses and to attenuate low frequency components of the transmitted television signal. A source of 110-volt, 60-cycle alternating current 169 is connected to the anode circuit of tube 165 through transformer 170 and to the control electrode-cathode circuit through transformer 171.

Across the secondary winding of transformer winding 171 are connected a condenser 172 of 2 microfarads and a resistor 173 of 2,500 ohms, one terminal of the resistor being connected to ground and a variable connection thereto being connected to the cathode of tube 165. A portion of resistor 172 is thus connected in the control electrode-cathode circuit of tube 165.

The phase relationship between the 60-cycle voltage E_p across the anode-cathode circuit of tube 165 and the voltage E_g across the control electrode-cathode circuit is shown in Fig. 5. No source of direct anode current is provided in the anode circuit of tube 165 (although such a source may be provided, if desired) and, therefore, the line marked E_b in Fig. 5 should be zero when these curves are applied to the circuit shown in Fig. 1. When the E_g curve becomes tangent to or intercepts the dash-line curve, gas-filled tube 165 breaks down and current flows in the anode circuit of the tube until the anode-cathode voltage is decreased below a certain value. If no correcting impulses were superposed upon the sine-wave voltage E_g , the tube would break down at point A during each cycle of the 60-cycle voltage. When the correcting impulses are received and impressed upon the control circuit of tube 165, along with the 60-cycle voltage, current will commence to flow sooner during each cycle of the 60-cycle source, for example, at point B and the current will flow for a longer period. The larger the amplitude of the correcting impulse, the earlier during each cycle of the 60-cycle source will tube 165 commence to pass space current and the larger will be the average amplitude of the anode current. The phase relationship of the 60-cycle voltage applied to the anode and control circuits, respectively, of tube 165 is preferably such that the tube "fires" or commences to pass space current during a portion of the cycle in which the anode-cathode voltage is decreasing from maximum to zero and in which the control electrode-cathode voltage is increasing, the maximum amplitude of the correcting impulses being insufficient to cause the tube to "fire" earlier in the cycle.

The output circuit of tube 165 is connected in series with the variable resistive element 178, secondary winding of transformer 170 and a portion of resistor 173 to the input of a filter 174 having a constant resistance R which equals 15,000 ohms at all the frequencies of the current impressed upon it from the 60-cycle source flowing through the anode circuit of the gas-filled tube. The filter 174 is a low-pass filter cutting off at about 42 cycle. It comprises the elements labeled L, 2L, C, 2C and R, the value of L being 40 henries, that of C being .175 microfarad and that of R being 15,000 ohms.

The output of filter 174 is connected to the filter comprising the series inductive element 175 of 40 henries and the shunt circuit comprising the inductive element 176 of 1 henry and the condenser 177 of 2 microfarads in series, the output resistor 156 of 15,000 ohms being connected across the shunt circuit comprising the elements 176 and 177. The circuit comprising elements 175, 176 and 177 is a low-pass filter having a cut-off frequency somewhat below 120 cycles.

The filter current flowing through the resistor 156 is a direct current the amplitude of which is varied in accordance with the average tone value of the field of view being scanned under control of the correcting impulses of the television signal. The condenser 155 is charged to a voltage

corresponding to the voltage drop across the portion of resistor 156 which is connected across the condenser. When the voltage drop across the resistor decreases below the voltage to which the condenser is charged, the condenser discharges through the resistor. The negative terminal of the charged condenser is connected to the cathode of the cathode ray tube 136. Therefore, as the voltage to which the condenser is charged increases, the bias of the control electrode of the cathode ray tube becomes more positive or less negative.

The correcting impulses of the signaling electromotive force impressed upon the control electrodes of vacuum tubes 134 and 164 are of negative polarity. The correcting impulses impressed upon the control electrode of tube 135, therefore, will be of positive polarity and the correcting impulses impressed upon the control electrode or grid of the cathode ray tube 136 will be of negative polarity and will be reproduced as black upon the cathode ray tube screen. The polarity of the correcting impulses of the television signal impressed upon the grid of the gas-filled tube 165 will be positive. These impulses cause current to flow in the anode circuit of the gas-filled tube and through resistor 156 to cause the condenser 155 to be charged.

The operation of the corrector circuit of Fig. 1 may be understood from the diagram of Fig. 9. The dotted line X shows the static characteristic of the gas-filled tube 165. Any combination of anode voltage E_p and grid voltage E_g lying on the line X or above this line, as viewed in this figure, will cause space current to flow in the anode circuit of tube 165. The ellipse Y shows the dynamic characteristic of the tube 165 when no signals are being received from the transmitter. In the diagram the plate voltage above zero is positive and the grid voltage to the left of zero is negative. As the sinusoidal 60-cycle voltage applied to the grid becomes less negative and the 60-cycle voltage applied to the anode becomes less positive (going along the ellipse in the direction indicated by the arrow), the ellipse will just touch the line X at point A and the tube will commence to pass space current at this point during each cycle of the 60-cycle wave. Current is thus passed to the filter 174 until the plate voltage falls to a certain value below which no current flows in the anode circuit. No current will flow during the remainder of the cycle until the point A is again reached. When signals are received from the transmitter T, impulses the amplitude of which measured between the peak amplitude and zero is representative of the average tone value of the image, are applied to the control electrode of tube 165 in addition to the 60-cycle voltage. If, for example, the image field is scanned 20 times per second along 240 lines and a correcting impulse is produced once per scanning line, there will be produced 4,800 correcting impulses per second or 80 impulses during one cycle of the 60-cycle current. When the average tone value of the field of view being scanned changes from dark to light, the amplitude of the correcting impulses increases and the tube 165 commences to pass space current earlier in the cycle, for example, at point B. Therefore, anode current will flow over a longer time during each cycle and the average anode current flowing through resistor 156 will be correspondingly increased. Thus, the bias on the cathode ray tube grid will be more positive due to the higher potential to which the condenser 155 is charged and

the image produced will have a lighter average tone value corresponding to the average tone value of the field of view being scanned. The voltage drop due to the flow of anode current through the resistive portion of the anode-cathode circuit of tube 165 reduces the voltage across the anode-cathode circuit by an amount which increases as the anode current increases. The effect of an increase in anode current in tube 165, therefore, is to increase the output voltage across the resistive element 156 (E_{output}) and to decrease the anode-cathode voltage (E_p). That is, the ellipse of Fig. 9 is displaced downward, the center of the ellipse being moved in a negative direction along a line parallel to the ordinate E_p . Thus, when the correcting impulses increase to a certain amplitude, the output voltage to which condenser 155 is charged increases correspondingly. However, the output voltage is increased only by a certain amount, depending upon the increase in amplitude of the correcting impulses, because an increase in the output voltage causes a decrease in the anode voltage and due to this decrease in anode voltage the correcting impulses will no longer be of sufficient amplitude to start the flow of space current at point B. As long as the amplitude of the correcting impulses remains constant, sufficient current will flow in the anode circuit of tube 165 to maintain the voltage across the condenser 155 at a constant value. When there is a decrease in amplitude of the correcting impulses, the condenser 155 will partially discharge through the portion of resistor 156 which is connected across the condenser.

Fig. 3 shows an arrangement which may be substituted for the portion of the apparatus shown to the right of lines X—X and Y—Y of Fig. 1. In this figure, incoming television image current after being transformed by the transformer 100 and amplified by amplifier 180 is applied to the input circuit of the thermionic tube 181 by means of a coupling condenser 182, the grid 183 of the tube 181 being biased by biasing battery 184 to which the negative terminal of the battery is connected through a resistor 185. The output circuit of the tube 181 is coupled by resistor 186 and condenser 187 to the input circuit of the amplifier tube 188 through resistor 189. The output circuit of the tube 188 contains the neon lamp 38, thyrite resistor 39, ballast resistor 79 and source of plate potential 40. The potential drop across the resistor 189 produced by the incoming correcting impulses, controls apparatus for varying the average current in the neon tube circuit in a manner which will now be described.

A transformer primary coil 190 is coupled to secondary coils 191 and 192, which primary coil 190 receives 60-cycle alternating current from the power source 193 through the variable capacitor 194. The secondary coil 191 is connected in the plate circuit of a gas-filled electron discharge device 199. Coil 192 is connected in circuit with a copper-oxide rectifier 195 and a filter circuit including condensers 196 and 197 and inductor 198, which filter circuit is connected across the resistor 189. Sixty-cycle current from the source 193 is also impressed upon the grid-cathode circuit of the gas-filled device 194 through the transformer 200, the 60-cycle electromotive force impressed upon the grid circuit being substantially 180 degrees out of phase with respect to that impressed upon the plate circuit. In the input circuit of the gas-filled electron discharge device 199 are connected in series an uncoupling

resistor 201 of high resistance to prevent any large current from flowing in grid-cathode circuit of tube 199, biasing battery 202, a tapped portion of the resistor 185 and battery 184.

The operation of the gas-filled device 199 will now be described. As transformer coil 190 is coupled to both secondary coils 191 and 192, with no incoming correcting impulses, the coil 191 has a light load and the rectifier 195 delivers maximum voltage to the filter represented by the numbers 196, 197 and 198 and current of relatively large amplitude flows through the resistor 189. This makes the cathode of the tube 188 positive with respect to its control electrode, thus causing a decrease in the average space current through neon lamp 38. When signals come in to the gas-filled discharge device 194 it passes more space current. As a result, increased current flows through the winding 190 and condenser 194, the voltage drop across the condenser increases and the voltage delivered by the coil 192 and the rectifier 195 is cut down. Due to the resulting decrease in current through resistor 189, the space current through tube 188 increases.

Fig. 4 shows a modified arrangement for producing a direct current component of a television image current corresponding to the average image tone value under control of a television signal having periodic impulses the amplitude of which varies in accordance with variations in average tone value of the image being scanned. The circuit may be conveniently separated into two parts. The function of the first part is to produce a direct current which is proportional to the peak amplitude of the "black" correcting signals. These signals are generated at the transmitting station by cutting off the light at the end of each scanning line as described above in connection with Fig. 1. The direct current output of the first circuit serves to control the output voltage of a high voltage rectifier which constitutes the second part of the circuit. In this circuit the television image signal after being transformed by the transformer 100 and amplified by the amplifier 210 is applied by means of the transformer 211 to the input circuit of an electron discharge device 212, the output circuit of which contains the primary of a transformer 213. The secondary of the transformer 213 is connected through a potentiometer resistor 214, the mid-point of which is connected through resistor 215 to the grid 216 of a gas-filled electron discharge device 217 and through resistance 218 to the grid 219 of an electron gas-filled discharge device 220. The device 212 is an isolating stage and serves to prevent "kicks" from gas-filled tubes 217 and 220 from getting into the signal tube 260. In some cases this tube 212 may be eliminated. Resistors 215 and 218 are isolating resistors and they prevent the tube 217 from firing tube 220 and vice versa. Sixty-cycle alternating current is applied to the plate circuits of the gas-filled tubes 217 and 220 by means of a transformer 221 having split secondaries 222 and 223. A resistor 224 limits the anode currents for the tubes 217 and 220 to a safe value, and condenser 225 and choke coil 226 smooth the impulses in the plate circuit before the current reaches the bias winding 227 and 228 of the impulse coils 229 and 230, respectively. By means of transformer 231, 60-cycle current from the source 232 is applied to the resistors 233 and 234 through the phase shifting condenser 235. The grid of each gas-filled tube 217 and 220 is thus

driven by 60-cycle voltage in addition to any signals from the tube 212.

The static characteristic of the tube 220 or 217 is shown in Fig. 6, the abscissa E_g being the voltage applied to the grid with respect to the cathode and the ordinate E_p being the voltage applied to the anode with respect to the cathode. Any combination of grid and plate voltage to the left of the line A will not cause current to pass, but any combination of grid and plate voltage which falls on, or to the right of, the line A will cause the tube to fire and it will continue to pass current until the plate voltage E_p is reduced below the ionization potential.

The periodic reduction in the voltage E_p below the ionization potential is produced by impressing 60-cycle alternating voltage E_p plus a direct current voltage E_a upon the plate circuit of the gas-filled tube. The time relations are shown in Fig. 5, in which the cycle variations of E_p and E_a are plotted against time. The dotted graph represents the "firing" line. This line represents the value of grid voltage required to discharge the tube, this value fluctuating with the cyclic variations of E_p . If at any given time the grid voltage is less negative than the voltage represented by the dotted line, the plate voltage being positive, the tube will pass current until E_p falls below the ionizing potential of the particular gas used in the tube. When no signals are incoming the grid voltage line first meets the "firing" line at point A. This is late in the cycle and but little current is passed. When signals are superposed on E_g (as shown, for example, in the left-hand half cycle in Fig. 5) the tube breaks down earlier. The breakdown point is represented by point B. The higher the signal peaks the earlier the breakdown will occur in the alternating current cycle and the greater the output current. The signals are so poled that the "black" correcting pulses cause discharges in the gas-filled tubes. The difference in voltage at the firing point between the curve representing the black signals superposed upon the grid voltage wave and the dotted curve must be less than at any point earlier in the alternating current cycle. If the adjustments are not made so that this is true, an impulse may fire the tube at the beginning of the cycle. Assuming the adjustments are correct, as the "black" peak becomes higher, firing occurs earlier in the cycle. The average output current of the gas-filled tube thus increases and the average plate potential decreases, due to the drop through the output circuit.

The rectifier part of the circuit will now be described. This rectifier supplies the voltage to the capillary or neon lamp 38. By controlling the rectifier terminal voltage, the average current through the lamp is changed. The biasing windings 227 and 228 of the impulse transformers 229 and 230 are connected in a circuit which goes from the negative terminal of battery 236 through the opposing resistors 233 and 234 to the cathodes of gas-filled tubes 217 and 220, through the discharge paths of these tubes and through secondary windings 222 and 223, resistor 224, choke winding 226, coils 227 and 228 and thence to the positive terminal of battery 236. Coils 237 and 238 are supplied with 60-cycle current from the generator 232 through variable resistor 239. Transformer 240 supplies voltage from generator 232 through the phase shifting condenser 241 to the resistors 242 and 243 portions of which are connected in the grid circuits of mercury vapor rectifier tubes 244 and 245, the

secondary coils 246 and 247 of the impulse transformers 229 and 230 also being connected in this circuit. A battery 248 supplies fixed bias for the grids of these two mercury vapor devices. Coils 227, 237 and 246 are thus the windings of an impulse transformer which fires tube 244, and coils 228, 238 and 247 are the coils of the impulse transformer 230 which fires tube 245. These impulse transformers have cores which are constricted in cross-section where the secondary windings 246 and 247 are located. This section of the core saturates sharply and for this reason the secondary only delivers voltage for a short part of the alternating current cycle. For a more complete description of the impulse transformer per se reference should be made to the United States Patent 1,880,412 to Burton, October 4, 1932.

Sixty-cycle alternating current is also applied to the output circuits of the mercury vapor tubes 244 and 245 by means of a transformer 249 having split secondaries 250 and 251. Transformers 252 and 253 may be used to supply heating current to the cathodes of the tubes 244 and 245. The outer terminals of secondary windings 250 and 251 are connected to the anodes of tubes 244 and 245. The mid-point of the secondaries of the transformers 252 and 253 and the common terminal of the secondary windings 250 and 251 are connected through a filter circuit comprising inductances 254 and 255 and condensers 256 and 257 to the load circuit which includes the neon lamp 38, thyrite resistor 39, and ballast resistor 79. Also connected in this load circuit is the output circuit of the electron discharge device 260, the input of which is fed by the secondary 261 of the transformer 211. The tube 260 is adapted to impress upon the lamp 38 the alternating current components of the received image current. The lamp 38 and the thyrite resistor 39 are connected to the lead going to the positive terminal of the rectifier so that the capacity of the rectifier and filter circuit to ground will not act as a shunt across the lamp 38 and the thyrite resistor 39 at the higher frequencies of the television signal. The output of the rectifiers 244 and 245 serves to insert direct current component into the current through the neon tube 38.

The time relation between the grid and plate voltage for one of the rectifier tubes is shown in Fig. 8. E_P is the plate voltage, E_G the grid voltage and the dotted line is the breakdown or "firing" curve. Although but one dotted line is shown, there are an infinite number of them and the temperature of the tube determines which relation exists at any one time. For instance when $E_G = -6$ volts, $E_P = 700$ volts for firing at 20° C., but if the bulb warms up to 35° C., E_P will fall to 540 volts for the same grid voltage. This means a change of 160 volts in the output voltage. By using a sharp impulse to fire the tube as, for example, those induced in the secondary windings 246 and 247 of the impulse transformers 229 and 230, the effect of temperature is made negligible because the sharp impulse pierces all the breakdown curves at once. It is for this reason the signal impulses are not used directly to fire the rectifier tubes, but are used to produce a direct current proportional to the direct current component at the transmitter and this is impressed upon impulse transformers instead. As the corrector circuit increases the bias current in the coils 227 and 228 of the impulse transformers 229 and 230, pulse A through the secondary windings 246 and 247 occurs earlier in the

cycle and this causes the tube to fire earlier in the alternating current cycle which in turn causes the output voltage to rise. Pulse B has no effect. When the corrector circuit decreases the bias current in the coils 227 and 228, the opposite effect is produced.

Fig. 7 shows the current-time relations of the impulse coil exciting current I_E , the bias current I_b , and the secondary impulses I_s produced in the coils 246 and 247. The nicks D and E in the I_b wave are caused by an increase of impedance in the secondary coils 246 and 247, when the cores unsaturate. A graph similar to Figs. 7 and 8 for the other rectifier tube would merely show E_P shifted 180 degrees together with its E_G , I_E and I_s .

In Figs. 3 and 4 the neon lamp 38 and scanning disc 54 (like the scanning disc 21) are employed for producing the television images instead of a cathode ray tube as shown in Fig. 1. Any suitable system for maintaining the discs 21 and 54 in synchronism may be used. In one such system, which is herein described by way of example, alternating current of substantially constant frequency is produced by a vacuum tube oscillator 57 which is located at the transmitting station for controlling the operation of the motor speed control circuit 58 at that station and current from this source is also transmitted over line 59 to the receiving station R for controlling the operation of speed control means 60 at that station. The motors 23 and 58 at both stations are thus maintained in synchronism. Suitable amplifiers 61 and 62 at the transmitting and receiving stations, respectively, are used to amplify the generated current. For a more complete description of a synchronizing system herein briefly described, reference may be made to United States Patent 1,999,376 of H. M. Stoller, issued April 30, 1935.

An observer E may view the image produced by the cooperation of the receiver scanning means and the light source 38 through an opening 63 in an opaque screen 64. Glow lamp 38 may be of any desired type adapted to supply light which varies with the variations in amplitude of the applied image current. A suitable lamp for this purpose is disclosed in United States Patent 1,918,309 of H. W. Weinhart, issued July 8, 1933. As therein described, the glow lamp may include a charge comprising a rare gas and a small percentage of active gas, as disclosed in United States Patent 1,871,266 of F. Gray, issued August 9, 1932.

It is apparent that the action of the correcting circuits disclosed herein is such that the periodic impulses as they appear in the control electrode-cathode circuit of cathode ray tube 136 (Fig. 1) or in the circuit of lamp 38 (Figs. 3 and 4) are of constant amplitude. For example, if in Fig. 1 the correcting impulses of negative polarity supplied to the cathode ray tube from the amplifier 135 increase in amplitude, the voltage across condenser 155 also increases sufficiently to maintain the amplitude of the impulses impressed upon the control electrode-cathode circuit at constant amplitude.

What is claimed is:

1. In a system including a source of television image electromotive force which is devoid of the direct component representative of average tone value of a field of view and having recurring impulses of predominant amplitude, the amplitude of which varies in accordance with the variations of said direct component, the combination of an

electric discharge device having a control circuit under control of said television electromotive force, and means for supplying said indirect component comprising a gas-filled electric discharge tube having an output circuit and a control circuit, a source of alternating electromotive force, means for supplying from said source to said output and said control circuits, respectively, of said gas-filled tube, alternating electromotive forces which are out of phase with respect to each other, a biasing circuit, including a filter for suppressing alternating components of the current supplied thereto, electrically associated with the output circuit of said gas-filled tube, means for impressing said television electromotive force upon the control circuit of said gas-filled tube to control the amplitude of the unidirectional current flowing in said biasing circuit in accordance with the amplitude of the recurring impulses of the television image electromotive force, and means for connecting said biasing circuit to the control circuit of said electric discharge device to control the biasing thereof.

2. In combination, a gas-filled electric discharge device having a cathode, an anode, a control electrode, an anode-cathode circuit and a control electrode-cathode circuit, a source of alternating current in said anode-cathode circuit, a second source of alternating current of the same frequency as that of the first source but out of phase with respect thereto in said control electrode-cathode circuit, and means for impressing periodically recurring voltage impulses of higher frequency and of varying amplitude upon said control electrode-cathode circuit for controlling the average amplitude of the current flowing in said anode-cathode circuit in accordance with the amplitude of said voltage impulses, said impulses causing anode current to flow in said discharge device during a portion of each cycle of said alternating current commencing at a time controlled by the amplitude of the impulses but always during the portion of the cycle in which the anode-cathode voltage is decreasing and the control electrode-cathode voltage is increasing.

3. In combination, a gas-filled electric discharge device having a cathode, an anode, a control electrode, an anode-cathode circuit and a control electrode-cathode circuit, a portion of said anode-cathode circuit being in said control electrode-cathode circuit, a source of alternating current in said anode-cathode circuit, a second source of alternating current of the same frequency as that of the first source but out of phase with respect thereto being in the common portion of said circuits, means for impressing periodically recurring voltage impulses of varying amplitude and of brief duration with respect to the intervals between successive impulses upon said control electrode-cathode circuit for con-

trolling the average amplitude of the current flowing in said anode-cathode circuit in accordance with the amplitude of said voltage impulses, the anode potential of said device decreasing while the control electrode potential is increasing and said impulses further increasing the potential of said control electrode to cause anode current to flow during a portion of each cycle of said alternating current and a constant resistance filter connected to said anode-cathode circuit for suppressing, in part at least, alternating components of the anode-cathode current.

4. In combination, a gas-filled electrical discharge device having a cathode, an anode, a control electrode, an anode-cathode circuit and a control electrode-cathode circuit, a portion of said anode-cathode circuit being in said control electrode-cathode circuit, a source of alternating current in said anode-cathode circuit, a second source of alternating current of the same frequency as that of the first source but out of phase with respect thereto being in the common portion of said circuits, means for impressing periodically recurring voltage impulses upon said control electrode-cathode circuit for controlling the average amplitude of the current flowing in said anode-cathode circuit in accordance with the amplitude of said voltage impulses, a constant resistance filter connected to said anode-cathode circuit for suppressing, in part at least, alternating components of the anode-cathode current, a cathode ray image producing device having a control circuit, a terminating resistor for said filter, a condenser connected to said terminating resistor, said condenser being charged to a potential corresponding to the slowly varying unidirectional current flowing through said terminating resistor, and means for connecting said condenser to said control circuit for supplying a biasing potential thereto.

5. In a television system, a source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of average tone value of a field of view and having periodic impulses the amplitude of which is representative of the average tone value of the field of view, an electric discharge device having an input and an output circuit, a source of alternating electromotive force having a frequency lower than the frequency of recurrence of said periodic impulses, means for impressing alternating electromotive force from said source upon said input and said output circuits and means for impressing an electromotive force from said source of television electromotive force upon said input circuit to produce in said output circuit an electromotive force corresponding to said slowly changing unidirectional component representative of average tone value.

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