

March 3, 1942.

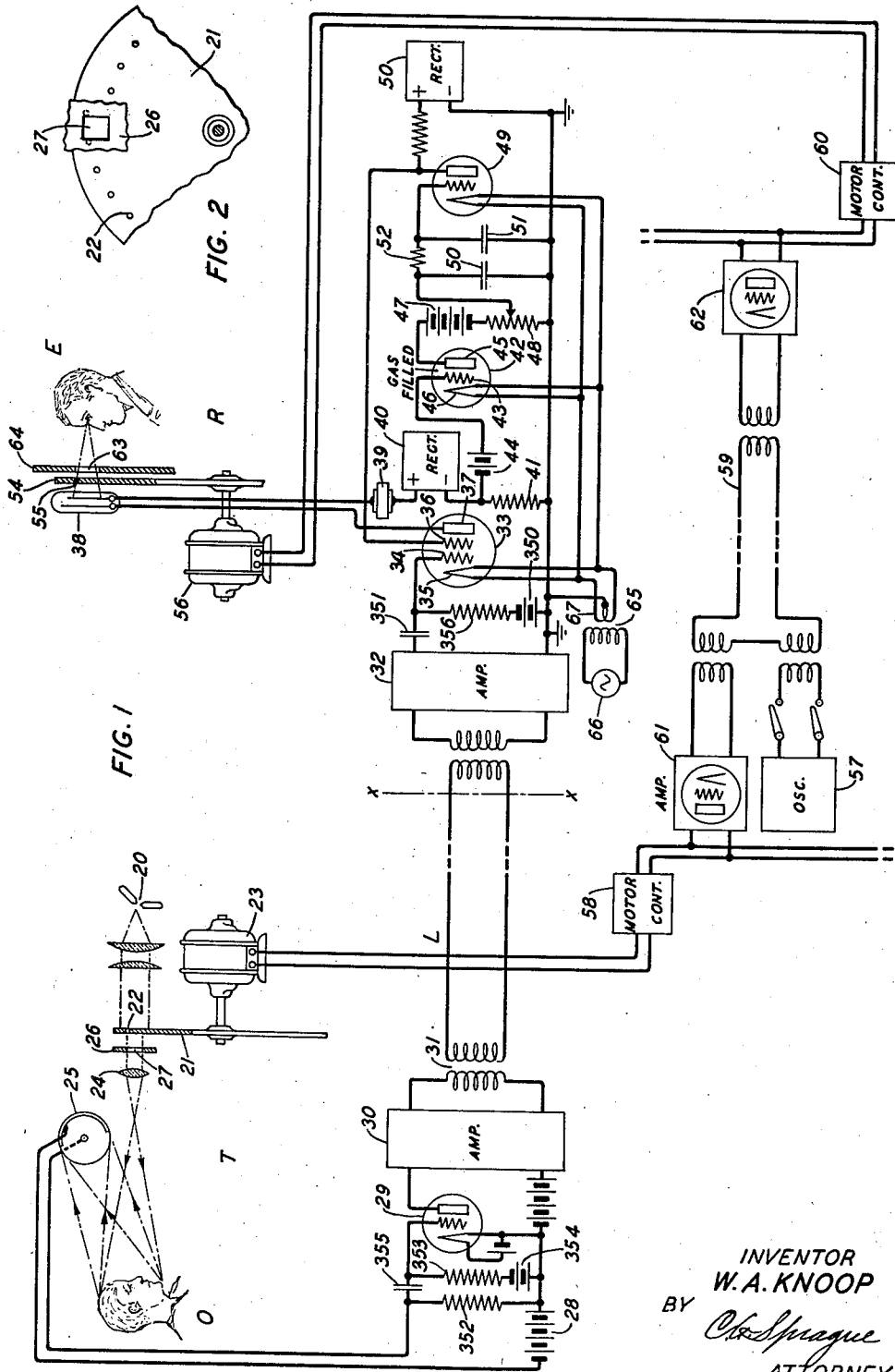
W. A. KNOOP

2,274,709

ELECTRO-OPTICAL IMAGE PRODUCTION

Filed Sept. 2, 1936.

5 Sheets-Sheet 1



March 3, 1942.

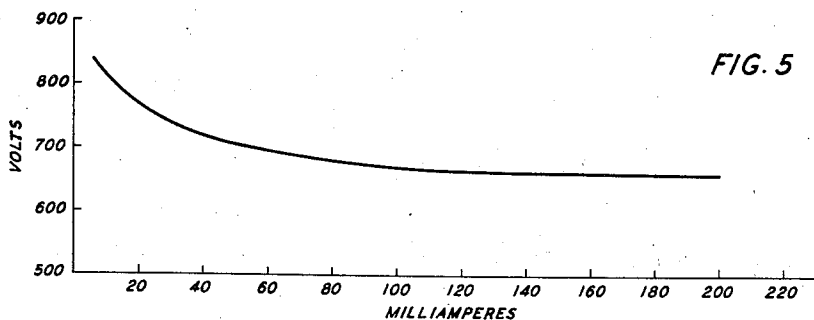
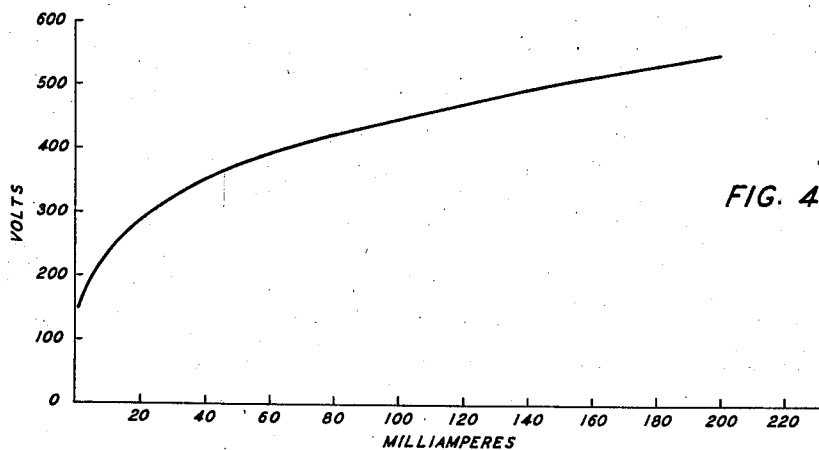
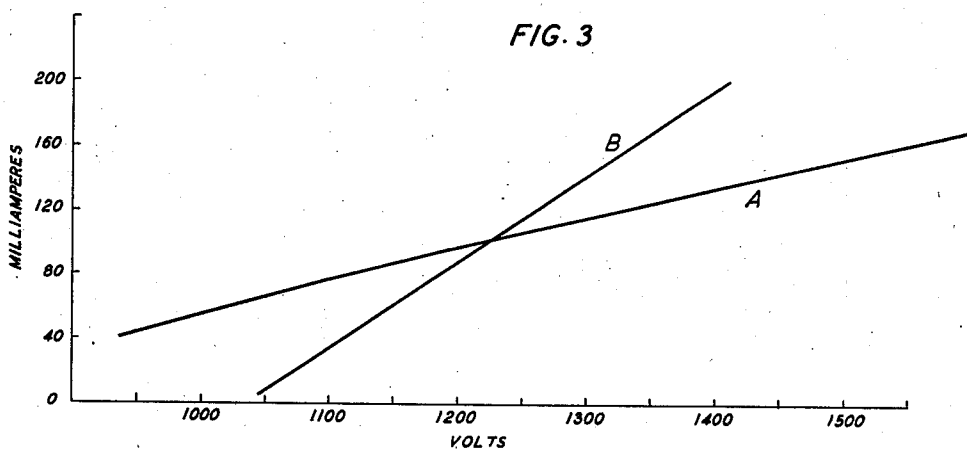
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ELECTRO-OPTICAL IMAGE PRODUCTION

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5 Sheets-Sheet 2



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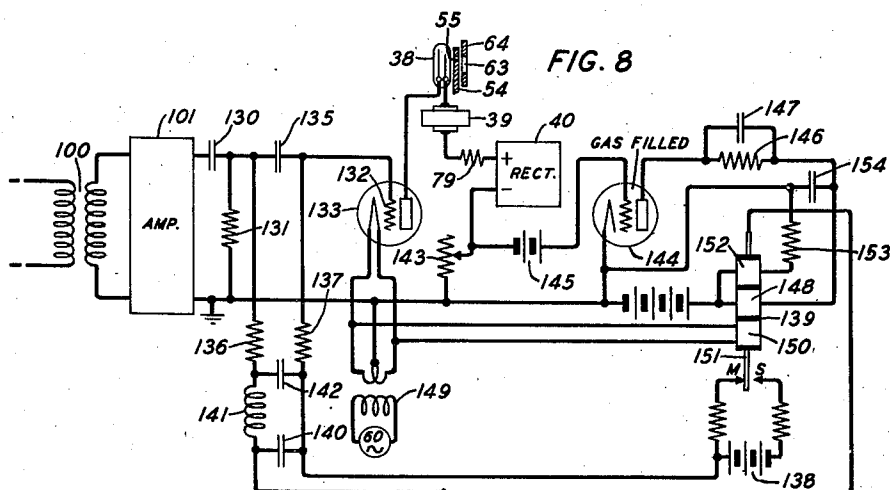
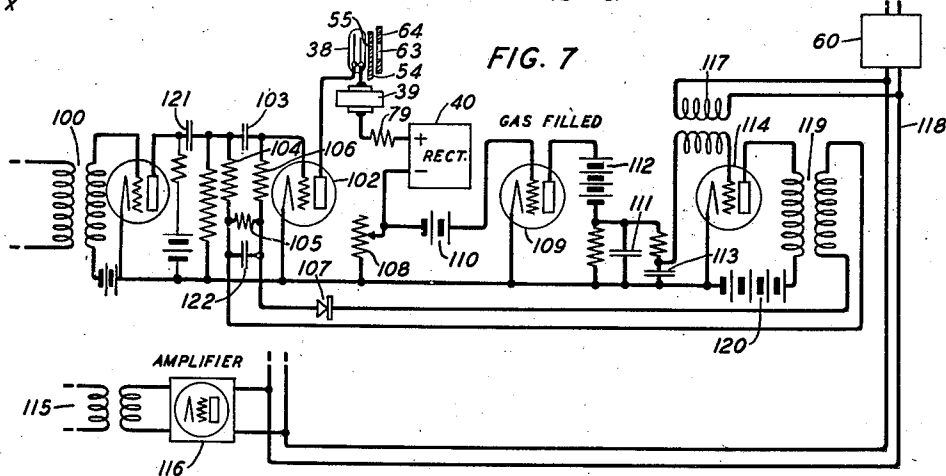
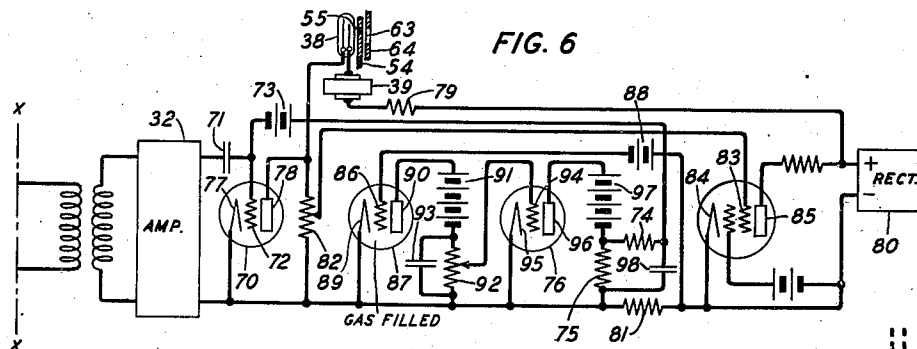
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ELECTRO-OPTICAL IMAGE PRODUCTION

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5 Sheets-Sheet 3



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ELECTRO-OPTICAL IMAGE PRODUCTION

Filed Sept. 2, 1936

5 Sheets-Sheet 4

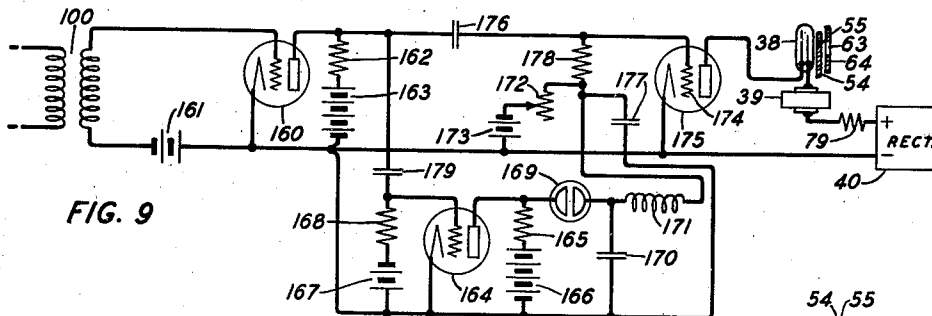


FIG. 9

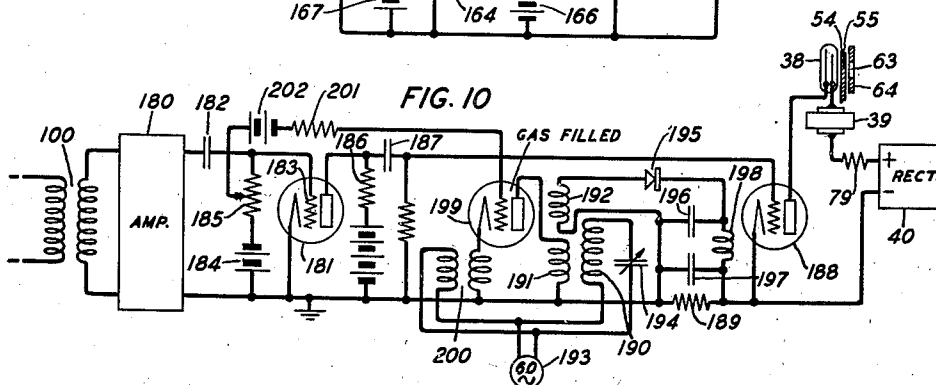


FIG. 10

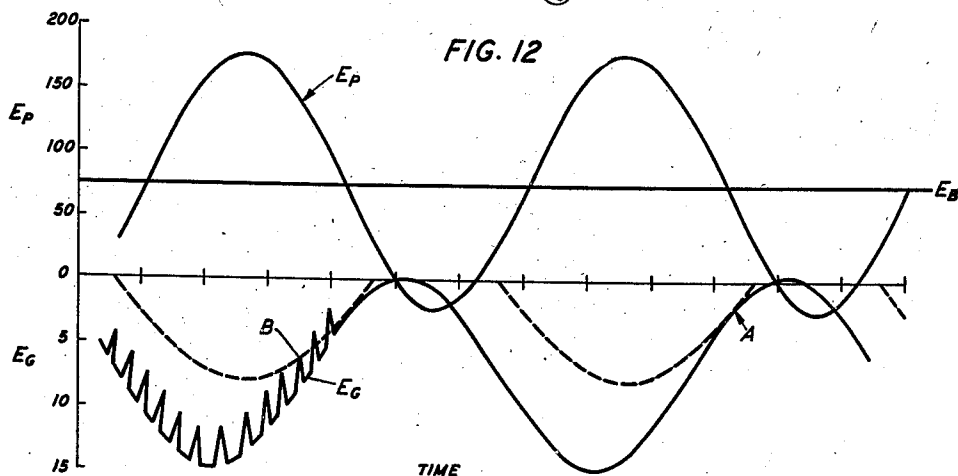


FIG. 12

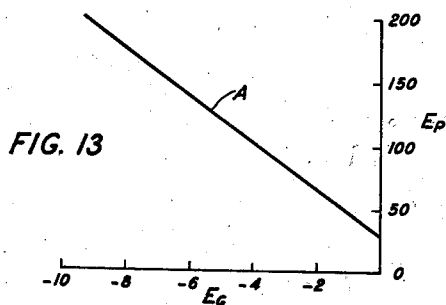


FIG. 13

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5 Sheets-Sheet 5

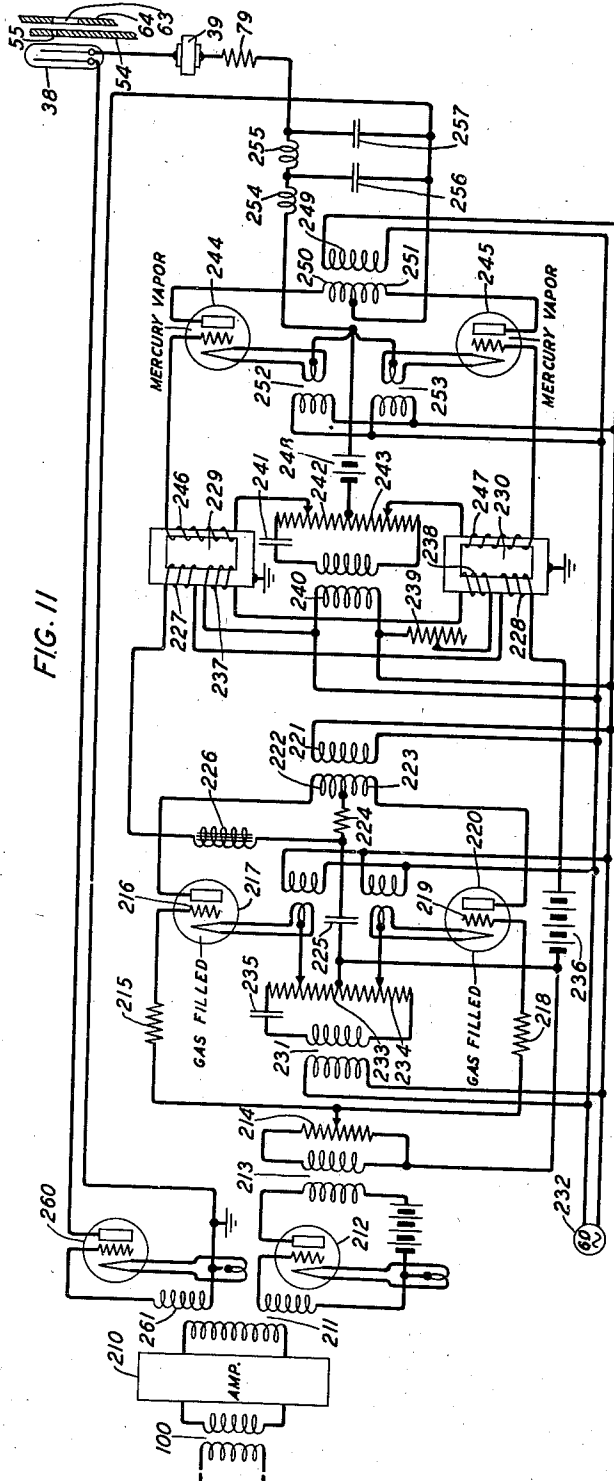


FIG. 11

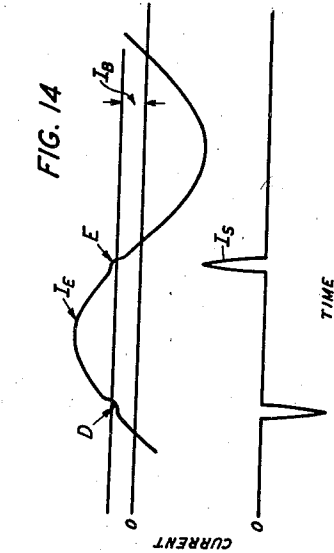


FIG. 14

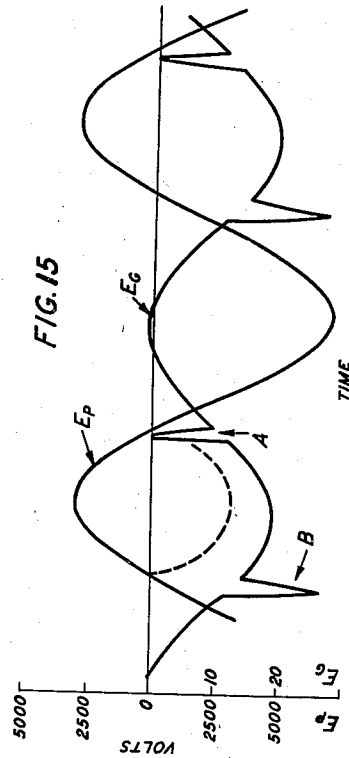


FIG. 15

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UNITED STATES PATENT OFFICE

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ELECTRO-OPTICAL IMAGE PRODUCTION

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Application September 2, 1936, Serial No. 99,023

11 Claims. (Cl. 178—7.3)

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

An object of this invention is to improve the quality of television images by increasing the accuracy with which the light tone values of the field of view are reproduced in the images thereof.

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 aver-

age 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 thyratrons. 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 each gas-filled tube, the voltage applied to the grid approximately 180 degrees out of phase with respect to the potential applied to the anode. A direct potential is also applied to the anode and the correcting impulses are superposed upon the voltage applied to the grid circuit.

The anode current of the gas-filled tube flows through a biasing winding of each of two impulse coils of the type disclosed in U. S. 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 substantially 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.

Other arrangements for correcting for the suppression of the direct and low frequency components of a television image current which components are representative of the average tone values of the field of view at the transmitting station may be used and several of these arrangements are described in greater detail hereinafter.

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

Fig. 1 is a diagrammatic view of a television system including apparatus for correcting for the suppression of the direct components of an image current, in accordance with the present invention;

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

Figs. 3 to 5, inclusive, are curves showing the current-voltage characteristics of certain circuit elements of the television image producing apparatus in accordance with the invention;

Figs. 6 to 11, inclusive, are diagrammatic views of modifications of a portion of the television system of Fig. 1; and

Figs. 12 to 15, inclusive, are curves which will be used in connection with Fig. 11 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 focused 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 a transformer to a suitable amplifying device 32 which may comprise a plurality of stages, and the output circuit of the amplifier 32 is connected through a condenser 351 to the input electrodes of a four-electrode electron discharge device 33 having control electrodes 34 and 36, a cathode 35 and an anode 37. Negative biasing potential is applied to the control grid 34 of the device 33 by means of biasing battery 350. A high resistor 356 is also included in the input circuit of the device 33.

Between the cathode 35 and the second control electrode 36 of the four-element discharge device 33 is impressed a potential for compensating for the suppression of the direct and low frequency components at the transmitting station which potential is generated by a circuit which will be described more fully below.

The output circuit of the device 33 comprises the discharge path between the cathode 35 and the anode 37 of the device 33, an image producing device such as a neon glow lamp 38, a potential dependent resistor 39, the purpose of which will be disclosed more fully below, a source of direct current plate potential 40, which may be a

rectifier supplied with alternating current and an output resistor 41. The resistor 39 may be made of a material known as "thyrite," for example.

Shunted across the resistor 41 is the input circuit of a gas-filled electron discharge device 42 having a control grid 43, an anode 45 and a cathode 46. The grid 43 of the device 42 is connected to the positive terminal of a battery 44 and one terminal of the resistive element 41 is connected to the negative terminal of this battery. The electromotive force from this battery opposes the potential drop across the resistor 41 as this latter potential is so large that without the opposing battery 44, a very large plate potential for the tube 42 would be required. If the resistance of the element 41 were made lower in order to eliminate the opposing battery 44, the sensitivity would be also reduced. When the current through the resistive element 41 falls to a low value due to a correcting impulse which is produced at the end of each scanning line, the potential drop across the resistive element 41 and, therefore, the negative bias on the grid 43 of the gas-filled discharge device 42, is lowered to such an extent that a discharge is initiated in the plate circuit of the device 42.

The plate circuit of the gas-filled device 42 comprises the discharge space between anode 45 and cathode 46, battery 47 and a resistive element 48 which limits the output current. Shunted across a portion of the resistive element 48 is the input circuit of an amplifying thermionic device 49 and also condensers 50 and 51. A resistive element 52 is connected in the lead going from resistive element 48 to the control electrode of thermionic tube 49 between the connections to the condensers 50 and 51. The condenser 50 which may be, for example, of a capacity of the order of $\frac{1}{10}$ microfarad, charges quickly when current flows through the anode circuit of the device 42 including the resistance 48. The voltage to which the condenser 50 becomes charged, opposes the voltage of the battery 47 and reduces the potential across the cathode-anode space of the gas-filled device 42 to such an extent that the discharge in the device 42 is extinguished. The condenser 51 which may be of the order of 2 microfarads, and the resistor 52 which is of the order of 12,000 ohms are used to smooth out the voltage wave applied to the grid of the electron discharge device 49 which amplifies the filtered output of the tube 42 and applies it as a potential to the screen grid 36 of the four-element tube 33 to thus control the current between the cathode 35 and the anode 37 of this device in accordance with the average value of the direct current component of the image current over a period between successive interruptions of the scanning at the transmitting station. A direct current source such as the rectifying device 50 supplies plate potential for the amplifier 49.

The portion of the divided resistive element 48 in the charging circuit for condenser 50 is sufficiently low in resistance to permit the condenser to charge rapidly but prevents an excessive charging current such as would damage the gas-filled tube. The rapid charging of condenser 50 causes the portion of the correcting circuit which is controlled by the voltage across the condenser 50 to respond rapidly to the correcting impulses. The portion of resistive element 48 in the discharge circuit for condenser 50 is of relatively high resistance such that the

condenser will not discharge appreciably during the interval occurring between successive correcting impulses produced at the transmitter.

Heating current for the filament of the tubes 33, 42 and 49 is supplied by means of a transformer 65 connected to a suitable alternating current source 66. The secondary winding 67 of this transformer has its mid-tap connected to ground.

The amplified alternating image current and the direct current component added by the control of the bias of the screen grid 36 are applied to the glow lamp 38. This lamp is biased by the direct current source 40 which is so adjusted that a predetermined minimum current flows through the lamp in the absence of any incoming signal. This is about the same as the minimum current corresponding to black. The smaller this can be made, the larger will be the ratio of maximum to minimum light produced by the lamp during operation of the television system.

Associated with the lamp 38 is a scanning disc 54 provided with a row of apertures 55 arranged in a spiral line and driven by a motor 56 in synchronism and in phase with the scanning disc 21 at the transmitter. 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 56 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 has been the practice heretofore in connection with television receiving circuits to employ a constant resistive element of sufficient size in series with a neon lamp in the plate circuit of a vacuum tube. An objection to this arrangement is that the impedance of the lamp and resistive element (that is, the ratio of change in the electromotive force to change of current) is relatively high. Such an arrangement, therefore, requires the use of a relatively large plate battery and a signal of relatively large amplitude on the grid of the vacuum tube. Also, when using a constant resistive element of the order of 5,000 ohms, the lamp under consideration would be unstable when the current through it

is less than 10 milliamperes, since the negative impedance of the lamp is of the order of 5,000 ohms at 10 milliamperes. If it is desired to operate under 10 milliamperes, a larger constant resistive element and therefore a larger plate battery and a larger signal voltage would have to be used.

Both in the case of thyrite and in the case of a neon lamp, the impedance decreases with increasing current. Moreover, as the current through the neon lamp increases, the voltage across the lamp decreases. In the case of the thyrite element, the voltage across the element increases with increasing current. These characteristics of neon lamps and thyrite resistive elements are well known in the art. When a thyrite resistive element 39, or any potential dependent resistive element having similar properties to thyrite, is placed in a series circuit with the neon lamp, 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 thyrite is approximated. A small resistive element may also be included in series with the lamp and thyrite to help straighten out the characteristic. Curve A of Fig. 3 shows the relationship between the current flowing through a neon lamp and a series resistor of about 5,500 ohms and the sum of the voltage drops across the lamp and resistor while curve B shows the relationship between the current flowing through a neon lamp, one quarter of a six inch thyrite unit and a 1,000 ohm resistive element and the sum of the voltage drops across the neon lamp, thyrite and the resistor. Fig. 5 shows the current-voltage characteristic of a neon lamp alone while Fig. 4 shows the current-voltage characteristic of a one-quarter thyrite unit. These thyrite units are made of commercial thyrite lightning arrestor discs cut into quarter sectors. This value is large enough to prevent heating which would cause the thyrite to change its property somewhat. The flat faces of these discs are coated with metal and conduction is from one face to the other. For further information on thyrite and its properties, reference may be made to Patent 1,822,742, issued September 8, 1931, to Karl B. McEachron.

It will be noted that the curve of the neon lamp alone shown in Fig. 5 has a slope which is strongly negative at the low values of current and the curve is nearly flat or slightly rising at high currents. By inserting an element of high resistance in series with the neon lamp a fairly straight line relationship between the current flowing in the circuit and the sum of the voltage drops across the neon tube and resistive element will result. However, due to the large dissipation of energy in the resistive element, the amplitudes of both the steady and the varying components of the voltage applied to the lamp will be greatly reduced, thus necessitating the use of a source of direct current 40 having a relatively high voltage and a signaling potential of increased amplitude applied to the grid 34 of tube 33. It will be apparent from a comparison of curves A and B of Fig. 3 that a marked improvement results from the use of a thyrite element and an element of relatively low resistance in series with the neon lamp instead of a relatively large resistive element. The sum of the impedances of the neon lamp, thyrite and low resistance element (curve B) is 1850 ohms while the sum of the impedances of the lamp and

high resistive element (curve A) is 4900 ohms. The following desirable results are realized due to the use of thyrite in the neon lamp circuit: (1) A current source of relatively low voltage may be used in the neon lamp circuit, and (2) a relatively large change in current takes place in the neon lamp circuit in response to a relatively small change in impedance across the output circuit of the vacuum tube in which the neon lamp is connected.

Fig. 6 shows a circuit which may be substituted for the portion of the circuit shown to the right of the line X—X of Fig. 1. In this circuit, a change in current through a resistive element in the neon lamp circuit is utilized to control a gas-filled tube which supplies correcting voltage to the input of the amplifier supplying signal current to the neon lamp. The alternating current components of the image current are amplified by the amplifier 32 and applied to the input circuit of the electron discharge device 70 through a coupling condenser 71. The circuit between the grid 72 and the cathode 77 of the device 70 includes a biasing battery 73, an input resistor 74 and also a resistor 75 which is included in the output circuit of a second electron discharge device 76 to supply correcting voltage to the tube 70. The anode circuit of the device 70 includes the discharge path between the cathode 77 and the anode 78 of tube 70, a neon lamp 38, a thyrite resistive element 39, a series resistive element 79 of about 90,000 ohms, a source of plate potential 80 and a series resistive element 81 of the order of 3,000 ohms. Shunted across the cathode-anode discharge path of the tube 70 is a resistive element 82 of about 400,000 ohms, the voltage drop across a portion of which is applied between the screen grid 83 and the cathode 84 of a screen grid thermionic device 85, the resistor 81 being also included in this grid-cathode circuit of device 85. The tube 85 is used to improve the regulation of the rectifying device 80.

One terminal of the resistive element 81 is connected to the cathode 89 of the gas-filled discharge device 87 and the other terminal is connected to the positive terminal of the biasing battery 88, the negative terminal of the battery being connected to the grid 86 of the device 87. The discharge or anode circuit of the tube 87 comprises the discharge path between the cathode 89 and the anode 90, a source of plate potential 91 and a resistive element 92 which is shunted by a condenser 93. The potential drop across a portion of the resistive element 92 is impressed upon an electron discharge device 76, the circuit connected to the grid 94 and the cathode 95, the output circuit of which comprises the discharge path between the cathode 95 and the anode 96, a source of plate potential 97 and resistive element 75. As previously described, the voltage drop across the resistive element 75 is applied to the grid-cathode circuit of the device 70 through the resistive element 74. Condenser 98 and resistive element 74 form a resistance-capacity filter to smooth the correcting impulses applied to the grid-cathode circuit of tube 70.

The operation of the device shown in Fig. 6 is as follows: When the correcting impulse is applied to the input circuit of the tube 70, the current through the lamp 38 decreases. As a result, the voltage drop across the resistive element 81, which is connected in series with the lamp 38, also decreases, thus lowering the bias of the grid 86 of the gas-filled discharge device

87 and thus initiating a discharge through the anode-cathode circuit of this device. The potential difference produced by the flow of current through the resistive element 92 in the output circuit of the gas-filled discharge device 87 is amplified by the tube 76 and the voltage drop across the resistive element 75 in the output circuit of the device 76 is applied to the grid circuit of the device 70. Tube 76 also functions as a phase reversing device so that, when the potential difference across the resistor 81 falls below a certain value, the potential of grid 86 becomes less negative with respect to the cathode 89, the current in the anode circuit of tube 87 increases, the grid of tube 76 becomes more negative with respect to its cathode, the current in the anode circuit of tube 76 decreases, the potential of the grid of tube 70 becomes less negative with respect to its cathode and the current flowing in the anode circuit of tube 70 and through the lamp 38 increases. The gas-filled tube alternately breaks down and restores due to the action of the condenser 93 which becomes charged to a voltage opposing the voltage of the anode battery 91 to such an extent that the gas in tube 87 becomes deionized. This occurs about 800 to 2000 times per second. Resistance 92 is high enough so that when the space current passes through it, the resistance drop subtracted from the battery voltage is less than the ionizing potential of the gas. Under these circumstances short rushes of current pass through the tube when the grid potential falls below a certain value. When the gas-filled device 87 passes more space current, a higher negative potential is applied to the grid 94 of the device 76 and this decreases the space current through its output resistor 75. This decreases the bias applied to the device 70 and the average current through lamp 38 increases.

When no signals are being received from the transmitting station, the current flowing through the lamp 38 and resistive element 81 is adjusted to a low value which is somewhat above the value at which the lamp 38 is extinguished. The light produced by the lamp when this value of current flows through it represents black or minimum tone value in the image to be produced. Suppose now that image current is being received and that the average tone value of the field of view being scanned is increasing, i. e., becoming brighter. Then the current through the lamp and the resistive element 81 will fall below the value representing black tone value at the end of each scanning line due to the correcting impulses produced as the result of interrupting the scanning at the transmitting station. This reduction in the current through the resistive element 81 will cause a current impulse to flow in the anode circuit of the gas-filled tube 70 once per scanning line and the average current flowing in the anode circuit of tube 76 will decrease. As a result, the average potential drop across the resistor 75 and the average voltage to which condenser 98 is charged will decrease. The negatively charged plate of condenser 98 being connected to the grid of tube 70 through the biasing battery 73, the average potential applied to the grid of tube 70 will become less negative and the current flowing in its anode circuit through the lamp 38 will increase. If now the average tone value of the field of view at the transmitter is becoming darker, the amplitude of the correcting impulses flowing through the resistive element 81 will be too low to cause the gas-filled tube 87

to break down. Then increased current will flow through the resistor 75 and the condenser 98 will be charged to a relatively high value, thus resulting in a reduction in the current flowing through the circuit of the lamp 38. Even when the average tone value of the field of view at the transmitter remains constant, the gas-filled tube 87 will break down periodically and the voltage across condenser 98 will alternately increase and decrease within narrow limits. When the discharge current in gas-filled tube 87 ceases, the voltage across condenser 98 will increase, and the average current through resistive element 81 will decrease until the correcting impulses flowing through the resistor 81 will cause one or more impulses of discharge current to flow in tube 87. The average current flowing through resistor 81 will increase, as a result, until the correcting impulses are no longer effective to start a discharge in tube 87.

The screen grid tube 85 is utilized to improve the regulation of the circuit. When the average current through the signal tube 70 and the neon lamp 38 goes up due to the action of the corrector circuit, the current through the resistor 82 decreases. This reduces the voltage between the cathode and the screen-grid 83 of the tube 85 and lightens the load on the rectifier 80.

Fig. 7 shows another circuit for correcting the suppression of the direct component of the image current. In this figure the image signals are applied through the transformer 100 to the input circuit of an amplifier thermionic tube 101. The voltage drop produced in the output of this tube is applied to the input of a signal thermionic tube 102 through condenser 103 across which direct component correcting voltages are applied. These voltages control the average current through the signal tube 102 and the neon lamp 38 which is connected in its output circuit. The condenser 103 serves as a by-pass around the resistances 104, 105 and 106. The condenser 103 is of the order of 0.01 microfarad. Its capacity is small compared to that of the interstage coupling condenser 121 but large compared to the input capacity of the tube 102. The condenser 121 blocks the plate potential of the tube 101 from the grid of tube 102. Resistances 104 and 106 are of the order of one-half megohm each and they are part of a resistance-capacity filter. The resistance 105 discharges the condenser 122 when the rectifier 107 stops supplying current. The condenser 122 stores the pulses from the rectifier 107. The resistance-capacity filter 103—104—106 should be symmetrical to prevent any stray capacity from shunting off the high frequency components of the signal.

When the space current through the neon tube 38 falls below the minimum value representing black tone value, the voltage drop across the resistor 108 connected in series circuit with the neon tube, falls to such a value that space current is permitted to flow through a gas-filled tube 109, biasing battery 110 being also connected in the grid circuit of the gas-filled device 109. When the flow of space current in the gas-filled three-electrode device 109 has been initiated, the current will continue to flow until the plate voltage falls below the ionizing potential. The action of the condenser 111 in storing up a charge the voltage of which opposes the voltage of current source 112, causes the gas in the gas-filled discharge device to deionize in a manner similar to the gas-filled discharge device in Fig. 6. Also

connected in shunt circuit with a portion of the output circuit of the gas-filled discharge device 109 is a condenser 113 which is connected in the input circuit of an electron discharge device 114. Also applied to the input circuit of the discharge device 114 is an alternating potential generated by a source 115 and amplified by the device 116 and applied by means of transformer 117 to the grid circuit of tube 114. If desired, current of the same frequency may be supplied to the input circuit of tube 114 as is used for synchronizing. In this case the motor control device 60 is connected in the line 118 which connects the amplifier 116 to the transformer 117. The output circuit of the device 114 includes the primary of the transformer 119 and a plate voltage battery 120. The current in the secondary of the transformer 119 is rectified by the rectifying device 107, stored by the condenser 122 and smoothed and filtered by the resistors 104 and 106 and condenser 103. The voltage to which the condenser 103 becomes charged biases the grid of tube 102.

The operation of the device in Fig. 7 is as follows:

Assume no signals. The lamp is passing its predetermined minimum of current. The gas-filled device 109 is breaking down and passing current at relatively long intervals, as for example, 200 per second. The grid voltage on the tube 114 is low and the alternating current output is high. The output of the rectifier 107 is therefore at a maximum value and the grid of the tube 102 is very negative, the average output thus being at a minimum. Now, if signals are applied to the grid of the tube 102, the grid becomes further negatively biased by the black pulses and the gas-filled tube 109 is fired much oftener, as for example, almost every scanning line. This causes the grid of the tube 114 to become more negative and cut down the output of the tube 114. The output of the rectifier 107 is therefore reduced and the resistor 105 allows the condensers 122 and 103 to discharge thus lowering the grid bias on the tube 102 and raising the average space current. As the space current rises the black signal no longer reduces the space current below minimum as the gas-filled tube 109 is fired more seldom (but oftener than with no signal at all).

Still another circuit for correcting for the suppression of the direct component of a television current is shown in Fig. 8. In this circuit the received television signals are applied to a transformer 100 and then amplified by an amplifier 101. The amplified signals are applied through a condenser 130 to an input resistor 131 of the last amplifying stage 133. The voltage drop produced across the resistor 131 is applied to the grid 132 of the output thermionic tube 133 through a condenser 135 of the direct component correcting circuit. Condenser 135 serves as a by-pass around resistors 136 and 137 and is of the order of .01 microfarad. Its capacity is small compared to that of the interstage coupling condenser 130 but large compared to the input capacity of the tube 133. Resistors 136 and 137 are of the order of one-half megohm each and substantially prevent the flow of high frequency signaling energy to ground through the capacity with respect to ground of the battery 138 and the relay 139. It would not be desirable to charge the coupling condenser 130 through resistor 131 by current from source 138, rather than to charge the con-

denser 135, because the capacity of the coupling condenser is large compared to that of the condenser 135 and, therefore, the time required for readjusting the voltage across the condenser 130 in response to correcting impulses would be large compared to the time required for readjusting the voltage across the condenser 135 of small capacity. It is desirable, of course, to have the correcting circuit respond rapidly to the correcting impulses so that the average tone value of the image produced will correspond at all times to the average tone value of the field of view which is being scanned at the transmitter. The capacity of the condenser 130 is made large so as to prevent low frequency phase shift. Condenser 140, retardation coil 141 and condenser 142 form a filter which prevents the 60 cycle component of the voltage generated by the relay 139 and battery 138 from reaching the grid of the tube 133.

When the space current through the neon tube 38 falls below the predetermined minimum value, the voltage drop across the resistor 143 in the plate circuit of the signal tube 133 falls to such a value that space current is permitted to flow through the gas-filled tube 144 in the input circuit of which is connected the resistor 143 and a biasing battery 145. The tube 144 is a gas-filled three-electrode tube and once the space current flows it will continue unless the plate voltage falls below the ionizing potential. In the output circuit of the gas-filled tube 144 are connected a resistor 146 and in shunt therewith, a condenser 147 for producing this latter result. The space current of the tube 144 also passes through a winding 148 of the relay 139 in such a direction as to bias the relay tongue to the right or spacing contact. Condenser 154 is used to by-pass the alternating components of the current produced by the gas-filled discharge device 144 through the high impedance winding 148. The relay tongue is vibrating continuously because it is driven by 60 cycle current from the transformer 149 through the winding 150 of the relay 139. Transformer 149 is also used to produce heating current for the cathodes of the discharge devices. When no space current flows through the gas-filled tube 144, the tongue 151 of the relay 139 is biased to the left or marking contact by the biasing current through the winding 152 and regulating resistor 153. When the average space current through the gas tube 144 equals the biasing current through the winding 152, the tongue 151 is unbiased and vibrates between contacts M and S and the average potential across the condenser 135 is half the voltage of the battery 138. As the average space current through the gas-filled tube 144 increases, the voltage to which condenser 135 is charged increases and vice versa.

Fig. 9 shows another circuit for correcting, at a receiving station, for the suppression of the direct component at the television transmitting station. Incoming signals after being transformed by the transformer 100 are applied to the input circuit of the electron discharge device 160, the grid of which is biased by the grid battery 161. The correcting impulses are of such polarity that when they are applied to the input circuit of device 160 they cause an increase in current through the resistance 162. As this resistance is coupled to the input circuit of electron discharge device 164 by means of coupling condenser 179, the change in voltage due to a correcting impulse causes the grid of tube 164 to become more negative thus reducing the space current in the out-

put circuit of the device 164 which output circuit comprises a resistor 165 and a source of plate potential 166. The grid circuit of the device 164 includes the biasing battery 167 and the input resistor 168. Also included in the output circuit of the tube 164 is a glow discharge lamp 169 which only lights when the black peaks cause the voltage across the anode circuit of the electron discharge device 164 to rise above a predetermined maximum. The reduction in current in the output circuit of tube 164 reduces the IR drop through the resistance 165, thus raising the anode potential and also the potential across the device 169. The current pulses through the glow discharge lamp 169 after being smoothed and filtered by the filter comprising condenser 170 and inductor 171, produce voltage drop across the resistor 172 in the input circuit of tube 175 which potential drop opposes that of the biasing battery 173 which supplies biasing potential for the grid 174 of the electron discharge device 175. Condenser 177 by-passes around the resistance 172 any pulses not smoothed out by the condenser 170 and the inductor 171. The output circuit of the device 175 includes the image producing lamp 38, thyrite resistor 39, resistor 79 and a source of plate potential 40. A voltage drop across the resistor 172 makes the grid potential of the tube 175 less negative and thus increases the level of the signal in the image producing device 38. The blocking condenser 176 couples the output circuit of tube 160 to the input circuit of the signal tube 175. The condenser prevents the direct current plate potential of tube 160 from reaching the grid of tube 175. Resistor 178 is also included in the input circuit of tube 175.

In the circuit of Fig. 10, the 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 199 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 199 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. 11 shows a circuit for reinserting the direct current component in television signals, which circuit is considered to be a preferred embodiment at the present time. 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 windings 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. 13, the abscissa E_g being the voltage applied to the grid with respect to the cathode and the ordinate E_p being the voltage ap-

plied 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_g upon the plate circuit of the gas-filled tube. The time relations are shown in Fig. 12, in which the cycle variations of E_p and E_g 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. 12) 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. 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 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. 15. 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. 14 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. 14 and 15 for the other rectifier tube would merely show E_F shifted 180 degrees together with its E_G , I_E and I_S .

Other circuits for correcting for the suppression of the direct current component are described and claimed in an application of J. R. Hefele, Serial No. 99,022, filed Sept. 2, 1936.

The feature of connecting the output of the correcting circuit to the television transmission circuit at a position subsequent to the point in the circuit at which the correcting circuit receives input voltage as disclosed in certain of the figures in this application is not, per se, applicant's invention and no claim to it is being made herein.

What is claimed is:

1. A television receiver comprising a plurality of electron discharge amplifying stages, a television image producing device and a source of direct current connected in the output circuit of the last of said stages, a circuit including a condenser of large capacity for coupling the input of said last amplifier stage with the preceding stage, a condenser of relatively small capacity in the input circuit of said last stage, and means for charging the smaller of said condensers only to control the direct component of the current from said source flowing through said image producing device.

2. In combination, a source of image current produced as the result of scanning a field of view along successive parallel lines and having an alternating component of predominant amplitude produced as the result of periodically interrupting said scanning, the direct and certain low frequency components of said image current having been suppressed in transmission, a source of current having an alternating component of a frequency equal to said alternating component of predominant amplitude of said image current or a harmonic or subharmonic thereof, and means for compensating for the suppression of said direct and low frequency components comprising means for varying the amplitude of the current from said source under control of the image current component of predominant amplitude.

3. In combination, a source of television image electromotive force which is devoid of the direct and certain low frequency components representative of the average tone value of a field of view but having recurring impulses the amplitude of which is representative of said average tone value, image producing apparatus for producing an image under control of electromotive force from said source, means responsive to impulses derived from said source of television electromotive force which recur at the same frequency as the impulses of said source for setting up a momentary flow of current when ever the amplitude of one of said derived impulses exceeds a predetermined value, the amplitude of said momentary current flow being independent of the amount by which the amplitude of the derived impulse exceeds said predetermined value, and means under control of said momentary currents for controlling said image producing apparatus to supply said direct and low frequency components thereto.

4. In combination, a source of television image electromotive force which is devoid of the slowly

changing 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, an electric discharge device having a control means, means for impressing said television image electromotive force upon said control means, and means for varying the biasing of said control means to correct for the suppression of said direct component, said last-mentioned means comprising means including a gaseous electric discharge tube having an output circuit and a control circuit for setting up a unidirectional electromotive force, means for impressing impulses derived from said source of television image electromotive force and recurring at the same frequency as the impulses of said source upon the control circuit of said gaseous tube to control the amplitude of said unidirectional electromotive force in accordance with the amplitude of said derived recurrent impulses, and means for impressing said unidirectional electromotive force upon the control means of said electric discharge device for biasing it.

5. A source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view or a portion thereof but having recurring impulses the amplitude of which is representative of said average tone value, an amplifier having control means and an output circuit, means for impressing television image electromotive force from said source upon said control means for controlling the unidirectional current in said output circuit, and means responsive to the recurring impulses of the current in said output circuit for maintaining the maximum or minimum values of said impulses in the output circuit at a substantially constant amplitude level.

6. In a television system, a source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view and having recurring impulses the amplitude of which is representative of said average tone value, electronic means comprising an anode, a cathode and a control means, an anode-cathode circuit including a source of unidirectional current, means for impressing electromotive force from said source of television image electromotive force upon said control means for controlling the amplitude of the unidirectional current in said anode-cathode circuit, means connected to said anode-cathode circuit for producing a continuous biasing electromotive force the amplitude of which corresponds to the amplitude of said recurring impulses, and means for applying said biasing electromotive force to said control means for causing the insertion in said anode-cathode circuit of a slowly changing unidirectional component representative of average tone value of the field of view.

7. A source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view or a portion thereof but having recurring impulses the amplitude of which is representative of said average tone value, an amplifier having control means and an output circuit, means for impressing television image electromotive force from said source upon said control means for controlling the current in said output circuit,

and means responsive to the recurring impulses of the current in said output circuit for maintaining the maximum or minimum values of said impulses in the output circuit at a substantially constant amplitude level, comprising means for setting up a momentary flow of current whenever the amplitude of one of said recurring impulses in said output circuit exceeds a predetermined value, the amplitude and duration of said momentary current flow being independent of the amount by which the amplitude of the actuating impulse exceeds said predetermined value, and means under control of said momentary currents for controlling said amplifier control means.

8. A source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view or a portion thereof but having recurring impulses the amplitude of which is representative of said average tone value, an amplifier having control means and an output circuit, means for impressing television image electromotive force from said source upon said control means for controlling the current in said output circuit, and means responsive to the recurring impulses of the current in said output circuit for maintaining the maximum or minimum values of said impulses in the output circuit at a substantially constant amplitude level, comprising means for setting up a momentary flow of current whenever the amplitude of one of said recurring impulses in said output circuit exceeds a predetermined value, a condenser connected to said amplifier control means, a low-pass filter connected to said condenser, and means under control of said momentary currents connected to said filter for controlling the charge on said condenser to bias said amplifier control means.

9. A source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view or a portion thereof but having recurring impulses the amplitude of which is representative of said average tone value, an amplifier having control means and an output circuit, means for impressing television image electromotive force from said source upon said control means for controlling the current in said output circuit, and means responsive to the recurring impulses of the current in said output circuit for maintaining the maximum or minimum values of said impulses in the output circuit at a substantially constant amplitude level, comprising means for setting up a momentary flow of current whenever the amplitude of one of said recurring impulses in said output circuit exceeds a predetermined value, means comprising a vibrating electromagnetic relay for controlling said amplifier control means, and means under control of said momentary currents for controlling said relay.

10. A source of television image electromotive

force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view or a portion thereof but having recurring impulses the amplitude of which is representative of said average tone value, an amplifier having control means and an output circuit, means for impressing television image electromotive force from said source upon said control means for controlling the current in said output circuit, and means responsive to the recurring impulses of the current in said output circuit for maintaining the maximum or minimum values of said impulses in the output circuit at a substantially constant amplitude level, comprising means for setting up a momentary flow of current whenever the amplitude of one of said recurring impulses in said output circuit exceeds a predetermined value, a source of alternating electromotive force, means under control of said momentary currents for controlling the amplitude of said alternating electromotive force, means under control of said alternating electromotive force for producing a relatively slowly varying unidirectional electromotive force, and means for applying said unidirectional electromotive force to said amplifier control means for controlling the biasing thereof.

11. A source of television image electromotive force which is devoid of the slowly changing unidirectional component representative of the average tone value of a field of view or a portion thereof but having recurring impulses the amplitude of which is representative of said average tone value, an amplifier having control means and an output circuit, means for impressing said television image electromotive force from said source upon said control means for controlling the unidirectional current in said output circuit, a current path, means for causing current to flow in said path whenever one of said recurring impulses in said output circuit exceeds a predetermined value, the amplitude of the current flowing in said path being independent of the amount by which the amplitude of the actuating impulse exceeds said predetermined value, a condenser of relatively small capacity connected in shunt with a portion of said current path for causing the current in said path to be interrupted whenever the condenser becomes charged to a certain potential, a resistor and a condenser of relatively larger capacity connected in shunt with said first condenser, a second amplifier having a control circuit and an output circuit, means for connecting said second condenser to the control circuit of said second amplifier for controlling the electromotive force across the output circuit thereof in accordance with the charge on said second condenser, and means for connecting the output circuit of said second amplifier to the control means of the first-mentioned amplifier for controlling the biasing thereof.

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