

Sept. 30, 1930.

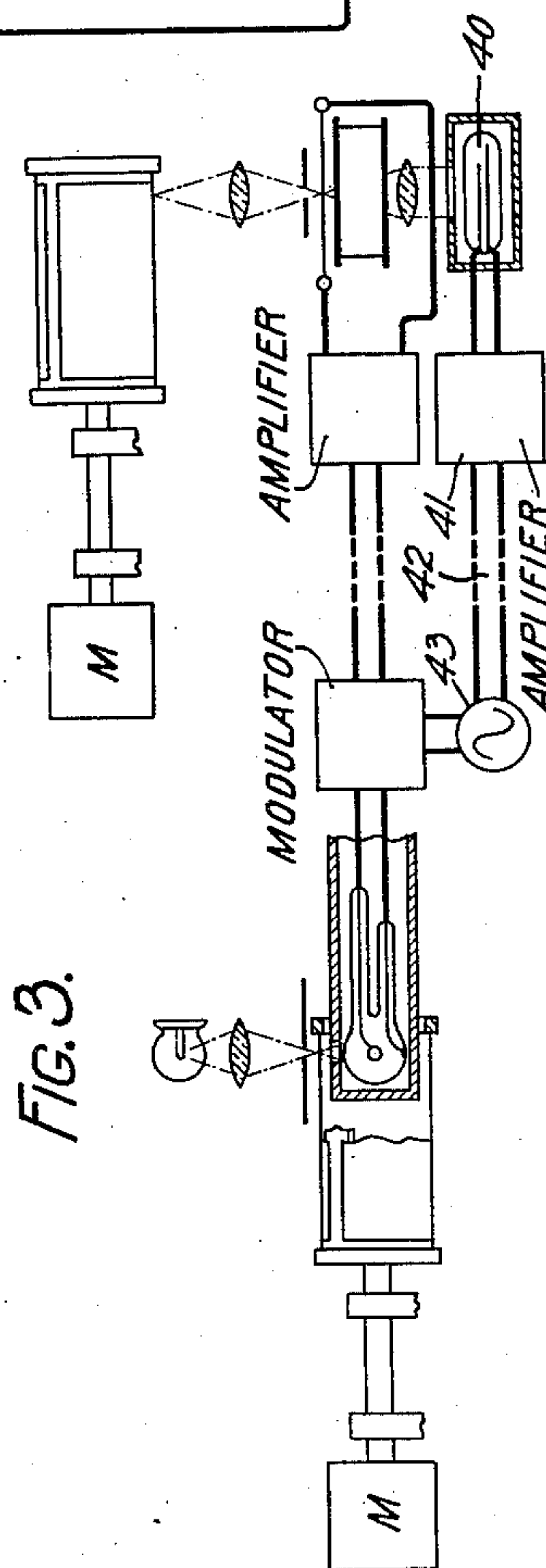
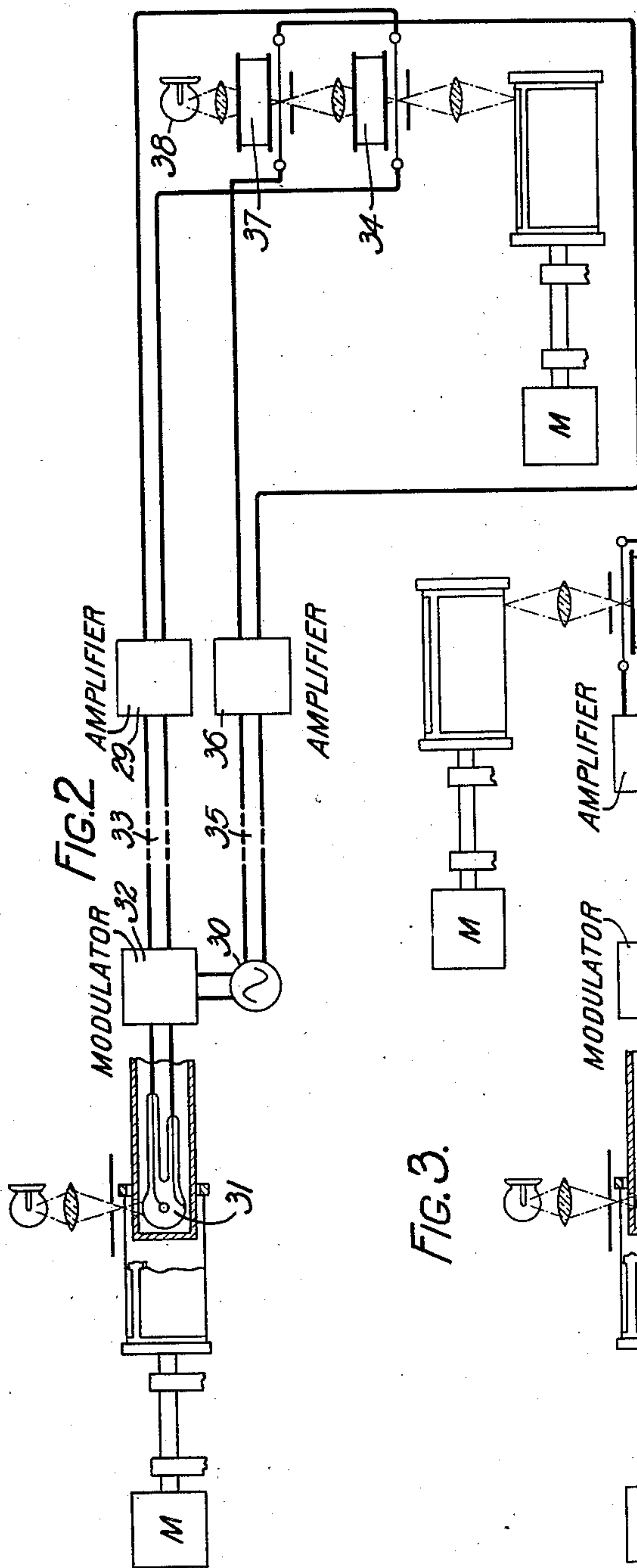
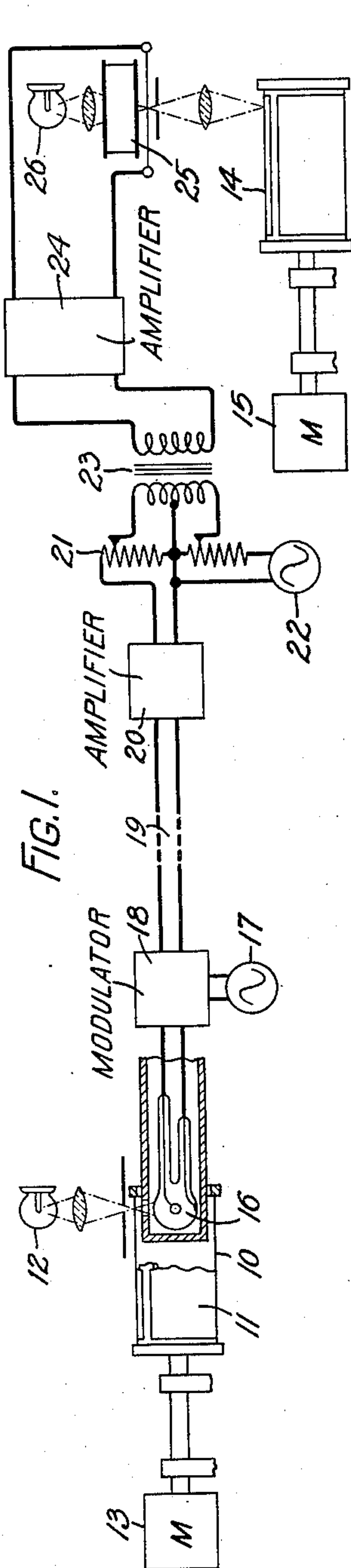
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1,777,016

ELECTROOPTICAL IMAGE PRODUCING SYSTEM

Filed May 19, 1928

2 Sheets-Sheet 1



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FIG. 4.

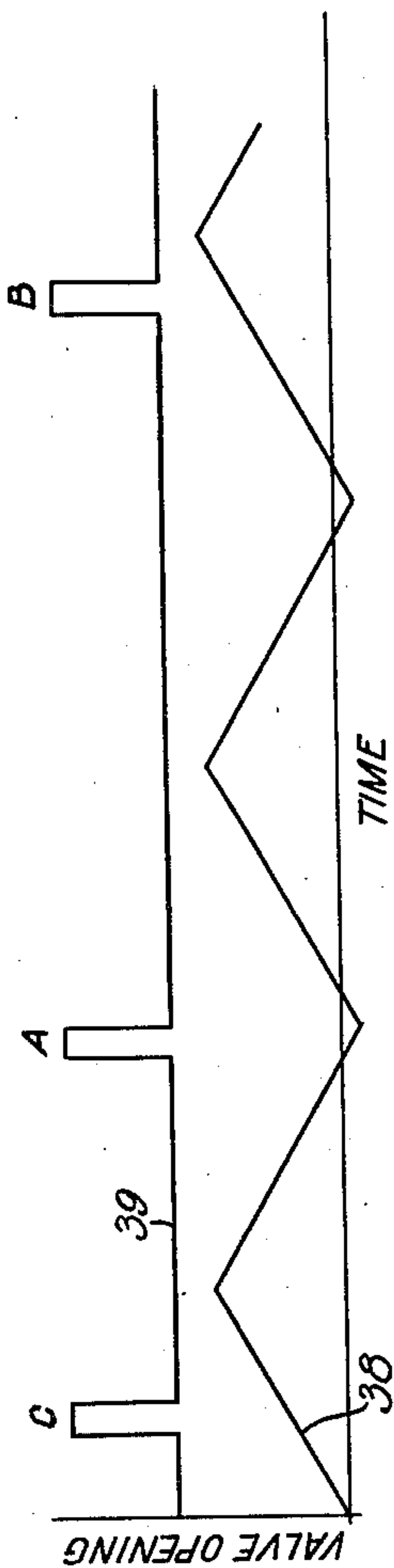
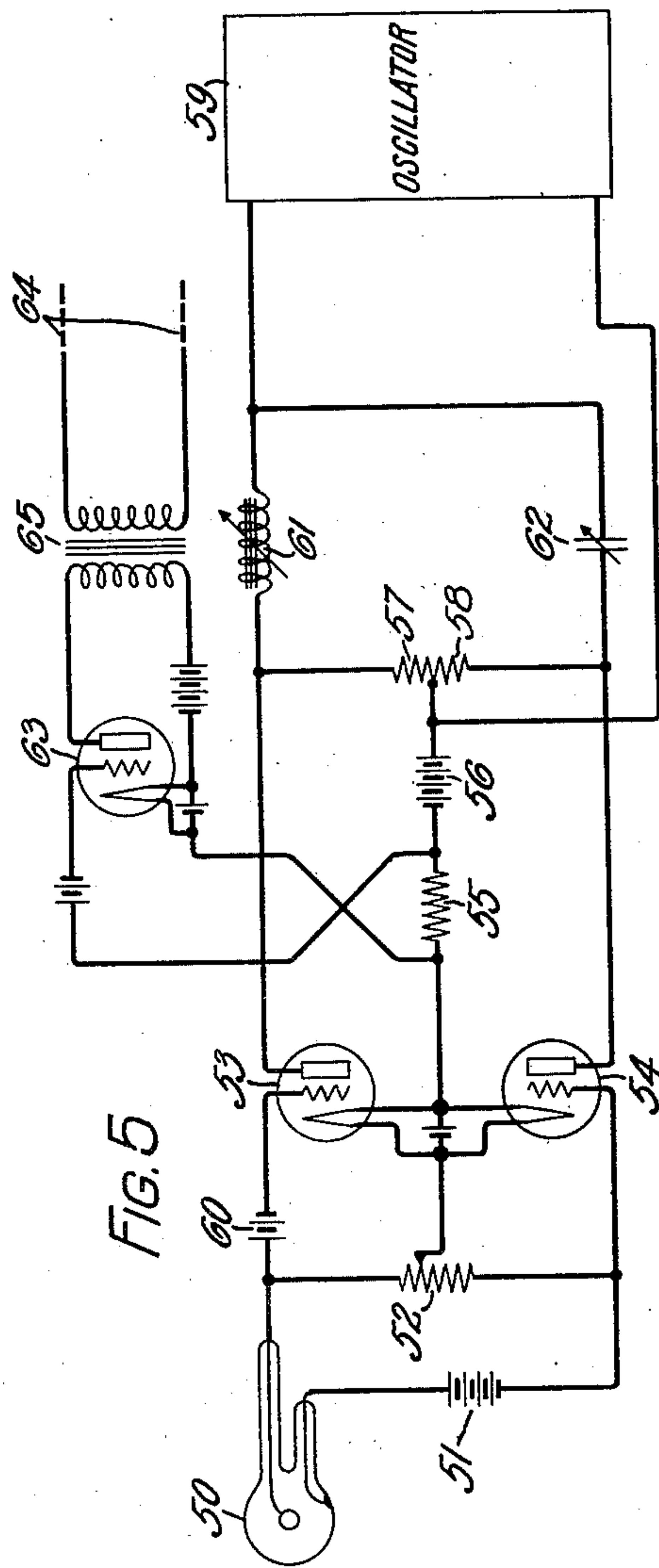


FIG. 5



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1,777,016

UNITED STATES PATENT OFFICE

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ELECTROOPTICAL IMAGE-PRODUCING SYSTEM

Application filed May 19, 1928. Serial No. 279,041.

This invention relates to electro-optical image production, and particularly to a carrier current image producing system and to methods of image production in which phase modulation of the carrier current is employed.

The general object of the invention is to control the production of an image by a carrier wave which has been modulated with respect to phase.

In one embodiment of the invention herein shown and described, by way of example, a carrier current modulated with respect to phase in accordance with the tone values of successive elemental areas of an object, is employed to control the actuation of a light controlling element such as a light valve for producing the image.

Instead of employing a single light controlling element, a plurality of such elements may be used for jointly controlling the production of the image, as in another embodiment of this invention described below. In this embodiment the actuation of one of the light controlling elements is controlled by unmodulated current of the carrier frequency and the actuation of another of the elements is controlled by the modulated carrier current. Each of these elements may be a light valve, or if desired, one may be a light valve and another a primary source of light such as a glow discharge lamp. One of the light valves or the glow discharge lamp controls the amount of light emitted in accordance with the variations in the instantaneous values of amplitude of the carrier current, while the other light valve is designed so that it opens abruptly for a short interval during each cycle of the unmodulated current of carrier frequency, the time of opening being varied in accordance with the phase variations of the modulated carrier current. It is thus apparent that the amount of light reaching the position at which the image is being produced is determined by the portion of the cycle of the carrier current at which the opening of the light valve, just mentioned, occurs.

A detailed description of several embodiments of the invention follows, reference be-

ing made to the accompanying drawing, in which:

Figures 1, 2 and 3 are circuit diagrams illustrating several embodiments of an electro-optical image producing system in accordance with this invention;

Fig. 4 is a diagram which illustrates the operation of the image producing system shown in Figs. 2 or 3; and

Fig. 5 is a diagrammatic showing of a circuit for modulating the phase of a carrier wave in accordance with the tone value variations of an object.

The image producing systems, shown in Figs. 1, 2 and 3 employ the usual apparatus for scanning the elemental areas of a picture or other object at the transmitting station and for synthesizing the elemental areas at the receiving station to form an image of the picture or object. The scanning and synthesizing apparatus shown in these figures is suitable for picture reproduction. A more detailed disclosure of this part of the system as applied to picture reproducing is found in Patent 1,606,227 to J. W. Horton, H. E. Ives and M. B. Long, November 9, 1926, and, as applied to television, in copending application to F. Gray, Serial No. 227,649, filed Oct. 21, 1927.

In Fig. 1 a drum 10 of transparent material, such as glass, has mounted thereon a negative picture representation 11, the degree of transparency of which varies in accordance with the tone values of the elemental areas thereof. Thus drum is rotated about its axis and at the same time moves in the direction of its axis so that light from a source 12 focused on the picture representation, describes a helical course thereon. The drum 10 is driven by a motor 13 in synchronism with a similar drum 14 at the receiving station which is driven by a motor 15. The drum 14 at the receiving station carries an element having a light sensitive surface on which the picture is to be reproduced. The light transmitted through the negative picture representation 11 reaches a photoelectric cell 16 and causes the amplitude of the current in the circuit associated with the photoelectric cell to vary in accordance with the

variations in tone value of the successively scanned elemental areas of the picture. The image current produced by the photoelectric cell and the carrier current of constant frequency from a source 17 are impressed on a phase modulator 18 to produce a carrier current which is modulated with respect to phase. This phase modulator will be referred to more in detail in connection with Fig. 5. The phase modulated wave is transmitted over a suitable channel 19 such as a wire line or a radio transmission channel. At the receiving station, the phase modulated wave is amplified by an electron discharge amplifier 20 and impressed across a portion of the winding of potentiometer 21. Current from a source 22 having the same frequency characteristics as that of the source 17 at the transmitting station is impressed on another portion of the winding of potentiometer 21. Instead of employing a separate source of carrier current 22 at the receiving station, carrier current may be transmitted from source 17 at the transmitting station. The mid terminal of the primary winding of transformer 23 is connected to the mid terminal of potentiometer 21 while the end terminals of the transformer winding are connected to the variable contacts of the potentiometer. The phase and amplitude of the current from the source 22 are so adjusted that when a black element of the negative picture representation is being transmitted, the current from this source flowing in the primary winding of transformer 23 is equal in amplitude and opposite in phase to the current from amplifier 20 flowing in this transformer winding. For this condition no current is transmitted through amplifier 24 to light valve 25 and no light from source 26 reaches the light sensitive surface mounted on the revolving drum 14. The light valve 25 may be of the type disclosed in U. S. Patent 1,638,555, granted to E. C. Wentz, August 9, 1927. When the tone value of the picture element in the path of the light beam from source 12 changes from black to some other tone value, a phase displacement takes place in the wave transmitted over channel 19 and impressed on the primary winding of transformer 23. Current proportional to the vector sum of the current from the source 22 flowing in the primary winding of transformer 23 and the phase modulated current transmitted over the channel 19 flowing in this winding of transformer 23 is impressed on the light valve 25, thus opening the light valve and exposing the light sensitive surface to light from the source 26. Since the change in phase of the wave transmitted over channel 19 varies in accordance with the change in tone value of the elemental areas of the negative picture representation, and since the current through the light valve and therefore the opening of the light valve varies in accordance with this change in phase of the image modulated carrier wave, it is apparent that a positive picture corresponding to the negative at the transmitting station is produced on the image receiving surface mounted on the drum 14.

In the embodiment of the invention shown in Fig. 2, carrier current from source 30 and image current set up by the photoelectric cell 31 are impressed on a phase modulator 32, and the phase modulated wave produced therein is transmitted over transmission channel 33 to the receiving station where it is amplified by amplifier 29 and impressed on light valve 34. Carrier current from source 30 is transmitted over a second channel 35 to the receiving station where it is amplified by amplifier 36 and impressed on light valve 37.

The light valve 37 opens and closes gradually over each cycle of the carrier current in accordance with the instantaneous values of its amplitude. This is indicated diagrammatically by the curve 38 of Fig. 4. As shown by the curve 39 of Fig. 4, the valve 34 opens abruptly only for a short period during each cycle. This may be accomplished by suitably designing the light valve so that it does not transmit light if the actuating current is less in amplitude than a certain value near the peak value of the phase modulated current impressed upon it. The periodic opening of the light valve 34 may also be realized by connecting it directly in the output circuit of a vacuum tube, the grid of which is so biased that no current flows in the anode circuit thereof except when the phase modulated wave impressed on its grid is near its maximum value. When the light valves 34 and 37 are operating as just described, the valve 34 opens a given amount once during each cycle, but the time at which the opening occurs varies with respect to the time when the valve 37 is at its maximum opening. For instance, at position A, indicated in Fig. 4, the valve 34 is open when the valve 37 is closed and thus no light from source 38 is transmitted to the picture receiving surface. At position B, valve 34 is open when valve 37 is near its maximum opening, thus permitting a maximum amount of light to reach the picture receiving surface. At position C, valve 34 is open when valve 37 is open an amount intermediate the maximum and minimum amounts. In this manner, the exposure of the light sensitive picture receiving surface is varied in accordance with the phase variations of the received phase modulated carrier wave.

The embodiment of the invention shown in Fig. 3 is the same as that shown in Fig. 2 with the exception that the light source 38 of constant intensity and the light valve 37 shown in Fig. 2 are displaced by a light source 40 which is connected to the output circuit of

amplifier 41. The light source 40 may be a glow discharge lamp which is capable of emitting light of an intensity which varies in accordance with the instantaneous values of amplitude of the carrier current from source 43 transmitted over channel 42 and amplified by amplifier 41. In this case the time in which light valve 44 opens varies with respect to the time at which the light emitted from the light source 40 is at its maximum intensity.

One arrangement for producing a phase modulated wave is disclosed in Patent No. 1,633,016 granted to R. V. L. Hartley, June 21, 1927. Another such arrangement is shown in Fig. 5. In this figure a photoelectric cell 50 is connected in series with battery 51 and resistance 52. The varying potential difference across the resistance 52 due to the variation in the light actuating the photoelectric cell 50, is impressed differentially on the control electrodes of the similar electron discharge devices 53 and 54 so that the output impedance of one of the discharge devices is increased when that of the other discharge device is decreased and vice versa. A biasing battery 60 is employed so that the control electrodes of the two electron discharge devices will be biased equally, and therefore so that these devices will have the same output impedance, when the photoelectric cell is not actuated by light. A resistance 55 and battery 56 are in a common portion of the anode circuits of the electron discharge devices 53 and 54. One of the equal resistance elements 57 and 58 is connected in each of these anode circuits. A source of carrier current 59 is connected across resistance element 57 through an inductive reactance element 61 while the same current source is connected across resistance element 58 through a capacitive reactance element 62. The potential difference across element 55 is impressed on the input circuit of an electron discharge device 63, the output circuit of which is connected to a transmission channel 64 through transformer 65. The current from the source 59 travels by two paths. One path is through the inductive reactance element 61 and resistance 57, said resistance element having in shunt therewith the resistance element 55 and the output impedance of electron discharge device 53 connected in series. The other path is through the capacitive reactance element 62 and resistance element 58, said resistance having in shunt therewith the resistance element 55 and the output impedance of electron discharge device 54 connected in series. It is apparent that the current components reaching the resistance element 55 by way of these two paths, respectively, are out of phase and the electromotive force impressed on the input circuit of electron discharge device 63 is proportional to the vector sum of these components. As the photoelectric cell 50 is ac-

tuated by light of varying intensity, and as a result the output impedance of one of the electron discharge devices 53 or 54 increases while the output impedance of the other device decreases, and vice versa, the phase relation between the two current components in resistance element 55 changes, thus resulting in a corresponding change in the phase of the current transmitted over channel 64.

It is apparent that the term "light controlling means" may be used to designate light valves such as indicated by the numerals 25, 34 and 37 and also sources of light such as the glow discharge lamp 40. Obviously, the glow discharge lamp 40 and the light valves control the light reaching the light sensitive image receiving surface mounted on drum 14 for controlling the production of the image.

What is claimed is:

1. An electro-optical image producing system comprising means for producing an electric wave which is modulated with respect to phase in accordance with the tone values of elemental areas of an object an image of which is to be produced, and means responsive to said phase modulated electric wave for controlling the production of said image.
2. An electro-optical image producing system comprising a source of carrier current of substantially constant frequency, means for modulating said current with respect to phase in accordance with the tone values of elemental areas of an object, and means actuated jointly by unmodulated current of said frequency and said phase modulated current for producing an image of said object.
3. An electro-optical image producing system comprising a source of carrier current of substantially constant frequency, means for modulating said current with respect to phase in accordance with the tone values of elemental areas of an object, and a plurality of light controlling means for controlling the light utilized in the production of the image, one of said controlling means being controlled by unmodulated current of said frequency and another by said phase modulated current for producing an image of said object.
4. In an electro-optical image producing system, a source of carrier current, means for scanning an object for producing an image current which varies in accordance with the tone values of successively scanned elemental areas of said object, and means for modulating said carrier current with respect to phase in accordance with the variations of said image current.
5. In an electro-optical image producing system, a source of carrier current, means for scanning an object for producing an image current the amplitude of which varies in accordance with the tone values of the successively scanned elemental areas of said object, means for modulating said carrier current with respect to phase in accordance with

the amplitude variations of said image current, and means responsive to said phase modulated wave for producing an image of said object.

5 6. An electro-optical image producing system comprising a source of carrier current, means for modulating current from said source with respect to phase in accordance with the tone values of elemental areas
10 of an object an image of which is to be produced, and means including a device for emitting light of an intensity which varies in accordance with the instantaneous values of said carrier current and a second device for
15 transmitting light for a short interval during each cycle of said phase modulated current for controlling the production of said image.

7. In an electro-optical image producing
20 system, a transmitting station and a receiving station, a source of carrier current at said transmitting station, means for modulating the carrier current from said source with respect to phase in accordance with the light
25 tone values of the elemental areas of an object an image of which is to be produced, light controlling means at said receiving station responsive to said phase modulated current, a second light controlling means re-
30 sponsive to said unmodulated carrier current, and means including said two light controlling means for controlling the production of an image of said object.

8. In an electro-optical image producing
35 system, a light sensitive device, a source of light for actuating said light sensitive device, means for controlling the intensity of the light from said source reaching said light sensitive device in accordance with the
40 tone values of the elemental areas of an object an image of which is to be produced, thereby producing an image current in said light sensitive device, a source of constant frequency current, means for shifting the
45 phase of the constant frequency current from said source in accordance with the amplitude variations of said image current, thereby producing a phase modulated current, a second source of light the intensity
50 of which varies in accordance with the instantaneous values of the amplitude of the unmodulated constant frequency current from said source, and means responsive to said phase modulated current for controlling the intensity of the light from said second source which reaches the position at
55 which the image is to be produced.

9. In an electro-optical image producing system, a plurality of electron discharge devices each having a cathode, a control electrode, an anode, an input circuit and an output circuit, a source of electromotive force connected in said input circuits in such a manner that a change in said electromotive
65 force causes the output impedances of said

electron discharge devices to change oppositely with respect to each other, a light sensitive device for causing said electromotive force to vary in accordance with the intensity variations of the light reaching said device, means for impressing alternating electromotive forces on the anodes of said electron discharge devices, said electromotive forces being of the same frequency but different in phase, and means connected to a
70 common portion of the anode circuits of said electron discharge devices for producing a light beam which varies in intensity in accordance with the intensity variations of the light reaching said light sensitive device. 80

10. The method of producing an image of an object electro-optically which comprises producing a carrier wave, modulating said carrier wave with respect to phase in accordance with the light tone values of the elemental areas of said object and controlling the light tone values of the image of said object in accordance with the phase relation between said unmodulated carrier wave
85 and said phase modulated carrier wave. 90

11. The method of producing an image of an object electro-optically which comprises modulating a carrier wave with respect to phase in accordance with the light tone values of successively scanned elemental areas of an object, an image of which is to be produced, controlling the intensity of light in accordance with the instantaneous values of amplitude of said carrier wave, transmitting said light periodically during a portion of each cycle of said carrier wave determined in accordance with the phase relation between said carrier wave and said phase modulated wave and utilizing said transmitted light for controlling the light tone values of the elemental areas of said image. 105

In testimony whereof, I have signed my name to this specification this 9th day of May, 1928. 110

RALPH K. POTTER. 115

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