

Aug. 28, 1934.

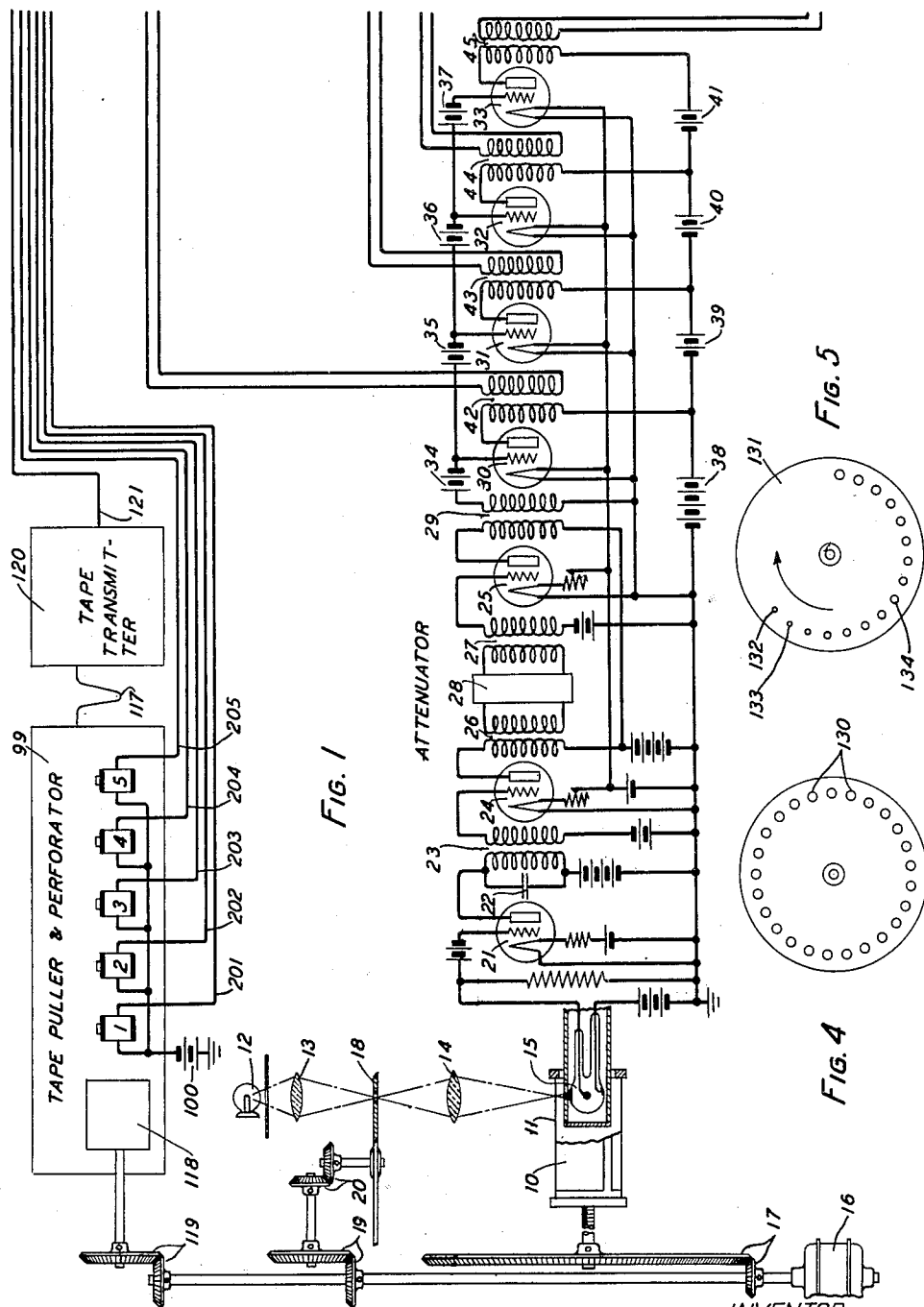
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1,971,674

ELECTROOPTICAL IMAGE PRODUCTION

Filed July 25, 1931

3 Sheets-Sheet 1



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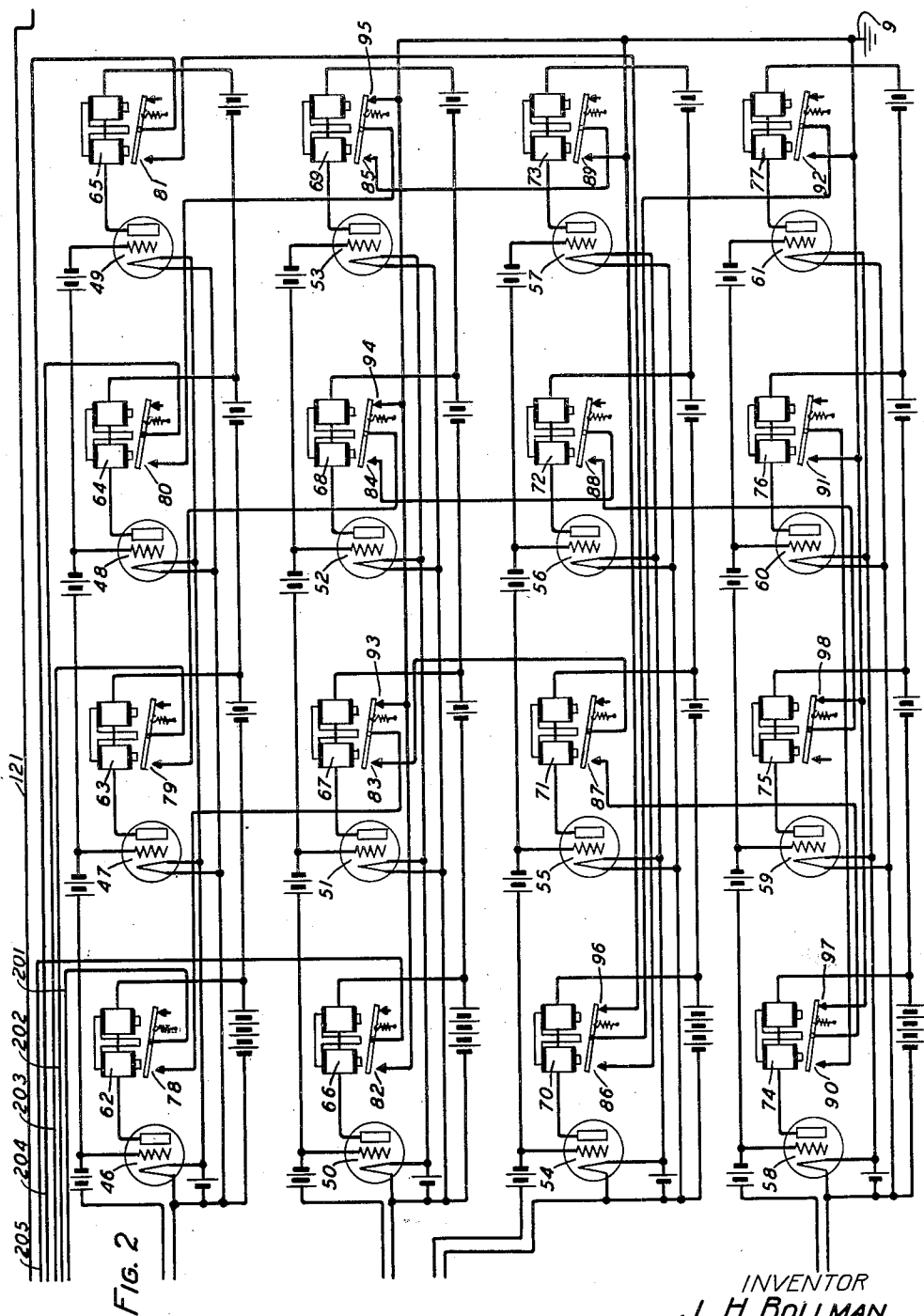
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ELECTROOPTICAL IMAGE PRODUCTION

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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

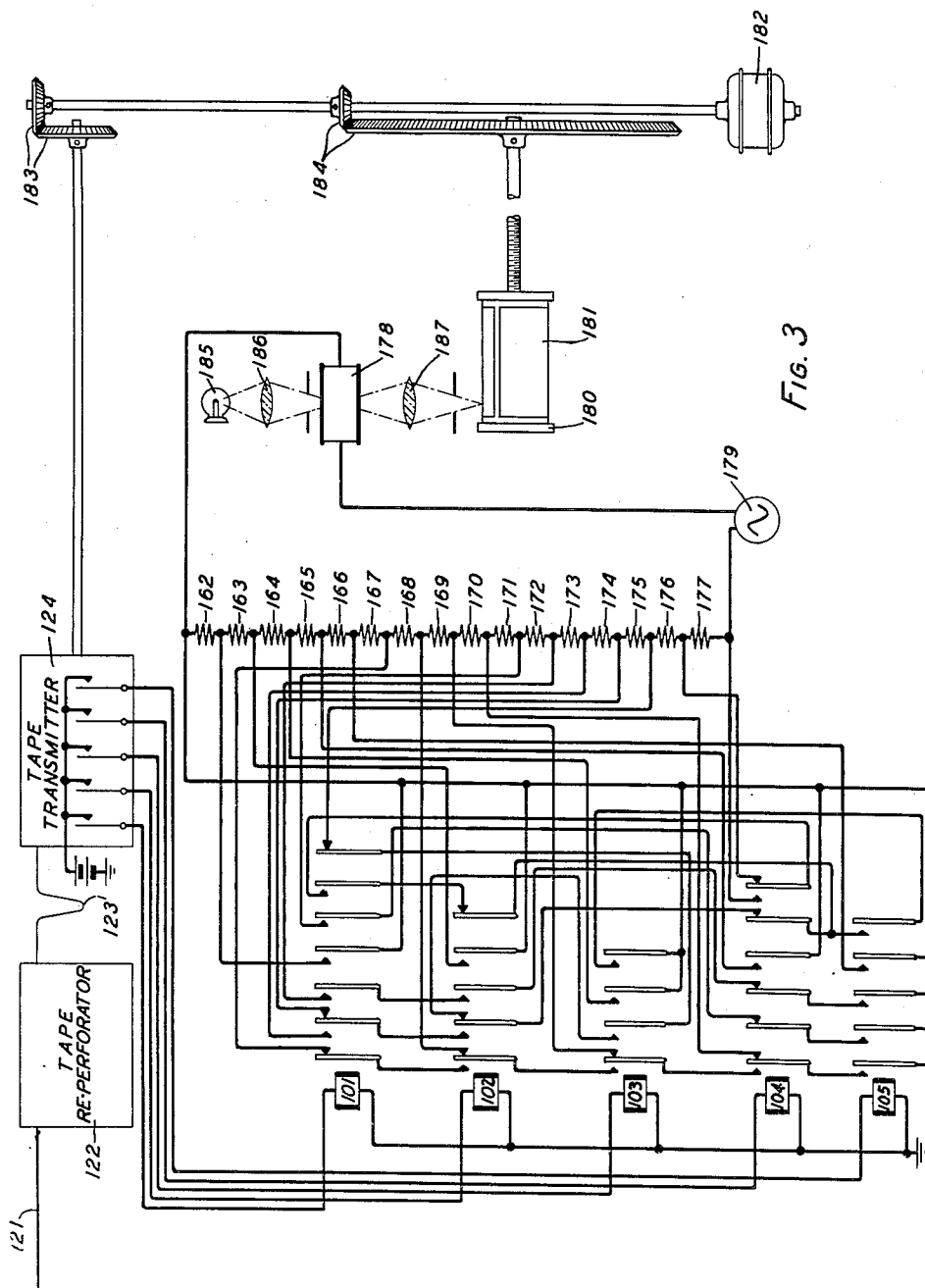


FIG. 3

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ELECTROOPTICAL IMAGE PRODUCTION

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Application July 25, 1931, Serial No. 553,098

7 Claims. (Cl. 178—5)

This invention relates to electro-optical systems and particularly to systems for reproducing pictures by the use of telegraph code signals.

The invention provides an improved system for the electrical transmission of pictures or the production of images at a distant point under control of transmitted current corresponding to the tone values of the elemental areas of a picture or other object. The amplitude of a periodically varying current is controlled in accordance with the tone values of successively scanned elemental areas of a field of view, and the resulting varying current is utilized to control the operation of relay means set to respond when said varying current reaches a predetermined value.

In a specific embodiment of the invention herein shown and described for the purpose of illustration, means are provided for directing, upon a light sensitive element, a beam of light which is caused to vary in accordance with the tone values of the successive elemental areas of a picture or object, an image of which is to be produced. There is provided a rotating disc making a single revolution in the period required for scanning a single elemental area and having apertures therein arranged along an arc of a circle for interrupting the beam of light at a high frequency compared to the frequency of scanning successive elemental areas so that a high frequency current modulated in accordance with the tone values of successively scanned elemental areas of the picture or object is produced in a circuit associated with the light sensitive cell. This modulated high frequency current, after being amplified by an alternating current amplifier which is preferably associated with a tuned circuit to increase the amplification efficiency, is impressed, through a transformer, upon a plurality of alternating current amplifying vacuum tubes connected in parallel and differently biased so as to operate over different ranges of impressed electromotive force, respectively. The output circuit of each of these vacuum tubes is coupled through a transformer to a plurality of rectifier vacuum tubes which are biased so as to operate over different values of impressed electromotive force, respectively. An electromagnetic relay is connected in the output circuit of each of these rectifier vacuum tubes and these relays control the selection of code combinations of telegraph signals to be punched in a tape or transmitted directly, said code combinations corresponding to the tone values of the elemental areas of a picture or object.

The apertures of the light interrupting disc

are preferably omitted over a portion of the circle so that the light beam is interrupted for a comparatively long period of time between the scanning of successive elemental areas, as disclosed and claimed in a copending application of J. W. Horton, Serial No. 555,669, filed Aug. 7, 1931. In order to avoid the rapid increase in current which would normally occur following the period during which the light beam is interrupted for a comparatively long interval, and the resulting false operation of relays, the first few light apertures of the light interrupter disc following this portion of the disc which interrupts the light for a comparatively long interval are given a tapered characteristic so as to cause the amplitude of the photoelectric current to increase gradually to the amplitude determined by the tone values of the elemental area of the field of view being scanned. This may be accomplished by employing apertures of gradually increasing size or by covering a few of the apertures of constant size with a film of gradually increasing transparency.

At the receiving station, a tape may be perforated similarly to the tape at the transmitting station under control of the received telegraph signals. This tape controls the actuation of a number of electromagnetic relays equal to the number of different tone values into which the field of view is analyzed at the transmitting station. These relays control the current through a light valve or similar device, as by varying the resistance in circuit therewith, and this light valve controls the amount of emitted light to produce an image, for example, by exposing a light sensitive surface.

A detailed description of the specific embodiment of the invention mentioned above follows, reference being made to the accompanying drawings, in which

Figs. 1 and 2 show diagrammatically the transmitting station of a code telegraph picture reproducing system in accordance with the present invention;

Fig. 3 shows diagrammatically the receiving station of a code telegraph picture reproducing system; and

Figs. 4 and 5 are plan views of apertured discs such as may be employed in connection with the apparatus shown in Fig. 1 for interrupting the scanning light beam.

Figs. 1, 2 and 3, when placed side by side in order with Fig. 1 at the left, show a complete code telegraph picture transmission system. The picture which is to be reproduced is in the form of a negative film 10 of varying transparency mount-

ed on the drum 11 of transparent material. A beam of light from source 12 is focused upon a small spot on the film by means of the lenses 13 and 14 and, after passing through the film, impinges upon the photoelectric cell 15. The drum 11 on which the picture film is mounted is driven by motors 16 through gears 17 to cause it to rotate and at the same time move slowly in an axial direction. The light beam impinging upon the picture film 10 thus scans the picture along a helical path. The scanning light beam is interrupted by an apertured disc 18 driven by motor 16 through gears 19 and 20. There is thus produced in the circuit of the photoelectric cell 15 a pulsating current having an alternating component, the frequency of which is controlled in accordance with the rate of interruption of the light beam and the amplitude of which varies in accordance with the tone values of the successively scanned elemental areas of the picture. The photoelectric current is amplified by the vacuum tube amplifier 21 in the anode circuit of which is a tuned circuit comprising a condenser 22 and the primary winding of transformer 23 tuned to the frequency of the alternating component of the photoelectric current. The secondary winding of transformer 23 is connected to an alternating current amplifier comprising vacuum tubes 24 and 25, transformers 26 and 27 and an adjustable attenuator 28. The output circuit of the amplifying vacuum tube 25 is connected through transformer 29 to the input circuits of amplifying vacuum tubes 30 to 33 inclusive. These vacuum tubes have different grid biasing potentials and different anode potentials, respectively, so that the operation of different tubes, respectively, is initiated in response to different values of alternating signaling current transmitted through the transformer 29.

The grid of vacuum tube 30 is biased by the electromotive force of battery 34; the grid of vacuum tube 31 is biased by the sum of the electromotive forces of batteries 34 and 35; the grid of vacuum tube 32 is biased by the sum of the electromotive forces of batteries 34, 35 and 36 and that of tube 33 is biased by the sum of the electromotive forces of batteries 34 to 37, inclusive. The vacuum tubes 30 to 33, inclusive also have different sources of anode potential, the tube 30 having the anode potential equal to the electromotive force of battery 38, tube 31 having the sum of the electromotive forces of batteries 38 and 39, tube 32 the sum of the electromotive forces of batteries 38, 39 and 40 and tube 33 having the electromotive forces of batteries 38 to 41 inclusive. When an elemental area of the negative picture representation 10 of relatively dark tone value is being scanned, the transmitted alternating current and the corresponding alternating electromotive force impressed upon the input circuits of vacuum tubes 30 to 33, inclusive is of low amplitude. As a result a varying current is caused to flow in the primary winding of transformer 42 and a corresponding alternating electromotive force induced in the secondary winding of this transformer. When an elemental area of somewhat lighter tone value is being scanned the alternating electromotive force impressed upon the input circuits of vacuum tubes 30 to 33 is of correspondingly greater amplitude and vacuum tubes 30 and 31 are operated to cause an electromotive force to be induced in the secondary windings of transformers 42 and 43. When the tone value of the elemental area being scanned is still lighter, vacuum tubes 30 to 32, inclusive operate and for elemental areas of very light tone value all four vacuum tubes 30 to 33 operate. When vacuum tubes 30 to 32, inclusive operate an alternating electromotive force is induced in the secondary windings of transformers 42 to 44, inclusive and when all four vacuum tubes operate an alternating electromotive force is induced in the secondary windings of all four transformers 42 to 45, inclusive. We may therefore consider the tone values of the picture as being grouped into four ranges of value, for example, very dark, dark, light and very light, and one, two, three or all four of the vacuum tubes 30 to 33 will be operated according to the group into which the tone value of the elemental area being scanned is classified. Each of these groups may be subdivided into as many groups as desired, for example, four. It is apparent that not only will one, two, three or four of the vacuum tubes 30 to 33 be operated as elemental areas falling in different groups of tone values, respectively, are being scanned, but also that the alternating electromotive forces induced in the secondary windings of transformers 42 to 45, inclusive vary over a range of values in accordance with the variations in tone value occurring within each of the four groups of tone values.

The secondary windings of transformers 42 to 45, inclusive, are connected to the input circuits of four different groups of rectifier vacuum tubes, respectively, the first group comprising vacuum tubes 46 to 49, inclusive, the second group comprising vacuum tubes 50 to 53, inclusive, the third group comprising vacuum tubes 54 to 57, inclusive, and the fourth, vacuum tubes 58 to 61, inclusive. Relays 62 to 77, inclusive, are connected, respectively, in the anode circuits of the vacuum tubes 46 to 61, inclusive. One or more of the rectifier vacuum tubes of the first group will be operated whenever the amplifier vacuum tube 30 is operated, one or more of the second group whenever vacuum tube 31 is operated, one or more of the third group whenever vacuum tube 32 is operated and one or more of the fourth group whenever vacuum tube 33 is operated. The vacuum tubes of each group are provided with different grid biasing and anode potentials, respectively, similarly to the vacuum tubes 30 to 33, inclusive, so that they operate to cause the anode current to reach a predetermined amplitude in response to input signal electromotive forces of different amplitudes, respectively. Suppose, for example, that a black or very dark elemental area of the negative picture 10 is being scanned and that the attenuation of the variable attenuator 28 is progressively reduced until current flows in the anode circuits of vacuum tubes 30 and 46, the current in the anode circuit of the vacuum tube 46 having sufficient amplitude to cause the operation of relay 62 and the closure of the circuit through contact 78. Then as elemental areas of lighter tone values are scanned, the current in the anode circuit of vacuum tube 30 will increase in amplitude until vacuum tube 47 and its associated relay 63 are operated to close contact 79 in addition to vacuum tube 46 and relay 62. As further increases in current in the anode circuit of vacuum tube 30 take place vacuum tubes 46, 47 and 48 and relays 62, 63 and 64 will be operated to close contacts 78 to 80 simultaneously and for a still further increase in current vacuum tubes 46 to 49, inclusive, and relays 62 to 65, inclusive, will operate to close contacts 78 to 81. When an elemental area of still lighter tone value is

scanned, current will commence to flow in the output circuit of vacuum tube 31 and in the output circuit of vacuum tube 50 so as to cause the operation of relay 66 to close contact 82. It is thus seen that we may divide the total range of picture tone values into 16 groups and the picture will be reproduced in 16 tone values, one corresponding to the range of tone values of each of the groups. When a black or very dark elemental area is scanned, relay 46 will operate; when an elemental area of slightly lighter tone value is scanned, relays 62 and 63 will operate simultaneously, etc. until all of the relays 62 to 77 are operated, in response to the scanning of a very light or white elemental area, to cause the closure of contacts 78 to 92 inclusive and the opening of contacts 93 to 98 inclusive.

When one or more of the relays 62 to 77 are operated, a circuit is completed from ground 9 through one or more of the leads 201 to 205 inclusive, through one or more of the punch magnets 1 to 5 inclusive of the tape perforator 99, to the grounded battery 100, thus causing the operation of different combinations of punch magnets 1 to 5 in accordance with the operation of the relays 62 to 77, inclusive, and punching code combinations in a tape 117 in accordance with the tone values of the successively scanned elemental areas of the picture 10. The motor 16 which drives the drum 11 and the light interrupting disc 18 also drives a cam operated punch 118 through gears 119 for punching the tape 117 with code combinations corresponding to the tone values of the successive elemental areas of the picture 10, one code combination being punched each time the light interrupting disc 18 makes a single revolution. The different combinations of punch magnets 1 to 5 which are energized in response to the operation of different groups of relays 62 to 77 respectively, are indicated in the following table:

Tone value of negative picture	Relays operated	Punch magnet energized
Black or very dark	62	1.
Do.	62 and 63	1 and 2.
Do.	62 to 64	1, 2 and 3.
Do.	62 to 65	1, 2, 3 and 4.
Do.	62 to 66	1, 2, 3, 4 and 5.
Do.	62 to 67	2, 3, 4 and 5.
Do.	62 to 68	3, 4 and 5.
Do.	62 to 69	4 and 5.
Do.	62 to 70	5.
Do.	62 to 71	1 and 5.
Do.	62 to 72	1, 2 and 5.
Do.	62 to 73	1, 2, 3 and 5.
Do.	62 to 74	2, 3 and 5.
Do.	62 to 75	3 and 5.
Do.	62 to 76	1, 3 and 5.
White	62 to 77	1, 3, 4 and 5.

The tape 117 is fed into a tape transmitter 120 which transmits code telegraph signals corresponding to the code punchings in the tape 117, over a telegraph conductor 121, such as a submarine cable, for example. Instead of punching a tape for controlling the transmission of a code signals over a line, the code combinations may be set up by means of relays taking the place of the punch magnets 1 to 5 which, together with a commutating device, control the transmission of the code signals directly without first punching a tape.

Any suitable system may be employed for reproducing a picture under control of the received code telegraph impulses. At the receiving station shown in Fig. 3, the code telegraph signals sent over line 121 are impressed upon a tape perforator 122 for controlling the punching of

code signals in a tape 123 to correspond with the punchings of tape 117 at the transmitting station. The tape 123 is fed into a tape transmitter 124 which is similar to the transmitter 120 at the transmitting station, for producing code signals which are impressed on one or more of the relays 101 to 105, inclusive, in accordance with the operation of the contacts of the tape transmitter 124. The combination of the relays 101 to 105, inclusive, which are energized in accordance with a given code signal, will correspond to the combination of punch magnets 1 to 5, inclusive, which are energized at the transmitting station for controlling the production of this code signal. One or more of the resistance elements 162 to 177 inclusive are short-circuited in accordance with the combination of relays 101 to 105 which are energized, the number of short-circuited resistance elements corresponding to the number of relays 62 to 77 which are energized at the transmitting station. The following table indicates the resistance elements which are short-circuited when various combinations of relays 101 to 105 are energized.

Tone value of positive picture to be reproduced	Relays operated	Resistance elements short-circuited
White	101	162.
Do.	101 and 102	162 and 163.
Do.	101, 102 and 103	162 to 164.
Do.	101, 102, 103 and 104	162 to 165.
Do.	101, 102, 103, 104 and 105	162 to 166.
Do.	102, 103, 104 and 105	162 to 167.
Do.	103, 104, and 105	162 to 168.
Do.	104 and 105	162 to 169.
Do.	105	162 to 170.
Do.	101 and 105	162 to 171.
Do.	101, 102 and 105	162 to 172.
Do.	101, 102, 103 and 105	162 to 173.
Do.	102, 103 and 105	162 to 174.
Do.	103 and 105	162 to 175.
Do.	101, 103 and 105	162 to 176.
Black or very dark	101, 103, 104 and 105	162 to 177.

The number of resistance elements which are short-circuited controls the amplitude of the current from a suitable source flowing through a light valve 178 to control the size of the light aperture therein. The source of current for actuating the light valve may, for example, be a source of alternating current 179 having a period which is low compared with the time required for reproducing a single elemental area of a picture. The tape 123 is fed into the tape transmitter 124 for causing the production of current impulses in relays 101 to 105 at a desired rate and a picture drum 180 which holds a light sensitive sheet 181 is driven at a corresponding rate under control of a driving motor 182 and the gears 183 and 184, respectively. Light from source 185 is directed upon a small spot of the light sensitive sheet 181 at any particular instant by means of the lenses 186 and 187. The picture drum is caused to rotate and at the same time to be moved slowly in an axial direction, similarly to the drum 11 at the transmitting station, to cause he successively illuminated spots on the picture receiving surface to describe, in effect, a helical path. The intensity of the light reaching successive elemental areas of the picture receiving surface 181 is controlled in accordance with the amplitude of the current flowing through the light valve 178 which in turn is controlled in accordance with the received code signals which determine the number of resistance elements 162 to 177 which become short-circuited by the action of the relays 101 to 105. A positive picture corresponding to the negative

picture 10 which is scanned at the transmitting station is therefore produced on the light sensitive surface 181. If desired, the relay circuits which control the short-circuiting of one or more of the resistance elements 162 to 177 could be rearranged so that a negative picture could be produced from a negative of the original picture, or so that a positive picture could be reproduced from a positive original.

The disc 18 for interrupting the scanning light beam from source 12 may be of the type shown in Fig. 4. This disc is of opaque material and has light transmitting apertures 13 arranged along a circular path near its periphery. These apertures may be of any suitable size and shape, but are preferably small and fairly closely spaced. It is often preferable to omit the apertures over a portion of its circle in order to cause all of the relays 62 to 77 inclusive to be restored to their unenergized condition between the periods of scanning successive elemental areas of the picture 10 and thereby reduce the possibility of false operation of the relays. A system employing such a device is described and claimed in a copending application of J. W. Horton referred to hereinbefore. The possibility of false operation of the relays may be further reduced by employing a light interrupting disc of the type shown in Fig. 5. This disc is similar to the one shown in Fig. 4 with exception that the apertures are omitted from a portion of the circular path indicated at 131 and that the apertures following this portion of the disc from which the apertures are omitted are of different size, respectively. The first aperture 132 is very small, the aperture 133 is slightly larger and the following apertures are of progressively increasing size up to the aperture 134. This aperture 134 and the remaining apertures are of constant size. In operation the disc is rotated in the direction indicated by the arrow. With such an arrangement the production of transient currents and the possibility of false operation of the relays 62 to 77 are avoided. The current in the circuit of the relay which is to be operated has a low amplitude at the beginning of this scanning period of each elemental area and this current gradually increases in amplitude until the current amplitude is reached at which the relay is designed to operate. If desired, the apertures of the scanning disc may all be of the same size and a film of progressively increasing transparency may be placed over some of the apertures following the portion 131 from which the apertures are omitted.

What is claimed is:

1. In an electro-optical image producing system, a source of current having an alternating component the amplitude of which corresponds to the tone values of successively scanned elemental areas of a field of view, an image of which is to be produced, a plurality of vacuum tube amplifying devices adjusted to operate over different ranges of impressed electromotive force, respectively, and having a common input circuit, means for impressing an electromotive force corresponding to the amplitude of the alternating component of said source of current upon said input circuit, a transformer for coupling the output circuit of each of said amplifying devices to the input circuits of a plurality of rectifying devices, an electromagnetic device in the output circuit of each of said rectifying devices and means under control of said electromagnetic devices for controlling the production of code signals corresponding to the tone values of the

successively scanned elemental areas of said field of view.

2. In an electro-optical system, a relay device which is adapted to operate when the electromotive force impressed upon it reaches a predetermined value, means comprising a source of light and a light sensitive device for varying over a range of values between fixed limits the electromotive force impressed upon said relay device, means for periodically interrupting the light from said source reaching said light sensitive device for causing said relay means to become inoperative and means for subsequently increasing in steps the intensity of the light from said source reaching said light sensitive device to cause the operation of said relay device when light of a predetermined intensity reaches said light sensitive device.

3. A code telegraph picture transmission circuit comprising a plurality of relays for controlling the selection of code signals to be transmitted, and means for controlling the operation of said relays, said means including a source of light, a light sensitive device and an apertured rotatable element the apertures of which have non-uniform light transmission characteristics for interrupting the light from said source reaching said light sensitive device.

4. In an electro-optical image producing system, a source of alternating electromotive force the amplitude of which varies in accordance with the tone values of elemental areas of an object an image of which is to be produced, a plurality of vacuum tube relays having a common input circuit connected to said source of alternating electromotive force, and a plurality of separate output circuits, one for each of said vacuum tube relays, said vacuum tube relays being differently biased, respectively, for producing alternating electromotive forces of a predetermined amplitude in said output circuits respectively in response to alternating electromotive forces of different amplitudes impressed upon said common input circuit.

5. In an electro-optical image producing system, a source of alternating electromotive force the amplitude of which varies in accordance with the tone values of elemental areas of an object an image of which is to be produced, a plurality of vacuum tube relays having a common input circuit connected to said source of alternating electromotive force, a plurality of separate output circuits, one for each of said vacuum tube relays, said vacuum tube relays being differently biased, respectively, for producing alternating electromotive forces of a predetermined amplitude in said output circuits respectively in response to alternating electromotive forces of different amplitudes impressed upon said common input circuit, and a plurality of groups of vacuum tube relays each group comprising a plurality of differently biased vacuum tube relays having a common input circuit, said common input circuits being connected to different of said separate output circuits respectively.

6. In a code telegraph image producing system, a source of alternating electromotive force the amplitude of which varies in accordance with the tone values of elemental areas of an object an image of which is to be produced, a plurality of vacuum tubes having separate input circuits, a plurality of electromagnetic relays each designed to operate in response to energizing current of the same amplitude connected in the output circuits of different vacuum tubes respectively, and

means controlled by the electromotive force of said source for simultaneously operating a plurality of said electromagnetic relays, the combination of relays operated being determined in accordance with the amplitude of the alternating electromotive force of said source.

7. In a code telegraph system, a source of alternating electromotive force the amplitude of which varies in accordance with the tone values of elemental areas of an object an image of which is to be produced, a plurality of electromagnetic relays, means comprising a plurality of

vacuum tubes differently biased, respectively, and having a common input circuit connected to said source of alternating electromotive force for causing the operation of different combinations, respectively, of said relays in accordance with the amplitude of the alternating electromotive force of said source, and means comprising a plurality of transformers for associating the output circuits of said vacuum tubes with said electromagnetic relays.

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15	90
20	95
25	100
30	105
35	110
40	115
45	120
50	125
55	130
60	135
65	140
70	145
75	150