

July 9, 1935.

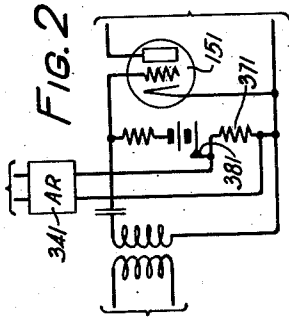
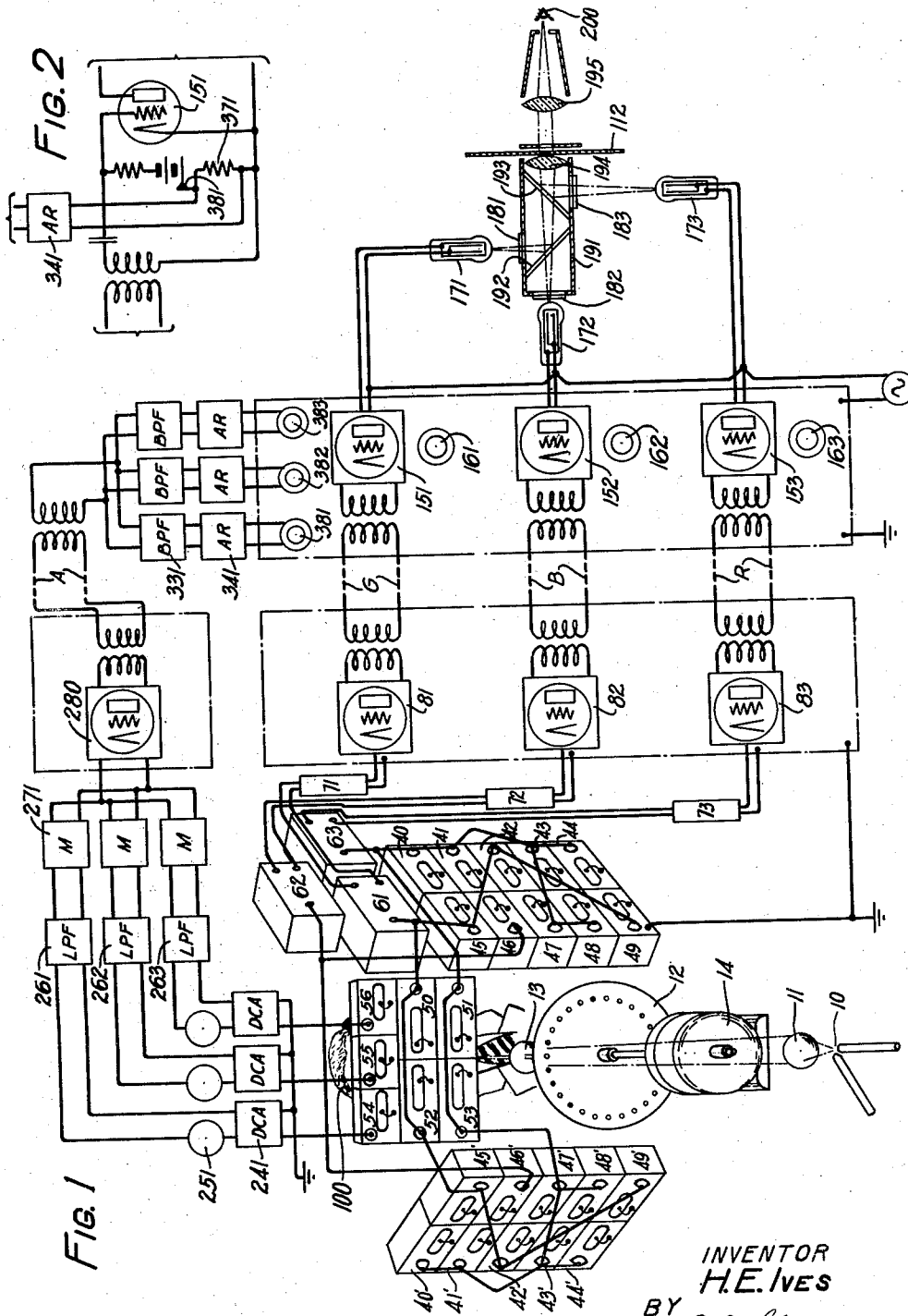
H. E. IVES

2,007,651

ELECTROOPTICAL SYSTEM

Filed Oct. 25, 1929

2 Sheets-Sheet 1



INVENTOR
H.E. Ives
BY *C. A. Sprague*
ATTORNEY

July 9, 1935.

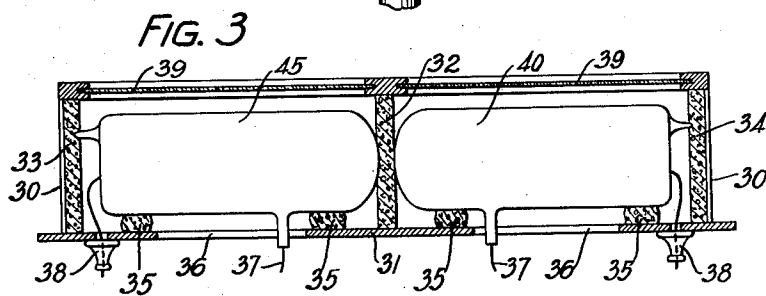
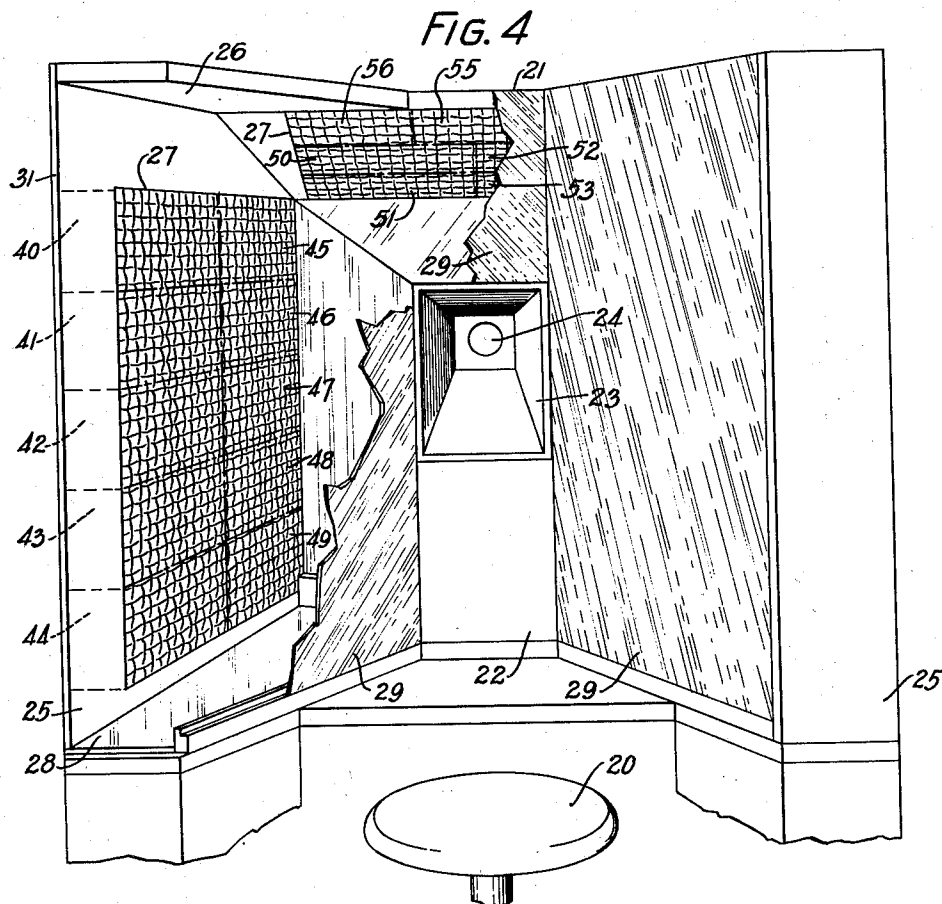
H. E. IVES

2,007,651

ELECTROOPTICAL SYSTEM

Filed Oct. 25, 1929

2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,007,651

ELECTROOPTICAL SYSTEM

Herbert E. Ives, Montclair, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application October 25, 1929, Serial No. 402,520

14 Claims. (Cl. 178—6)

This invention relates to electro-optical systems and more particularly to a system for electrically producing images of objects in their natural colors.

5 Heretofore it has been known that by suitably controlling and observing light from a plurality of sources of suitably colored light, images in the natural colors of remote objects could be produced. Such a system is disclosed in a patent
10 to H. E. Ives, No. 1,878,147, September 20, 1932. In this system three light sources corresponding to three primary colors are separately controlled by corresponding image currents produced by the scanning of the object, an image of which is to
15 be produced. Beam scanning is employed in which an intense beam of white light is caused to illuminate successively the elemental areas of the scanned field. The light reflected from the illuminated areas is picked up by light sensitive devices to produce the image currents for
20 each primary color channel.

In the three color process of image production employed in the foregoing system, the color of each elemental area of the image is determined
25 by the relative luminosity of the particular primary colors used at the receiver. One set of primary colors would require one relationship; a different set, another relationship. The graphs showing this relationship constitute the "color mixture curves" for the primary colors. Since
30 the luminosity of the primary colors is controlled by the image currents and the image currents are produced by the light sensitive devices, the relative response of each device for each color channel throughout the spectrum corresponds to
35 the color mixture curve for the corresponding primary color. The required response may be obtained by coordinating the photoelectric cell response with the light transmission characteristic of the filter used therewith.

Furthermore in the Ives system referred to above the direct current and lower frequency components of the image currents of each color channel are suppressed in order to facilitate the
45 amplification and transmission of the higher frequency components, which are characteristic of the details of the image. The direct current and low frequency components are characteristic of the average tone value of the field of view. Their
50 suppression at the transmitter is compensated at the receiver by adjustment of the average luminosity of each primary color, a convenient method being to adjust the direct current bias of the last amplifier tube which furnishes current to the discharge lamp. The reasons for

suppressing the direct current and low frequency components of the image currents are fully explained in an application of H. E. Ives and Frank Gray Serial No. 181,511, filed April 6, 1927.

The present invention is an improvement upon
5 prior systems for the production of images of pictures or moving objects in their natural colors, wherein image currents for controlling a plurality of primary colors are separately produced and utilized.

One feature of the invention is a system in which an indicator shows the amount of direct current which must be inserted for each color channel to compensate for the suppression of the
10 direct current and low frequency components in the corresponding color channels. This compensation may be effected automatically, and a separate set of photoelectric cells is preferably used for this purpose.

Another feature is a system having a diffusion
20 screen in front of the color sensitive cells to prevent color shadows in the produced image. In this system a beam of substantially white light is used to illuminate successively the elemental areas of the object, the reflected light from each
25 area after passing through the diffusion screen impinging upon a plurality of groups of color selective photoelectric cells and filters, the spectral response of each group coinciding substantially with the mixture curve of the corresponding
30 color of the selected set of primary colors.

Another feature is the combination of primary color sources in which a neon cathode glow lamp is used for the red, and argon cathode glow lamps, for the green and blue, each with a suitable color
35 light filter.

Still another feature is the method of adjusting a system in which the suppression of the direct current and low frequency components is compensated by the introduction of direct current at the receiver, the method comprising adjusting the direct current component for each
40 primary light source to produce good white light, the alternating image currents meanwhile being cut off, and then applying and adjusting the alternating image currents from a black and white
45 test object until the image appears correspondingly black and white.

An embodiment selected to illustrate the invention is a trichromatic television system of the
50 beam scanning type having three direct transmission channels for the higher frequency components of the image currents of each primary color channel and three modulated carrier current channels for the transmission of the direct
55

current and lower frequency components. Each carrier current channel is substantially like the carrier current channel for the direct current and lower frequency components of the image currents of Patent No. 1,671,302 issued to R. C. Mathes, May 29, 1928, except that the average tone value of which these components are representative, is the average tone value for the corresponding primary color. The primary color sources at the receiver are three high intensity glow discharge lamps, a neon lamp for the red, and two argon lamps, one each for the green and blue. Appropriate color filters are used with each source to approximate Maxwell's primary colors, the response of the photoelectric cells with the associated color filters being determined by Maxwell's color mixture curves. The color sensitive photoelectric cells are arranged in three banks somewhat in front of the object field, one bank on either side, and one above. Cells for each of the primary color channels appear in each bank in order to prevent color shadows in the produced image. In order further to obviate color shadows diffusing screens are placed between the object and each bank of cells. A separate set of cells one corresponding to each of the primary colors is located in the upper bank for controlling the average luminosity of each of the primary colors. The control may well be effected however by segregating the direct current and low frequency components produced by the main cells in a manner obviously similar to the method of separation described in the Mathes patent, supra.

The invention finds its greatest field of usefulness in connection with television, but its scope is defined by the appended claims.

A more detailed description of the invention follows and is illustrated in the accompanying drawings:

Fig. 1 is a schematic representation of the optical and electrical circuits of a three-channel television system arranged for producing images of objects or pictures in their natural colors.

Fig. 2 is a circuit detail showing certain features in connection with the automatic control of the grid bias of the amplifiers at the receiving station.

Fig. 3 is an elevation partly in section of a photoelectric cell compartment containing two cells.

Fig. 4 is a perspective view partially broken away of the cabinet and mounting arrangement for the light sensitive cells at the transmitting station.

Referring to Fig. 1 the apparatus in the left half of the drawings is at the transmitting station and that in the right half of the drawings is at the receiving station and the two stations are interconnected by suitable transmission channels.

The object or subject 100 an image of which is to be produced in natural colors, is illuminated spot by spot by means of an intense beam of white light. The light successively reflected from the elemental areas of the object is picked up by means of color selective light sensitive cells. Light from a source 10 is directed by means of lens 11 onto the scanning field of a scanning disc 12 and through an aperture of the scanning disc and the lens 13 to the object being scanned. The scanning disc is rotated by a synchronous driving motor 14. The object being scanned is positioned in a suitable cabinet in which is mounted on three sides light sensitive cells 40, 41, 42, 43, 44, 45, 46, 47, 48 and 49 to the left of the object,

light sensitive cells 40', 41', 42', 43', 44', 45', 46', 47', 48' and 49' to the right of the object and light sensitive cells 50, 51, 52 and 53 at the top. These 24 cells are divided into groups which are color selective. Light sensitive cells 40, 41, 43, 44, 47 and 48 and the correspondingly positioned cells on the opposite side and cells 51 and 53 are relatively responsive through the spectrum according to the color mixture curve of the red primary color. Light sensitive cell 46 and the corresponding cell on the opposite side are responsive according to the color mixture curve of the blue primary color and cells 42, 45 and 49 and also the corresponding cells on the opposite side and cells 50 and 52 are responsive according to the color mixture curve of the green primary color. These light sensitive cells may be inherently color selective or the color selectivity may be obtained by color filters positioned in the front of the cell containers. All of these cells having the green filters are connected in parallel, as shown, and to a common amplifier 61. Similarly, the cells having blue filters are connected in parallel and to a common amplifier 62, and the cells having red filters are connected in parallel and to a common amplifier 63. These three groups are connected through the delay circuit networks 71, 72 and 73, respectively, whose function will be described later, to amplifiers 81, 82 and 83 and these amplifiers are in turn connected to three transmission lines G, B and R respectively.

The arrangement of the photoelectric material with respect to the field of view to be scanned is seen to differ from that heretofore employed according to which the light sensitive material is distributed forwardly of the field. In the preferred arrangement herein described and illustrated the photoelectric material extends backward from the front of the field in such a distance that portions of it lie at the sides of the object or objects in the field so that a large part of the light reflected from the scanned elemental areas which are most remote from the front of the cabinet will be collected by the light sensitive material. If all of the light sensitive material is near the front of the field relatively less light from these remote areas reaches the photoelectric material than from the elemental areas which are near the front of the field. That is, when the head of a person, for example, is being scanned it is necessary for best results that the photoelectric material lie both to the sides of the person's head and well in front thereof. This has not been the practice heretofore with the result that the sides of the head in the image appear dark and indistinct as though insufficiently illuminated. For the most natural reproduction it is essential also that the light sensitive material be so distributed that a considerable portion of it lies above the subject and near the front wall of the cabinet or the front of the field. It is desirable also that the photoelectric material be positioned not only at the sides or rear of the field but that it extend from there forwardly to the front of the field. This has the advantage of improving the image when there are several objects in the field or when a position of the object or objects is changed within the field in a general direction of the scanning beam. The same principles of distribution of the photoelectric material or means for receiving the reflected light of course apply to any field which is being scanned regardless of its size. Obviously, if the depth of the field of view to be scanned is increased the photoelectric material which is above

and at the front of the field should be somewhat extended toward the rear of the field, the same proportion of distribution being preferably maintained as in the smaller field of view herein illustrated.

At the receiving station the currents transmitted over the three channels are received respectively by the amplifiers 151, 152 and 153 and the amount of amplification is governed by the controls 161, 162 and 163. The amplified currents are supplied to glow discharge lamps 171, 172 and 173, respectively. These lamps are of the type disclosed in a patent to H. W. Weinhart, No. 1,926,889, Sept. 12, 1933. Light emitted from these lamps is passed respectively through color filters 181, 182 and 183 to produce the primary colors green, blue and red, which when combined in the proper amounts produce a good quality of white light. Lamps 171 and 172 are filled with argon gas and lamp 173 is filled with neon gas at low pressure. Any other suitable known light sources may be substituted for those here shown. Light from these three sources after passing through the color filters is directed into a common path by means of transparent mirrors 192 and 193 in the chamber 191. The composite or mixed beam of light comprising the three primary colors is transmitted through the lens 194, scanning disc 112 and lens 195 to the point of observation 200. The scanning disc 112 at the receiving station is similar to the scanning disc 12 at the transmitting station. Synchronism between the two scanning discs may be maintained by any suitable means such as the system disclosed in patent to H. M. Stoller and E. R. Morton, No. 1,763,909, June 17, 1930.

In this system the direct current and low frequency components of the photoelectric currents are suppressed at the transmitting station and their absence is compensated at the receiving station by means of suitable adjustments of the receiving circuit. This may be done manually or automatically by adjusting the grid biases of the receiving amplifiers in the several color channels, as the general color tone of the field of view of the object whose image is being transmitted changes. Instructions for making these adjustments manually may be transmitted by the transmitting operator to the receiving operator over a telephone line, not shown. As was the case prior to this invention the transmitting operator may simply describe the general color tone of the object an image of which is being produced or according to the present invention give instructions based on current readings obtained from instruments in the different photoelectric cell circuits at the transmitting station. If the latter information is given the dial at the receiving station for adjusting the grid biasing of the three amplifiers may be calibrated so that the receiving operator simply sets them to the current readings given by the transmitting operator. An arrangement for automatically adjusting the grid biases is shown in the drawings. The effect of the direct current and low frequency components which are not transmitted by the main transmitting channels are impressed upon the receiving apparatus by means of a second set of transmission channels which are controlled either by the main or an auxiliary set of photo-electric cells at the transmitting station. This correcting current, comprising the direct current and low frequency components of varying amplitude, may be obtained from auxiliary photoelectric cells 54, 55 and 56, corresponding to the green, blue and red

primary colors respectively. These cells are likewise relatively responsive through the spectrum according to the color mixture curves of the primary colors. The current from cell 54 after being amplified in the direct current amplifier 241 which has as much amplification as can be reasonably maintained is passed through milliammeter 251, low pass filter 261 having a cut-off at about 10 or 15 cycles per second so that the current coming out of it represents the average value of the variations over a period of time at least equal to the flicker time, the flicker time being substantially the same as that of the persistence of vision. It may be desirable to average the current over a somewhat longer period of time as in the case when the cut-off of the low pass filter 261, is, say 10 cycles per second. The current passed by the filter 261 is transmitted to the oscillator modulator 271 where it modulates a suitable carrier current. The modulated carrier current passes to the common amplifier 280 and then to the transmission line A for transmission to the receiving station, where it is impressed upon a band pass filter network 331, through which it passes to the amplifier-rectifier 341. As a result an amplified direct current correcting current of suitable strength passes through the resistance 371 (see Fig. 2) in the grid circuit of the last tube of the receiving amplifier 151 in one of the main transmission channels. The varying direct current passing through the resistance 371 from the correcting channel varies the biasing or the operating point on the characteristic curve of the last amplifier tube and thereby effects the insertion of the correct direct current component to compensate for the suppressed direct current and low frequency components at the transmitter. The correcting current transmitted by the low pass filter 261 is of low frequency and consequently causes a low frequency variation in the carrier current amplitude thus permitting the use of a transmission channel having a narrow frequency band.

Two other correcting channels originating with the light sensitive cells 55 and 56, similar to that originating with light sensitive cell 54 and above described are shown thus serving each of the three main channels. By this arrangement of automatically biasing the last stage in the receiving amplifiers, substantially the same effect is produced as would occur if the low frequencies could be directly transmitted over the main transmission channels. The different correcting currents are transmitted by different carrier frequencies in the arrangement shown. However, separate transmission circuits might be provided for the transmission of each of these three correcting currents and the separating filters at the receiving station eliminated. As a further modification these three transmitting circuits might transmit directly without the use of carriers, provided the transmission circuits are capable of directly transmitting the direct current and very low frequency components. Such circuits, however, over considerable distances are not usually commercially available and for this reason recourse to carrier current circuits would in most cases be preferable. Manual adjustment of the grid bias is provided for by means of the variable contact control 381.

The low frequency correcting currents transmitted over the correcting current transmission channels should be received substantially in phase with the higher frequency currents transmitted over the main transmission channels. An

arrangement for accomplishing this and thus obtaining the most correct production of the received images consists of introducing a delay circuit network at some point in the main transmission system. Such compensating delay circuit networks 71, 72 and 73 are shown in each of the three main transmission channels at the transmitting station and they are designed to operate in cooperation with the low pass filters 261, 262 and 263 in the low frequency correcting transmission channels. The latter, which are essential elements in the low frequency channels for the direct current components, cause transmission lag in these circuits. The delay circuit networks in the main transmission circuits are designed to introduce a corresponding lag in the high frequency transmission channels so that there is substantially no time displacement between the alternating current components and the corresponding shifts in the value of the direct current components transmitted by the corresponding high frequency and low frequency channels, respectively, upon reaching the receiving station. These delay circuit networks in general comprise a filter network of the low pass type. An acoustical arrangement suitable for this is shown in a patent issued to R. C. Mathes, No. 1,696,315, issued December 25, 1928. These compensating delay circuit networks might be located at the receiving station. They may even be omitted, as it will be an uncommon occurrence for the character of an object or scene to change so largely and so suddenly as to produce serious disturbing effects, though in a multiple channel system such as a color transmission system this refinement is more desirable than in a single channel or even a multiple channel monochrome system. Such a disturbing effect would appear as an incorrect average tone value lasting only for the time of the delay introduced in the correcting circuit, while the details of the picture would come through correctly.

The auxiliary light sensitive cells 54, 55 and 56 controlling the correcting circuits need not have the highest speed of action. In fact, a sluggish cell having a high sensitivity may be preferable since if it is possible to employ cells so sensitive that the current with a small amount of amplification is large enough for transmission it may be transmitted over direct current telegraph circuits and amplified at the receiving station.

Fig. 3 shows the mounting arrangement of the photoelectric cells, showing for example, two cells 40 and 45. A box-like container 30 is mounted upon the vertical wall 31 of the cabinet shown in Fig. 4. The photoelectric cells are supported in the container by a sponge rubber partition 32 which serves as a partial support for the cells 40 and 45. The other ends of the cells are supported at the container ends by sponge rubber inserts 33 and 34. Sponge rubber elements 35 in the form of segments of a circle support the cells at the bottom, rear and top. Slots 36 are provided in the back of the housing 31 to provide a partial view of the cells from the outside of the cabinet and to provide for attachment of the leads 37. The other terminals of the photoelectric cell are brought out through the insulators 38. Color filters 39 form the front of the cell compartment and different color filters may be selected so as to provide a different color grouping such as heretofore disclosed in Fig. 1.

The relative position of an object or subject, an image of which is to be produced, the light sensitive cells and the scanning beam is gener-

ally shown at the transmitting station in Fig. 1. Further details of a cabinet in which the light sensitive cells are supported and positioned in an arrangement to most advantageously receive reflected light from the elemental areas of the object being scanned is shown in Fig. 4. The arrangement is particularly applicable to television transmission in systems in which an intense beam of light from any suitable source is caused to traverse the person or other object scanned in parallel adjacent lines, the light reflected from the object being collected by photoelectric cells covering a large area.

It has been found that the generation of photoelectric currents especially in scanning three dimensional objects is more likely to fall within the range of the straight line characteristic of the amplifying apparatus by placing a portion at least of the light sensitive cells on the side walls or top or bottom of the cabinet or both, rather than having all of the cells in front of the subject. This arrangement permits considerable freedom in the position of the object without greatly varying the signal strength. In a preferred arrangement one group is at the right of the subject, one at the left and one above. The cells at the right and the left may be arranged in vertical planes coincident with or parallel to the sides of the cabinet and the one at the top may be in a horizontal plane. A preferable arrangement is to have all the planes converge somewhat towards the front of the cabinet. Mirrors may be employed within the cabinet to increase the amount of light gathered by the cells from the subject. As shown in Fig. 4 the cabinet or booth 21 comprises the front wall 22 on the sides of which is a box-like arrangement 23 having an opening 24 through which the scanning beam is projected. At each side of the cabinet is a compartment 25 containing photoelectric cells and additional cells are placed in the compartment 26 in the top of the cabinet. A seat 20 may be provided for the person being scanned. A bank of cells 40 to 49 is provided in compartment 25 at the left, as shown and a similar bank 40' to 49', not shown, is placed in compartment 25 at the right. Similarly, a bank of cells 50 to 56 are contained in compartment 26. The light sensitive cells are electrically screened by grounded metal housings with open wire mesh 27 in front of them. Improved results are obtained by the use of mirrors 28, which direct light to the photoelectric cells which would otherwise not reach them. In order to better distribute the light reflected from the object to the photoelectric cells translucent screens 29 are placed between the object and the light filters. Such screens may be made up of two thicknesses of glass of the kind in which one surface is plain and the other ribbed, with the ribs running in different directions, preferably at right angles to each other. Such a screen effectively distributes the light, and avoids color patches which are sometimes apparent in the produced image due to the large size of the light filters associated with the light sensitive cells and the proximity of the subject unless means are provided to distribute and diffuse the light.

The operation of the color television system of this invention may best be understood by following through the sequence of operations in receiving an image. The receiving apparatus is initially adjusted, with the higher frequency components of the image currents interrupted, by regulating the current through the three receiv-

ing lamps 171, 172 and 173 so that their superposed light appears white in color. This is done partly by varying the amount of the direct current components by means of the controls 381,

382 and 383 upon which the higher frequency components from the sending station are finally superimposed and partly by properly selecting mirrors 182 and 183 of different reflecting powers or light filters 181, 182 and 183 of proper densities. As a result of this adjustment a good white light should be obtained with the current to each lamp at a convenient value with respect to its range of adjustment and in the region of the mid point on the straight line characteristic of the last stage amplifier tubes. With this condition attained the higher frequency components of the image currents resulting from the scanning of a black and white test object at the transmitting station are introduced and their strengths adjusted by means of the controls 161, 162 and 163 until the image appears black and white. When this adjustment has been made and a colored test object placed in position at the transmitting station, the image will appear approximately correct in color if the average tone of the field corresponding to each primary color is of substantially average value. The compensating circuits are next completed and adjusted to maintain proper tone rendering as the average tone of the scanned field changes.

Failure to compensate for the suppression of the direct current and low frequency components of the image currents may be illustrated by assuming that the black and white test object previously mentioned is replaced by a uniformly colored field. Since there is no alternating current signal transmitted when scanning an object field of uniform color, the produced image at the receiving station will appear white. Similarly, if the average color of the whole field is altered when colored objects are being scanned, an adjustment must be made in the direct current components alone. Consequently, the only adjustment which need be made as different colored objects are introduced once the black and white object has been properly adjusted for, is the control of the direct current components at the receiving station. In the illustrative arrangement of this invention direct current components of the proper values are automatically provided.

In general the rendering of tone values and of image details must be far more accurate for color television than for monochrome television. If, for instance, the image currents for one of the primary colors causes the corresponding amplifier tube to operate over the curved portion of its grid voltage or plate current characteristic, but not in the case of the other two primary colors, spurious colors will be introduced. Similarly, if one primary color image contains more marked transients or degradation of edge sharpness than another, color fringes result. Another source of error occurs with objects which are scanned in the round, such as the human face, if the diffusion of light to the photoelectric cells is insufficient. In this instance the image shows color shadows and highlights exactly in the same manner as it would if the object were illuminated by colored lights whose illumination is not properly mixed before falling on the object. In the arrangement shown for generating the photoelectric currents at the transmitting station, special provision is made in the distribution and positioning of the photoelectric cells and in the light distributing and diffusing means to eliminate the difficulties

due to improper illumination of the object and for the control of the photoelectric currents.

What is claimed is:

1. In an electro-optical system for producing images of pictures or moving objects in their natural colors, a plurality of primary color sources, means to produce image currents corresponding separately to each of said sources, said image currents comprising direct current and lower frequency components and higher frequency components and the relative proportions of said currents corresponding to the color mixing proportions of the primary colors of said sources, means to suppress the direct current and lower frequency components, means to control the light from each of said sources by the higher frequency components of the corresponding image currents, means to separately control the light from each source to compensate for the suppressed direct current and lower frequency components, means to continuously determine the amount of compensating control, and means to combine the light from said sources to produce the image in natural colors.

2. In a television system for producing images of objects in their natural colors, a plurality of primary color sources, means to produce image currents corresponding separately to each of said sources the relative proportions of said currents corresponding to the color mixing proportions of the primary colors of said sources, means to transmit the higher frequency components of said image currents over one set of transmission channels, means to transmit the direct current and lower frequency components over another set of channels, and means to control each primary color source by both the direct current and lower frequency transmitted components and the higher frequency transmitted components to produce the image.

3. In a television system for producing images of objects in their natural colors, three sources of primary colors light from which when viewed together in suitable amounts appears white, a light reactive device corresponding to each primary color source, the relative response of said devices through the spectrum corresponding respectively to the color mixture curve of the corresponding primary color, means to direct light to said devices which is reflected from successively scanned elemental areas of an object field to produce image currents, means to transmit the higher frequency components of said image currents over one set of transmission channels, means to transmit the direct current and lower frequency components over another set of channels, and means to control each primary color source by the transmitted components of both the direct current and lower frequencies and the higher frequencies to produce the image.

4. In an electro-optical system for producing images of pictures or objects in their natural colors, three sources of primary colors, light from which when viewed together in suitable amounts appears white, a light reactive device corresponding to each primary color source, the relative response of said device through the spectrum corresponding respectively to the color mixture curve of the corresponding primary color, means to direct light to said devices characteristic of the color of successively scanned elemental areas of the picture or object field to produce image currents, means to transmit the higher frequency components of said image currents over one set

of transmission channels, means to transmit the direct current and lower frequency components over another set of channels, and means to control each primary color source by both the corresponding direct current and lower frequency transmitted components and the higher frequency transmitted components to produce the image.

5. In a television system for producing images of objects in their natural colors, three sources of primary colors, light from which when viewed together in suitable amounts appears white, a pair of light reactive devices corresponding to each primary color source, the relative response of said devices through the spectrum corresponding respectively to the color mixture curve of the corresponding primary color, means to direct light to said devices characteristic of the color of successively scanned elemental areas of the object field to produce image currents, means to transmit the higher frequency components of the image currents of one device of each pair over a set of transmission channels, means to transmit the direct current and lower frequency components of the other device of each pair over another set of channels, and means to control each primary color source by both the corresponding direct current and lower frequency transmitted components and the higher frequency transmitted components to produce the image.

6. In a television system for producing images of objects in their natural colors, three primary color sources, a photoelectric cell corresponding to each primary color, a light filter associated with each cell, the relative response of said cells through the spectrum to light incident thereon after passing through the associated filters corresponding respectively to the color mixture curve of the corresponding primary color, means to illuminate an object field with white light and to direct reflected rays from successively scanned elemental areas upon said cells through said associated filters to produce image currents, means to transmit the higher frequency components of said image currents over one transmission system, means to transmit the direct current and lower frequency components over another transmission system, and means to control each primary color source by the transmitted components of both systems to produce the image.

7. A color television system comprising a plurality of color selective light sensitive cells each responsive according to the color mixture curve of a primary color of a set of primary colors, means associated therewith at a transmitting station for suppressing the direct current components of the photoelectric currents generated and for transmitting the fluctuating current components of said cells, a second plurality of color selective light sensitive cells each responsive according to the color mixture curve of a primary color of the same set of primary colors, means associated with each of said second set of cells at the transmitting station for suppressing the fluctuating current components and for transmitting the direct current components for each of said second set of cells, and means for utilizing the effects of all of the transmitted current components in the production of an image in natural colors.

8. In a television system, means for producing image currents corresponding to a plurality of primary colors used to produce an image of an object comprising means for traversing a beam of light over the object, banks of light sensitive elements for receiving light reflected from the

object, different sets of said light sensitive elements producing image currents corresponding to different ones of the plurality of primary colors and a light diffusing screen located between said object and said light sensitive elements.

9. In a television system, means for scanning an object comprising means for traversing a beam of light over the object and banks of light sensitive elements for receiving light reflected from the object, a light filter for each of said light sensitive elements, one portion of said filters transmitting one primary color, a second portion a second primary color, and the remaining portion a third primary color, and translucent material between said object and said light filters to assist in equalizing the distribution of light to said filters.

10. In a television system, means for scanning an object comprising means for traversing a beam of light over the object, a large light sensitive surface for receiving light reflected from the object, a filter between said surface and said object for transmitting a primary color, and a translucent screen between said filter and said object comprising two sheets of ribbed glass, the ribs of one sheet being at an angle to those of the other to assist in equalizing the distribution of light to said filters.

11. In a television system means to produce an image of an object in natural colors, comprising a neon glow discharge lamp with filter to produce red light, an argon glow discharge lamp with filter to produce green light, and another argon glow discharge lamp with a different filter to produce blue light, the light of each of said colors comprising radiations of a narrow range of wave lengths, and means to combine said colored light to produce the image.

12. The method of operating a television system for producing images of pictures or moving objects in their natural colors, said system comprising a plurality of primary color sources, means to produce image currents corresponding separately to each of said sources, the direct current and lower frequency components of each of said image currents being suppressed and the higher frequency components being used to control the primary color sources for the production of the image, and means to compensate for the suppressed components by separately controlling the primary color sources, which method comprises interrupting the control of the primary color sources by the higher frequency components of the image currents, setting the compensating means to approximately the midpoint of its operating range, adjusting the intensity of the light from each primary color source to produce a good white light by the combined light from said sources, superposing the higher frequency components and adjusting the amount of control exerted by the higher frequency components of the image currents produced by the scanning of a black and white test object until the image appears correspondingly black and white.

13. Television apparatus for scanning three dimensional objects comprising a light source, means including said light source for producing a moving beam of light for successively and repeatedly illuminating elemental areas of the object or objects in a three dimensional field of view, means for setting up image currents including means for receiving light from within a large solid angle reflected from said object or objects at each instant, which means simultaneously selects the primary color components from different por-

tions of said received light, and optical means for compensating in part at least for unequal intensity of said portions of received light.

14. An electro-optical system for producing an
5 image of an object in its natural colors, comprising three lamps having discontinuous spectra and which respectively emit light of different primary colors which if combined in proper amounts will produce white light and light of the
10 various colors of a continuous spectrum, light

filters associated with said lamps for passing respective primary color bands of wave lengths, means for impressing incoming image currents upon said lamps to control the amount of light emitted therefrom and at times to cause two of
5 said lamps to emit light simultaneously within the respective bands of their associated filters, and optical means for mixing the light from said filters.

HERBERT E. IVES. 10