

April 14, 1936.

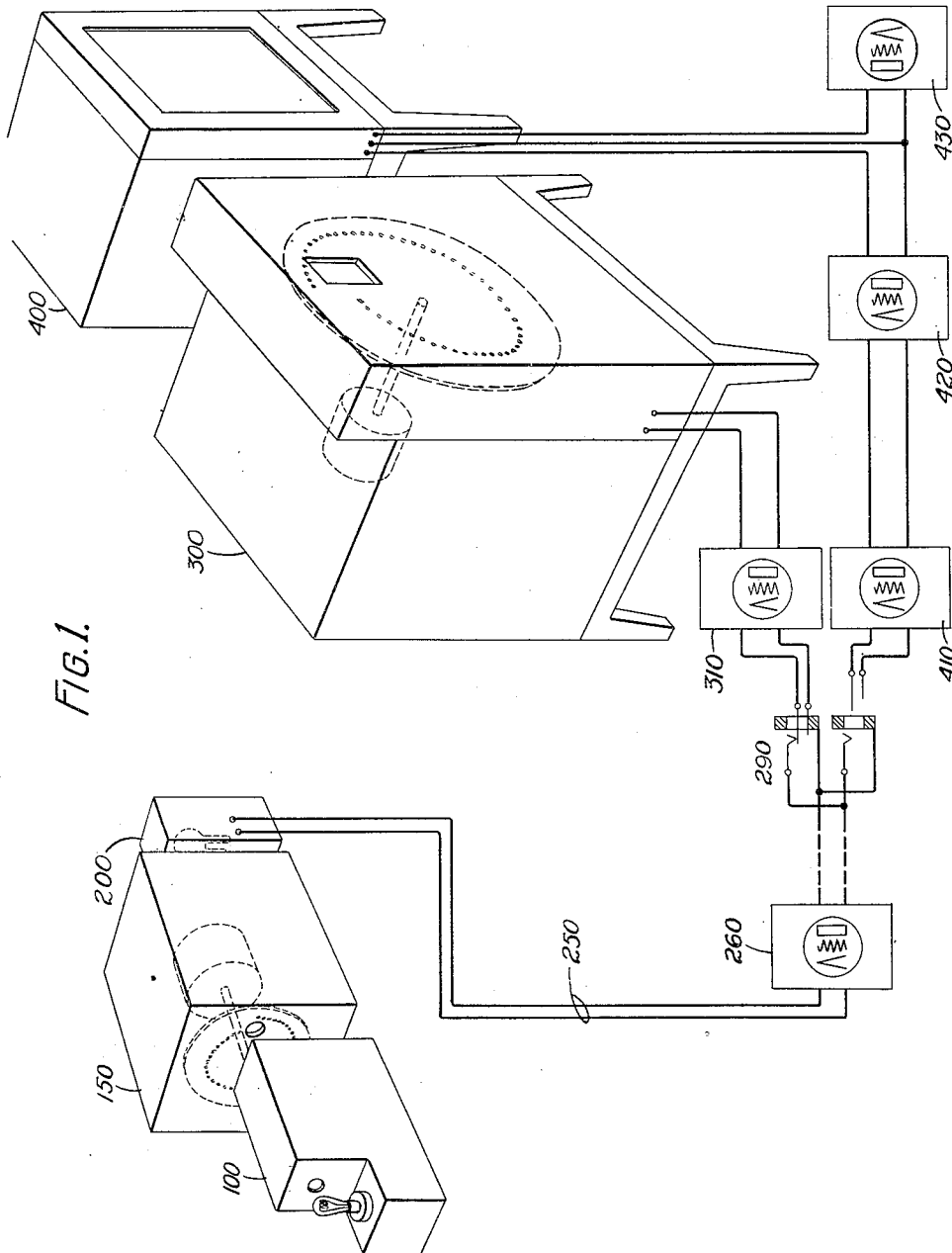
H. E. IVES ET AL

2,037,471

ELECTROOPTICAL SYSTEM

Filed April 6, 1927

4 Sheets-Sheet 1



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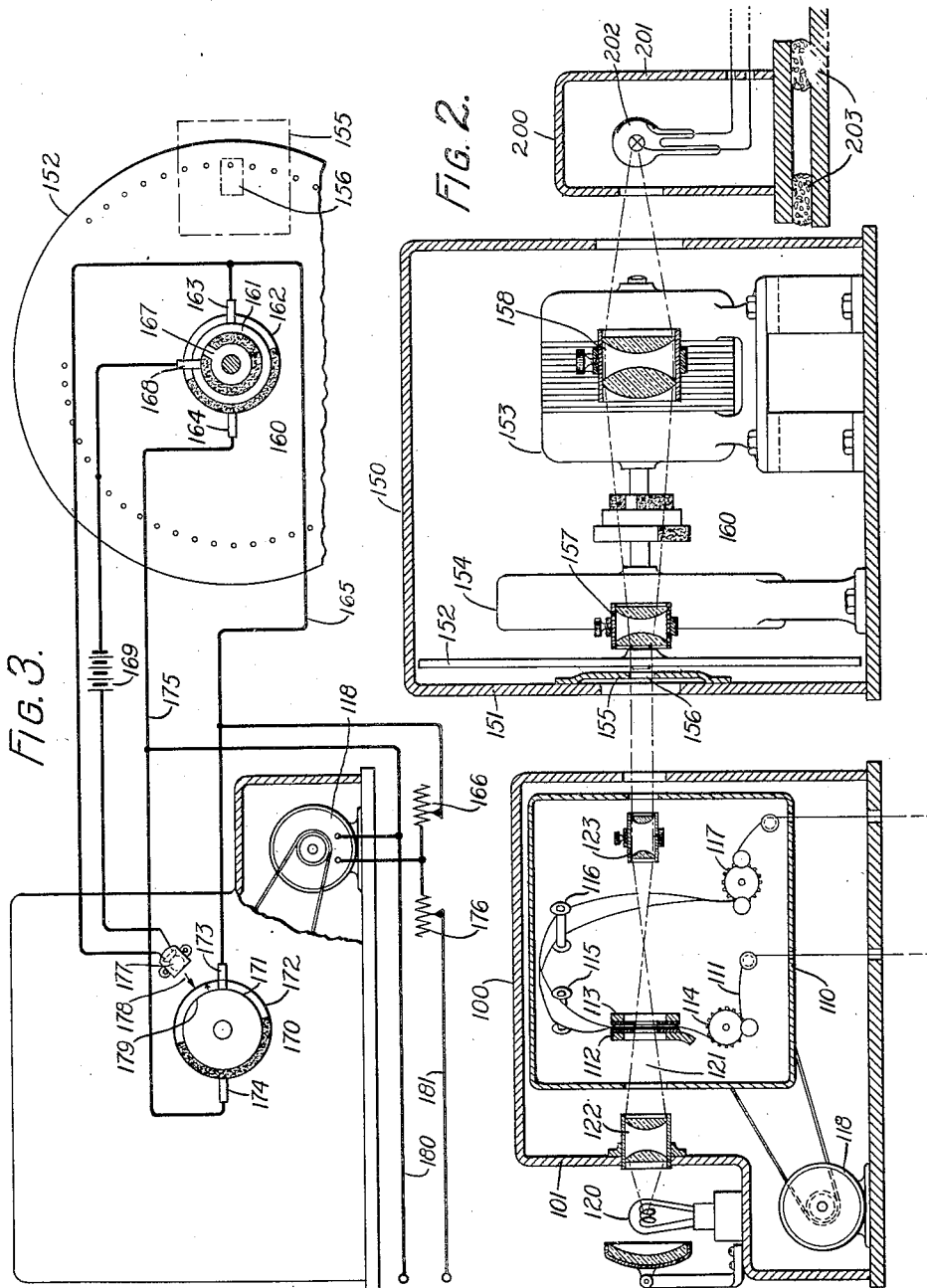
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4 Sheets-Sheet 2



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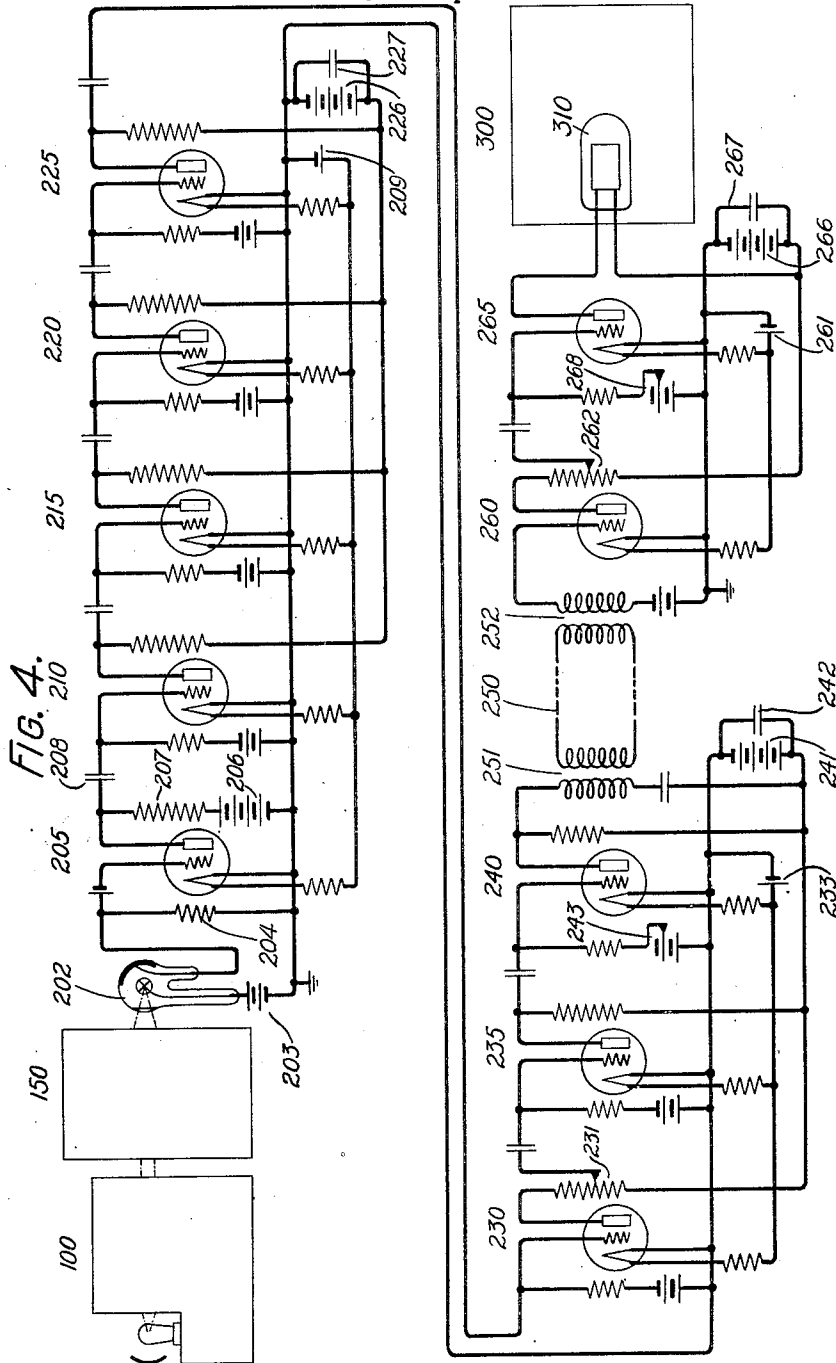
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ELECTROOPTICAL SYSTEM

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4 Sheets-Sheet 3



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Filed April 6, 1927 4 Sheets-Sheet 4

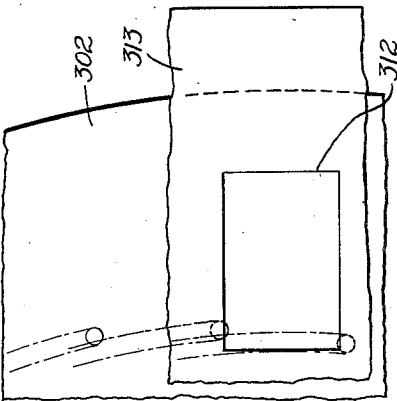


FIG. 7.

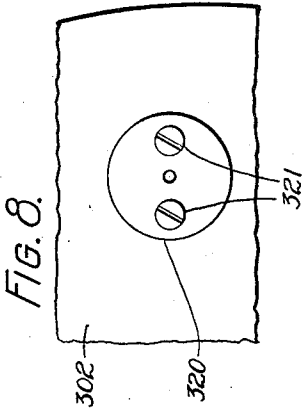


FIG. 8.

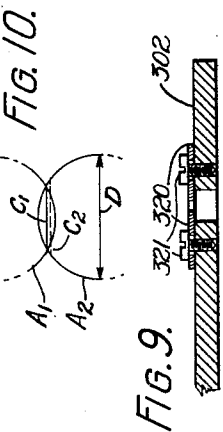


FIG. 10.

FIG. 9.

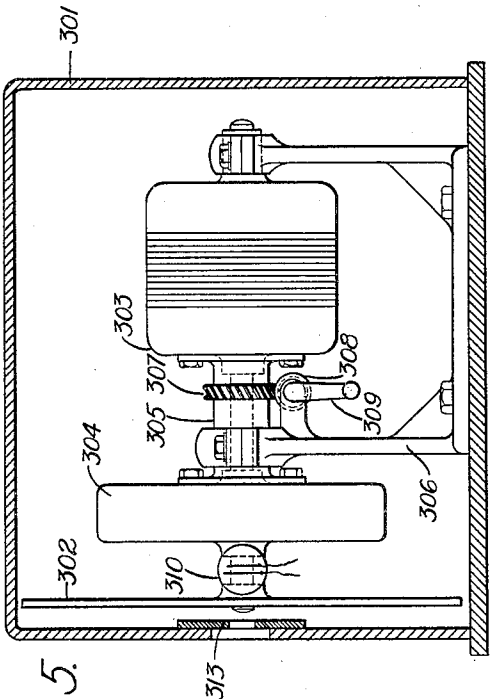
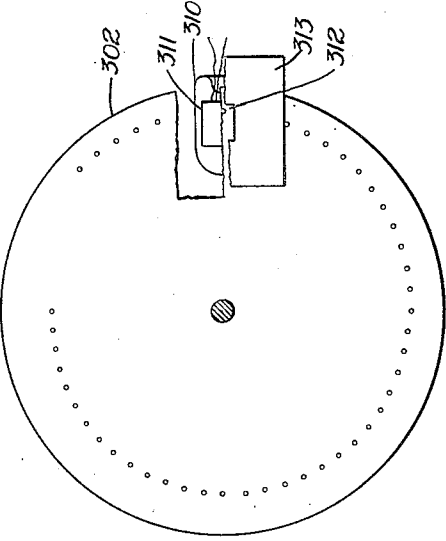


FIG. 5.

FIG. 6.



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2,037,471

ELECTROOPTICAL SYSTEM

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Application April 6, 1927, Serial No. 181,511

42 Claims. (Cl. 178—6)

This invention relates to television and more particularly to that branch of television which pertains to the transmission of moving pictures.

Successful television is dependent upon the rapid point by point scanning of the object, the translation of the light from the elemental areas scanned into voltage or current having corresponding electric variations, the transmission of current representative of such variations, and the translation of the received current back into light effects corresponding to the elemental areas of the object, all without appreciable distortion in the received picture.

The present invention is the outgrowth of an extended research having practical television as its ultimate object. It was perfected in the form of apparatus and methods for television of moving pictures, but, in general, is equally applicable to television of moving objects. It comprises a number of distinct features or aspects among which may be mentioned the following:

The direct current components of the current through the photoelectric cell are suppressed at the transmitter and compensation is effected at the receiver.

The area viewed at the receiver, in which the image is built up by light from a local source, is illuminated equally throughout at any instant but is screened except for a single point or elemental area which corresponds to the elemental area of the object which is at that instant (by virtue of the intermediate apparatus including the scanning apparatus at the transmitter) controlling the amount of illumination of the whole receiving field. The next instant the control is passed to an adjacent elemental area at the transmitter, as the scanning proceeds, and simultaneously the screening is changed at the receiver to expose only the elemental area of the receiving field which is positioned to correspond to the one then being scanned at the transmitter.

The produced picture or image should be substantially free from scanning line effects and this is accomplished by having the scanning beam of light cover a path somewhat wider than the pitch distance of adjoining paths or in other words making the paths overlap.

A close-up or enlarged view of a part of the picture or scene being transmitted may be desired at the receiving station and provision is made for this by projecting a magnified image of each frame of the film so that only the desired portion covers the field of scanning at the transmitting station. In this procedure the resolving power of the television disc is used to best ad-

vantage and the quality of the produced picture is maintained.

Maintaining the receiving apparatus in synchronism and in phase with that of the transmitting apparatus is essential and the latter is accomplished by a novel means consisting of rotating the entire assembly of the scanning disc and its driving motors when the apparatus is in operation, which causes the necessary angular displacement of the scanning disc to bring it into phase with the transmitting scanning disc with which it is operating in synchronism.

In projecting moving pictures the film is advanced from frame to frame during the interval between adjacent pictures and during this period of film shift or advance the scanning operation ceases. Provision for this is made by confining the spirally arranged scanning apertures to a sector of the scanning disc of about 315°, and shifting the film during the passage of the remaining portion of 45°.

In an embodiment of the invention selected for illustration and described in detail hereinafter, standard moving picture apparatus is employed for projecting an image of the picture to be transmitted upon the scanning device at the transmitting station. The scanning apparatus employs a disc having spirally arranged apertures together occupying a sector of about 315°, electrically driven and arranged to successively cause the light for small elemental areas of the picture to be impressed upon a light sensitive cell which in turn is connected through suitable amplifiers to a transmission circuit. The transmission circuit connects at the receiving station through suitable amplifying apparatus with a light translating device associated with a scanning disc similar to that at the transmitting station. The scanning discs at each station are operated in synchronism and an arrangement such as that disclosed in a copending application of H. M. Stoller and E. R. Morton, Serial No. 181,314, filed April 6, 1927, may be used for maintaining synchronism.

The light sensitive cell, the amplifier apparatus and the optical system are protected against sound, mechanical jars or electrical disturbances from the synchronizing and driving motor equipment associated with each station to guard against the introduction of distortion. A more detailed description of the invention follows and is illustrated in the accompanying drawings.

Fig. 1 is a general schematic arrangement of an embodiment of this invention showing in per-

spective the terminal apparatus of transmitting and receiving stations which are electrically interconnected.

Fig. 2 is a general view of the transmitting apparatus showing the principal elements of a moving picture projector and an associated picture transmitting device, which indicates the relation of the elements.

Fig. 3 is a view showing the electrical apparatus and circuits employed in obtaining synchronism between the moving picture projector and the picture transmitting apparatus.

Fig. 4 is a circuit drawing showing the electrical connections and principal amplifying elements employed in transmitting picture current from the transmitting to the receiving station.

Fig. 5 is a view of the receiving apparatus showing the principal apparatus elements.

Fig. 6 is a front view of the receiving scanning disc and the apertured screen bounding the area of the reproduced picture.

Fig. 7 shows the paths taken by the scanning beam of light across the field of view.

Fig. 8 and Fig. 9 show construction details pertaining to the apertures in the scanning disc.

Fig. 10 is a diagram used in explaining the operation of the apertures in the scanning disc.

A general schematic arrangement of an embodiment of this invention is shown in Fig. 1 the terminal apparatus at the transmitting and the receiving station being shown in perspective. The moving picture projector apparatus 100, the television scanning apparatus 150, and the photoelectric translating device 200 comprise the principal transmitting apparatus. By means of this apparatus a moving picture film is scanned by a beam of light which is impressed upon a light sensitive cell which in turn converts the light variations into corresponding electric current variations. The varying current is transmitted by a transmission circuit 250, and amplified by suitable amplifying apparatus 260 which may be located at both the transmitting and receiving stations. At the receiving station suitable switching apparatus 290 is provided for connecting the receiving apparatus with the transmission line.

Two types of receiving apparatus are here shown, one 300, which has a small field of view and employs a receiving lamp having a uniformly illuminated field equal to that of the picture and whose light intensity varies throughout its entire area in accordance with the tone values of elemental areas of the picture being transmitted, and which is caused to project its light for such elemental areas in synchronism with the picture being scanned and thereby producing an image of the original picture; and the other, 400, has a large field of view and employs a large receiving lamp having an area equal to the field of view, but which is divided into small elemental areas whose light intensity is caused to vary in accordance with that of the corresponding elemental areas of the picture. The latter arrangement having a large field of view is shown in the copending application of F. Gray, Serial No. 181,537, filed April 6, 1927, now Patent No. 1,759,504, granted May 20, 1930. Suitable terminal amplifying and current controlling networks are associated with each receiver. They comprise an amplifier 310 for the first mentioned receiver, and an amplifier 410 and oscillating current generators 420 and 430 for the second mentioned receiver. By means of the switching apparatus 290 either or both of the receivers may be operated at one time.

The image of the picture produced by the receiver 300 is comparatively small and is designed to be viewed at close range, while that produced by the receiver 400 is much larger and can be viewed from a distance and by a number of persons at the same time. In either case, the elemental areas of the received picture are illuminated to an intensity corresponding with that of similar elemental areas of the picture whose image is being transmitted, the chief difference being that one of the receivers is designed for producing a small image of particularly fine grain and the other for producing a large image.

A general view of the transmitting apparatus showing the principal elements of a moving picture projector and the associated picture transmitting apparatus is shown in Fig. 2. The moving picture projecting apparatus 100 is similar to standard projecting apparatus. The film moving apparatus and the driving motor are preferably enclosed in a metallic housing 101. The film moving apparatus is carried by the frame 110. The gears directly engaging and driving the moving picture film 111 are shown, but certain connecting and speed reducing gears contained within the frame or casing 110 are not shown, as arrangements for stepping or moving the film are well-known. The film is fed through the light beam between the guides 112 and 113 by the intermittently moved sprocket wheel and then directed to one side of the light beam by the guides 115 and 116, and to the winding sprocket wheel 117, and onto a rewinding reel, not shown. The power for moving the film is obtained from the motor 118 which is so controlled by means of suitable synchronizing apparatus that it advances the film in accordance with the requirements of the television scanning apparatus. The method of synchronizing will be described later. Light for the projecting apparatus may be obtained from any suitable source 120 and a light beam 121 is directed through the film by suitable lenses 122 and collected by the lenses 123 to form an image of the picture of the desired size on the scanning disc 152 of the television transmitter. The lens system is so arranged that the picture may be enlarged as projected on the scanning disc and thus transmit an enlarged picture of a part of the film, thereby giving the effect of a close-up view of a particular portion.

The television transmitter 150 is enclosed in the metallic casing 151. It consists primarily of a scanning disc 152 containing a set of small apertures spirally arranged throughout about 315°, a driving motor 153, a synchronizing motor 154, an apertured plate 155 containing an opening 156 which determines the boundaries of the field of view and a suitable lens system 157 and 158 for directing the light passing through an aperture in the scanning disc upon the light sensitive cell 202. Each picture in the moving picture film is projected through the opening in the apertured plate 155 and upon the scanning disc 152. The scanning disc makes at least one revolution for each picture. The spiralled arrangement of the small apertures through the scanning disc is such that the entire picture is scanned in a series of adjoining parallel lines by one aperture after another, thus successively projecting the light intensities of all of the elemental areas of the picture upon the light sensitive cell. The general operation of the television scanning apparatus is similar to that shown in the copending application of H. E. Ives, Serial No. 138,845, filed

October 1, 1926, now Patent No. 1,932,253, granted Oct. 24, 1933.

The translating apparatus 200 for translating the varying light energy from each elemental area of the picture into electrical energy is mounted in the metal shielding housing 201 and consists primarily of a light sensitive cell 202. This apparatus is mounted upon suitable cushioning material 203 to reduce the effects of mechanical vibrations reaching the light sensitive cell. The other elements of the transmitting apparatus are also made as free from vibration as practical and are mounted to eliminate the transmission of vibration either to or from the different elements. The metallic housing for the elements is also designed to largely prevent electric and magnetic disturbances from reaching the amplifying or other electrical apparatus used in transmitting the picture currents.

The picture projecting apparatus and the television transmitting apparatus are each driven by separate motors 118 and 153 respectively. The picture film and the television disc must be so synchronized in their movements that the film is progressed from picture to picture during the latter part of each revolution of the scanning disc. The arrangement for controlling the operation of the two driving motors is shown in Fig. 3. A small sector of the scanning disc, about 45°, contains no apertures for the passage of light and when this sector passes the field of view, the projecting apparatus advances the film from one picture to the next. The operation of the motor 118 is controlled by and synchronized with the motor 153. This is accomplished by varying the current supplied to the motor 118 by means of interconnected commutators 160 and 170 associated with the television scanning apparatus and the picture projecting apparatus, respectively. The commutator 160 is mounted directly upon the shaft carrying the television scanning disc and the commutator 170 is mounted on a shaft geared to the projecting apparatus in such a manner that it rotates at the same rate as the television disc and substantially in synchronism and in phase therewith. Each commutator contains a continuously conducting slip ring 161 and 171, respectively, and a partially conducting ring 162 and 172, respectively. The conducting and the non-conducting angular portions of the rings 162 and 172 are alike and as here shown each spans 180°. A brush 163 is associated with the slip ring 161 and a brush 173 is associated with the slip ring 171, and these two brushes are interconnected by the conductor 165. A brush 166 engages the partially conducting ring 162 and a brush 174 engages the partially conducting ring 172, and these two brushes are interconnected by the conductor 175. The slip ring 161 is in electrical connection with the conducting portion of the ring 162 and the slip ring 171 is in electrical connection with the conducting portion of the ring 172. With this arrangement it is obvious that the conductors 165 and 175 may be short-circuited by either commutator one half the time, and excepting the effect of the width of the brush no more than half the time if the conducting portions of the rings 162 and 172 rotate at the same rate and occupy similar angular positions with respect to their brushes, or in other words, are rotated in phase with each other. If the commutators do not bear similar angular positions, the circuit is closed for more than half the time. This short-circuiting circuit comprises the commutators 160 and 170,

and the conductors 165 and 175 are connected across the terminals of the motor 118 through the adjustable resistance 166. When the relation of the control commutators is such that they shunt the control circuit for a minimum duration of one-half a revolution and in view of the resistance 176 in the supply circuit, a minimum amount of current is shunted from the motor 118 and it operates at maximum speed. The resistance 176 is made adjustable and is so adjusted that the motor tends to run a little faster than necessary. This causes the commutator 170 associated with the projecting apparatus to tend to run faster than the commutator 160 associated with the television apparatus but when the former runs ahead, it advances the phase relationship of the ring 172 ahead of that of the ring 162 and thereby causes the circuit 165 and 175 to shunt the motor 118 somewhat more than half the time and thus reduces the speed of the motor and causes the commutator 170 to drop back into phase with the commutator 160. This process maintains synchronism and proper phase relationship with sufficient accuracy to cause the advance of the film from picture to picture in the allotted time during the latter part of each revolution of the scanning disc 152. Power for the motor 118 is supplied through the conductors 180 and 181.

In the operation of the synchronizing arrangement here shown, slight adjustments of the resistance 166 must be made and a stroboscopic method is employed for indicating the phase relation between the scanning disc and the projector. A contact ring 167 forming a part of the commutator 160 mounted on the shaft carrying the scanning disc momentarily connects with the brush 168 to close a local circuit through the battery 169 and the lamp 177 once in each revolution. A mark 178 is fixed to the projector housing and another mark 179 is fixed on the commutator 170 in such a way that both marks may be observed when illuminated by the lamp 177. The positioning of these marks is such that if the commutators 160 and 170 are in phase the two marks are in substantial alignment when the lamp 177 is momentarily lighted by connection made by the contact ring 167. The transient illumination of the mark 179 appears as if it were a broad stationary band of white. One edge of this band is quite sharp because the lamp lights up quickly. The appearance of the sharp edge of the band opposite a certain reference point such as the mark 178 on the projector housing indicates that the projector is operating in proper phase relation with the television disc.

The terminal amplifier and general circuit network employed at the transmitting and receiving terminals are schematically shown in Fig. 4. The picture projecting apparatus 100 and the television scanning apparatus 150 and the receiving apparatus 300 are diagrammatically indicated. The light sensitive cell and the amplifying apparatus are carefully protected against extraneous electrical and mechanical pick-ups, though this is not shown in this drawing. Electrical disturbances are guarded against by enclosing the amplifier apparatus in metal shielding and by separating the different stages by metal shields. All metal parts of the shielding should preferably be grounded and this is particularly essential in the first stage. As a further precaution, the amplifier is protected against sound distortions and mechanical jars. This can be accomplished by supporting the apparatus

on felt and rubber pads and lining the shielding with a sound deadening material such as felt. The housing containing the television disc and motor may also be lined with felt to reduce the sound coming from this source. The photo-electric cell is carefully mounted to prevent mechanical disturbance reaching it. Special precautions are desirable in connection with the first amplifier tube and this may be accomplished by suspending it with rubber bands and loading with a lead mass.

Referring to the circuits of Fig. 4, the light sensitive cell 202 and the battery 203 are connected in series with the resistance 204. Varying light excitation of the light sensitive cell causes a varying current through resistance 204 and a corresponding variation in potential occurs across the resistance, which potential is impressed upon the grid of the first space discharge amplifier 205. Due to the inherent capacity of the amplifier tube 205 at the frequencies in the upper portion of the range transmitted, resistance 204 must be small to reduce the time constant of this circuit. This further enfeebles the very small energy from the light sensitive cell. The plate circuit of this amplifier is energized by the battery 206 connected through the resistance 207 between the filament and the plate. This first stage amplifier is connected through the condenser 208 with a number of similar amplifiers 210, 215, 220 and 225, all condenser-resistance coupled. The plate circuit of these amplifiers is energized by the common battery 226. This battery is shunted by a condenser 227 to facilitate the passage of high frequency current and to substantially eliminate the effects of voltage variations of the battery. The filament current for these amplifiers is furnished by a common battery 209. Grid biasing batteries are employed for each stage beyond the first stage. The amplifier stages above described are followed by other stages employing vacuum tubes of somewhat larger capacity. The stages 230, 235 and 240 complete the amplifier at the transmitting station. The plate circuits of these amplifiers are energized by the common battery 241. This battery is shunted by a condenser 242 to facilitate the passage of high frequency current and to substantially eliminate the effects of voltage variations of the battery. The filament current is supplied from the common battery 233. The output of the amplifier 230 is controlled by the variable connection 231. Each amplifier stage has suitable grid biasing batteries. Each stage has a condenser in the output circuit which insulates the succeeding grid circuit from the direct current in the output circuit. This condenser is also of a size (at least in some of the stages) to suppress the low frequencies which it is necessary to have suppressed. The amount of the biasing of the last stage 240 may be varied through the connection 243. The output of the amplifier at the transmitting station is coupled with the transmission line 250 through the repeating coil 251. A coil suitable for repeating coil 251 is disclosed in a copending application of H. Whittle, Serial No. 177,818, filed March 23, 1927, now Patent No. 1,809,879, granted June 16, 1931.

At the receiving station the transmission line is connected with the receiving circuits through the repeating coil 252. The received signal is here amplified to a value suitable for actuating the glow discharge receiving lamp. The receiving amplifying equipment is similar to that employed in the last stages at the transmitting

station. As here shown two stages 260 and 265 are employed. The space current is supplied from the battery 266 which is shunted by a condenser 267 which facilitates the passage of high frequency current and substantially eliminates the effects of voltage variations of the battery. The filament current for each stage is supplied by the common battery 261. The output voltage of the amplifier 260 may be adjusted by means of the potentiometer 262. A grid bias of the proper amount is applied to each stage, and in connection with the last stage the biasing is adjustable as shown by the movable contact at the biasing battery 268. The last stage of the amplifier is directly connected with the glow discharge receiving lamp and by means of the adjustable grid bias of this stage the direct current through the glow discharge lamp is adjusted to the proper amount as hereinafter described.

An assembly of the receiving apparatus is shown in Fig. 5. The apparatus is enclosed in a metal housing 301. The principal moving elements are the scanning disc 302, the driving motor 303 and the synchronizing motor 304, all operating on one shaft. The frames of these two motors are rigidly connected together by the coupling sleeve 305. The assembly of these elements is mounted so that it may be rotated for adjusting purposes in the cradle frame 306 which in turn is fastened to the base of the housing. The angular adjustment of this assembly is brought about by means of the worm gear 307 fastened to the sleeve 305, and the engaging worm 308 fixed in suitable bearings attached to the cradle 306. The worm may be rotated by any suitable means such as the crank 309. Upon turning this crank in one direction or the other the angular position of the scanning disc 302 may be made to take up any given position, and in this way it is brought into proper phase relationship with a similar scanning disc at the transmitting station. A glow discharge lamp 310 having an illuminated area equal to that of the picture produced is positioned directly behind the scanning disc 302 and coinciding with the field of vision. An apertured plate 313 having a rectangular aperture 312 bounding the field of vision is placed immediately in front of the scanning disc and symmetrical with reference to the illuminated area of the glow discharge receiving lamp 310. During each revolution of the scanning disc each aperture successively passes before the viewing field and thus causes a succession of parallel paths of light to pass from the glow discharge lamp to the observer through every elemental area within the viewing field. As already stated, if each elemental area is scanned 15 to 20 times a second, an effect of substantially continuous illumination is secured and a picture is produced dependent upon the variations of the light intensities for each elemental area.

A fragmentary front view of the aperture plate bounding the viewing field, the scanning disc and the uniformly illuminated field of the glow discharge lamp is shown in Fig. 6. The receiving scanning disc contains the same number and has the same angular arrangement of its spirally arranged apertures as the transmitting scanning disc. A sector of the disc of approximately 45° corresponding to the period when the film is shifted at the transmitting station is left blank as no picture signals are being transmitted during the passage of this portion of the disc over the viewing field. The size of the illuminated area 311 of the glow discharge lamp as previously pointed out is at least as large as the viewing

aperture 312 in the aperture plate 313. These relationships of the areas must exist since at any given instant the intensity of the illumination of the whole surface of the glow lamp represents the tone value of an elemental area of the picture whose image is being transmitted and only a small elemental area of the glow discharge lamp is exposed to view through one aperture in the scanning disc, and during each revolution of the scanning disc all of its apertures pass over different elemental areas of the lamp and cover the whole viewing field.

The radial distance between the centers of adjoining apertures and the diameter of the apertures determines the spacing or overlap of the successive parallel scanning lines. If the radial distance between centers of the adjacent apertures is greater than the diameter of the apertures a decided line structure will appear in the produced picture, but if the radial distance is somewhat less than that of the diameter of the apertures the line structure is practically eliminated. It has been found that when the diameter of the apertures is about one-fourth greater than the radial distance between centers of the adjacent apertures the overlap is such that line structure in the produced picture is scarcely visible. This overlapping of the scanning paths is especially shown in Figs. 7 and 10. A portion of the scanning disc 302 with three successive apertures and the fixed aperture plate 313 with the opening 312 bounding the field of view shows the apertures of such diameter and radially positioned that each succeeding aperture sweeps the field of view with an overlapping as above explained. The angular positioning of each succeeding aperture is such that when the one preceding is just passing beyond the field of view the succeeding one is coming into the field of view.

Referring to Fig. 10, A₁ represents one position of an aperture and A₂ an adjacent and overlapping position of an adjacent aperture, the paths of the two apertures being overlapping in the manner shown in Fig. 7. The length of line C₁ is preferably of the order of D/2 so that the sum of the times of exposure of any point on the line of the line C₁ is of the order of the time of exposure of any point outside the overlapping region. Likewise the time of exposure of any point on any other line parallel to C₁ within the overlapping area, such as C₂, is of this same order. While this gives only an approximation to equal times of exposure of all points, the departure from equality is practically negligible. If a closer approximation is desired the shape of the aperture can be varied. Square apertures having their diagonals on the center lines of their paths of travel and the distance between center lines equal to half the length of the diagonal would be desirable, since small variations in the paths of travel would not then cause much departure from true equality of times of exposure of all points. Or the center portions of the apertures could be square and the overlapping portions triangular.

The accurate location of the apertures on the scanning disc and thinness of the plate at the edge of the aperture is important. The scanning disc may be constructed either by making it of thin material where the apertures are located and directly drilling the apertures through the plate with the necessary precision to obtain accuracy, or the scanning disc may be made of thicker material with comparatively large apertures covered by thin plates with the aperture of the proper size in the plates. This arrangement is shown in

Figs. 8 and 9. A portion of the scanning disc 302 is shown with the apertures drilled considerably larger than required for the passage of light and with reasonable accuracy. Each opening is then covered with a thin plate 320 having an aperture of the proper size. The plates may be fixed to the scanning disc by any suitable means such as the screws 321. The openings in these plates through which the screws pass are somewhat larger than the screws to permit the plates being moved into position to properly locate the scanning aperture therein. As the plates are accurately located, the screws are tightened to hold them permanently in correct position. The accurate positioning of these plates may be accomplished by means of suitable jigs or measuring instruments or by setting up the scanning disc and passing a beam of light through each aperture individually upon a suitable screen and moving each plate until the spot of light on the screen is in proper position for the aperture being located. A preferred method consists in drilling the larger apertures in the scanning disc by means of a machine drill with their centers accurately located on the desired spiral and then centering each small aperture by means of a jig having portions accurately fitting the small and large apertures, respectively.

The operation of the system is as follows: Photoelectric current is produced in light sensitive cell 202 by light received from the moving pictures. The variations of this current to be utilized in the production of an image at the receiver are amplified in the successive stages of the amplifier at the transmitting station, impressed upon the line 250 by the transformer 251, and, after transmission, transformed by transformer 252 into voltage variations in the input circuit of amplifier 260. The amplified output current flows through resistance of potentiometer 262 which determines the amount of voltage impressed upon amplifier 265. The glow discharge lamp is in the output circuit of the final stage of amplification of amplifier 265.

A very important feature of this invention pertains to the suppression at the transmitter of direct current and low frequency components of current and means at the receiver for compensating for the effect of this suppression. The suppression is primarily effected by condenser 209 or other condensers similarly located in the transmitting amplifier.

Heretofore attempts have been made to produce a practical television system employing a modulated carrier current to transmit the variations corresponding to the tone value of the elemental areas of the object or picture. Theoretically it would appear necessary to provide a transmitter equipment capable of handling all frequencies from 0 to a frequency perhaps as high as 40,000 cycles per second depending upon the maximum point by point variation in the tone value of the object. It is because of this wide range that experimenters in television have assumed that it would be necessary to employ a modulated carrier current of high frequency even when the system is intended for operation with transmission lines rather than through the ether by radio. It will at once be apparent that, because of the high maximum frequencies and the wide range of frequencies present in the modulating current, that method would necessitate a carrier current of very high frequency and the transmission of a very wide band of frequencies

so that transmission over wires by that method would present a very difficult problem.

The present inventors in their attempt to arrive at a solution of the problem presented by television encountered another obstacle as the result of the unusual conditions. On account of the small amount of light falling into the light sensitive cell at any instant from an elemental area of an object whose image is to be transmitted, the variations produced in current through the cell in accordance with the light variations are therefore at best exceedingly minute. This weak variable current can be successfully utilized only by amplifying it many fold. It was found that when this large amplification was employed the image at the receiver might be clear for a time and then gradually become indistinct due to the loss of detail either in the high lights or the shadows. It was discovered that this distortion was due to the large amplification of very small slow changes in the potentials of the batteries employed in connection with the first stages of the amplifier, which, by reason of the large amount of amplification, were sufficient to introduce prohibitive bias in the final stages of the amplifier.

It was desired by the present inventors to perfect a television system utilizing commercial wire telephone channels as well as a system which would be adapted to radio transmission. A solution was ultimately found, based upon the observed fact that each object viewed presents a mean degree of illumination productive of a mean direct current value in the photoelectric cell upon which is superposed a pulsating current produced by the point by point variations in the reflective power of the object or the density of a moving picture film. This mean direct current or direct current component will not have a constant value but will change from time to time during transmission as the general aspect of the field of view changes, rising with a greater proportion of bright areas in the field and falling with an increasing preponderance of dark areas.

The solution reached was the suppressing of the direct current and low frequency components at the transmitter and the reinsertion of a compensating direct component at the receiving end by proper polarization of the light source or its equivalent and the discarding or neglecting of the other low frequencies involved. The low frequency range suppressed is ordinarily from 0 to 10 cycles. Since this covers the range of the slow disturbing potential variations of the batteries associated with the transmitting amplifier these variations are likewise, in accordance with the invention, prevented from being transmitted by properly locating the suppressing means. The suppression of the low frequency and direct current components is preferably brought about by the use of filtering condensers in the outputs of the first stages of the amplifier, such as condenser 208, which are so designed that there is a gradual cut-off below ten cycles. As there are many stages of amplification it may be necessary to provide a similar filtering arrangement in the output circuits of other stages of the amplifier, and, in extreme cases, it may be necessary to utilize this feature in connection with each stage. Fig. 4 shows condensers in each stage but ordinarily these condensers in the later stages may be so large as to pass frequencies below 10 cycles.

At the receiving station adjustment is preferably made in the following manner. Potentiometer 262 is set in such position that no potential

from the picture current is impressed upon the amplifier 265. Biasing battery 268 is then adjusted until the "C" potential is in the region of the mid-portion of the straight part of the input-voltage, output-current characteristic. The glow lamp 310 then emits a steady light. Potentiometer 262 is then slowly adjusted to increase the amplitude of the picture potentials impressed upon the amplifier 265. As the potential is increased a value is finally reached such that detail begins to fade from the image either in the shadows or the high lights, or both. If the fading takes place simultaneously in the shadows and the high lights it is an indication that the adjustment of the battery 263 is correct, that is, that it corresponds to the middle of the straight part of the amplifier characteristic. If, however, fading of detail first occurs in the shadows it is an indication that the biasing potential from battery 263 should be less negative; whereas if the fading of detail is in the high lights the biasing potential should be more negative. When an adjustment has been made such, that the biasing potential is in the middle of the straight part of the amplifier characteristic, the voltage from the potentiometer may be slightly decreased so that there will be no distortion in either the high lights or the shadows.

This adjustment, however, does not take into account the fact that the lamp will have some illumination at times when black should be represented. The lamp 310 has a certain striking voltage below which no glow will occur. It is preferable to operate continuously above this striking voltage, that is, to permit a very slight illumination to be present when the picture voltage is minimum and the darkest portion of the picture is being produced. By a proper choice of amplifier and striking voltage of the glow discharge lamp this condition may be realized without noticeably affecting the quality of the picture.

The scope of the invention in its various aspects is defined by the appended claims.

What is claimed is:

1. A television system comprising means for scanning a picture or object an image of which is to be produced electrically, said picture or object having changing aspects, means at the transmitting apparatus cooperating with said scanning means to produce image current and for suppressing the direct current component of said image current, and means at the receiving apparatus for compensating in varying amounts for the varying amounts of direct current component suppressed under the various aspects of the picture or object.

2. The method of television which comprises producing currents corresponding to the tone values of the object and having both direct and alternating components, suppressing the direct and certain low frequency components at the transmitting station, and introducing direct current in varying amounts to compensate for the said suppressed direct and alternating current components at the receiving station.

3. The method of transmitting moving pictures which method comprises generating picture current from moving pictures suitable for transmission over a telephonic transmission channel by causing light modulated by the picture whose image is to be produced to be rapidly impressed point by point upon a light sensitive cell, producing thereby direct current pulsations varying in amplitude with the intensity of the light transmitted point by point from the picture, convert-

ing said pulsating current into alternating currents, combining said alternating currents with varying amounts of direct current locally supplied at a receiving station the amounts being such as to produce direct current pulsations similar to those previously produced, and employing the combined alternating and direct current to vary the luminosity of the receiving illuminating device, and illuminating therewith a viewing area point by point in synchronism with the point by point scanning of the picture whose image is being transmitted.

4. The method of image production by the successive illumination of small portions of the total scanned area, which method comprises successively illuminating at uniform intensity elemental portions of an elemental strip of the said scanned area, and subsequently illuminating at uniform intensity elemental portions of another elemental strip which partially overlap the adjacent strip.

5. In a television or image producing system, a scanning disc having spirally arranged apertures, the paths of which overlap when the disc is rotated.

6. In a television or image producing system, a scanning disc, apertures in said disc, means to project light through said apertures, said apertures being so arranged that upon rotation of the disc overlapping light traces are produced.

7. In a television or image producing system, a scanning disc, a plurality of circular apertures arranged spirally on said disc, the radial distance between centers of adjacent apertures being less than the diameter of the aperture.

8. In a system for producing moving pictures electrically, the combination with means including a scanning device at the transmitting station for producing an image at a receiving station of an image produced on said scanning device, of a moving picture projector arranged to project a succession of images on said scanning device to produce a moving picture on said scanning device, said projector having image forming means which receives light rays from a picture carrier and directs said received rays to form said images on said scanning device, and means to synchronize the movements of said projector and said scanning device to cause each image to be scanned at least once.

9. In a system for producing moving pictures electrically, the combination with means including a scanning disc at the transmitting station for producing an image at a receiving station of an image produced on said scanning disc by a moving picture projector arranged to project a succession of images on said scanning disc to produce a moving picture on said scanning disc, means to synchronize the movement of said projector and said scanning disc, and means to cause the said scanning disc to cease its scanning operation during the period of advancing the moving picture film from one picture to the next.

10. In a system for producing images electrically, a scanning disc comprising a plate, a plurality of spirally arranged perforations large enough to be accurately centered on a spiral centerline, and an aperture plate having apertures too small to be accurately formed as perforations in said disc plate, and means to accurately center the aperture plate so that its center is on the spiral determining the radial location of the apertures.

11. In a system for producing moving pictures electrically, the combination with means including a scanning disc at the transmitting station

for producing an image at a receiving station of an image produced on said scanning disc, of a moving picture projector arranged to project a succession of images on said scanning disc to produce a moving picture on said scanning disc, and means to cause a selected portion only of each image to be scanned, whereby the resolving power of the scanning disc is used to best advantage in transmitting any given picture.

12. In a system for producing moving pictures electrically, the combination with means including a scanning disc at the transmitting station for producing an image at a receiving station of an image produced on said scanning disc, of a moving picture projector arranged to project a succession of images on said scanning disc to produce a moving picture on said scanning disc, and means to cause the central portion of each image to be scanned, whereby the resolving power of the scanning disc is used to best advantage in transmitting any given picture.

13. A system for transmitting and amplifying a signal having a direct current component, said system comprising means for eliminating that component and amplifying another of the components of the signal, and means included in said system for combining with the amplified other component direct current for restoring the original proportion between the direct component and the other component.

14. In combination, a source of variations characteristic of visual aspects of a subject, said variations having a direct component and alternating components, a system for transmitting and amplifying certain of said alternating components and for eliminating said direct component, and means included in said system for restoring said direct component at the proper amplitude.

15. A scanning device for use in the television transmission of motion picture films comprising a rotatable member having a plurality of scanning elements arranged thereon in such manner as to scan the picture portion only of the said motion picture film.

16. A rotatable scanning device of opaque material having a plurality of light transmitting apertures arranged thereon to scan an image field during a portion of a revolution thereof and to interrupt the scanning during the remainder of the revolution.

17. In a system for transmitting motion pictures, film moving means and scanning means cooperating to cause separated portions only of the motion picture film to be scanned and to prevent the scanning of portions between said separated portions.

18. A method of scanning motion pictures which comprises scanning a frame of a motion picture film while stationary, subsequently moving the film to permit a succeeding frame to be scanned, and interrupting the scanning operation while the motion picture film is being moved.

19. In a system for transmitting pictures recorded on a motion picture film, means for intermittently moving said motion picture film, a light sensitive device, and means for directing light from illuminated elemental areas in succession of said motion picture film upon said light sensitive device to produce an image current only during the periods that said motion picture film is stationary.

20. In a system for transmitting a plurality of pictures in succession, means for successively and intermittently moving said pictures into position for transmission, a light sensitive device, means

for actuating said device in accordance with the tone values of elemental areas of said pictures to produce an image current, said means comprising a rotatable device having a plurality of light apertures for transmitting light to said light sensitive device and an opaque portion for periodically preventing the transmission of light to said light sensitive device, and means for synchronizing said picture moving means and said rotatable device to prevent the transmission of light to said light sensitive device during the periods that said pictures are being moved into position for transmission.

21. In a system for the transmission and reception of motion pictures, moving scanning means having scanning elements arranged thereon to scan the pictures of the motion picture film, a similar moving scanning means for producing images of the pictures scanned at the transmitter, the scanning elements being omitted from a portion of said scanning means to interrupt the picture transmission and reception during the time that the motion picture film is in motion.

22. In a system for transmitting pictures recorded on a motion picture film, means for moving said motion picture film, a light sensitive device, and means for directing light from illuminated elemental areas in succession of the picture portions only of said motion picture film upon said light sensitive device to produce an image current.

23. In a television system for transmitting motion picture film, means for moving the film to be transmitted, and means including a mask and a rotatable scanning device for analyzing the picture portion only of the film thereby omitting the frame lines and edges of said film from said analyzing.

24. In a system for transmitting by television motion picture films having successive pictures thereon separated by a frame line on the film, means for moving the film pictures to be transmitted, means for analyzing the varying intensities of light and shadow on the film pictures and converting said varying intensities of light and shadow into electrical variations, and means including a mask for scanning the picture portion only of said film.

25. In a television system for transmitting motion picture film, means for moving the film to be transmitted, and means for analyzing the picture portion only of the film.

26. In a system for transmitting motion picture films by television, means for moving a motion picture film, a scanning element, means provided by said scanning element for analyzing the intensity of light and shadow on said film, means for converting the varying intensities of light and shadow on the film into electrical variations, and means also provided by said scanning element for scanning the picture portion only of said motion picture film.

27. The method of analyzing motion picture films having frame lines separating successive picture frames thereof for television transmission which consists in advancing the film and in analyzing the film in such manner as to analyze the picture portion only thereof.

28. In a television or image producing system, a scanning disc having a plurality of rectangular apertures arranged spirally on said disc, a side of each of said apertures forming an acute angle with the disc radius which passes through the center of said aperture and the paths of said apertures overlapping when the disc is rotated.

29. In a television or image producing system, a scanning disc having a plurality of apertures arranged spirally on said disc, each aperture comprising a rectangular portion and two triangular portions adjacent opposite sides of said rectangular portion, said apertures being so arranged that the paths of the triangular portions overlap when the disc is rotated.

30. The method of image production by the successive illumination of small portions of the total scanned area, which method comprises successively illuminating at uniform intensity elemental portions of an elemental strip of the said scanned area, and subsequently illuminating at uniform intensity elemental portions of another elemental strip, each elemental portion comprising a rectangular section and two triangular sections adjacent opposite sides of said rectangular section, the portion of said second elemental strip corresponding to one triangular section overlapping the portion of said first elemental strip corresponding to the adjacent triangular section.

31. A method of television image production which comprises repeatedly scanning a field of view, each complete scanning taking place within the period of persistence of vision, to produce an image current having a direct component representative of the average light tone value of the field and alternating components representative of the variations in tone value along a scanning path, amplifying and transmitting to a receiving point alternating components of said image current and suppressing said direct component, producing under control of a local source of current at the receiving station light of an intensity representative of the average tone value of said field of view, thereby compensating for the suppression of said direct component, and causing the amplitude of the current from said local source to increase and decrease under control of the receiving alternating image current to produce corresponding light variations representative of the variations in tone value along the scanning path.

32. In a system for producing images electrically, a scanning disc comprising a plate having a plurality of perforations therethrough each materially larger than a scanning aperture, a perforation being positioned at each point where a scanning aperture is required for scanning purposes, a scanning aperture plate having a scanning aperture therethrough, said aperture plate being of substantially uniform thickness and of maximum thickness not materially greater than the maximum dimension of the scanning aperture, and means securing said aperture plate to said perforated plate in a position to both cover a perforation and overlap a section of said perforated plate all around said perforation with the scanning aperture overlying said perforation.

33. In a system for producing images electrically, a scanning disc comprising a plate having a plurality of spirally arranged perforations therethrough, each materially larger than a scanning aperture, a scanning aperture plate having a scanning aperture therethrough, said aperture plate being of substantially uniform thickness and of maximum thickness not greater than the maximum dimension of the scanning aperture, and means securing said aperture plate to said perforated plate in a position to both cover a perforation and overlap a section of said perforated plate all around said perforation with

the scanning aperture overlying said perforation.

34. The method of image production by the successive illumination of small portions of the total scanned area, which method comprises successively illuminating at uniform intensity elemental portions of an elemental strip of the said scanned area, and subsequently illuminating at uniform intensity elemental portions of another elemental strip which overlaps at least one-half of said first mentioned strip.

35. The method of image production by successive illumination of small portions of the total scanned area, which method comprises successively illuminating at uniform intensity elemental portions of an elemental strip of the said scanned area, and subsequently illuminating at uniform intensity elemental portions of another elemental strip which overlaps substantially one-half of said first mentioned strip.

36. In a television or image producing system, a scanning disc having spirally arranged apertures, the paths of which overlap one-half when the disc is rotated.

37. In a television or image producing system, a scanning disc, apertures in said disc, and means to project light through said apertures, said apertures being so arranged that upon rotation of the disc half overlapping light traces are produced.

38. In a television system, means to produce an image by successively illuminating small portions of the total scanned area repeatedly within the period of persistence of vision, including means to successively illuminate at uniform intensity elemental portions of an elemental strip of the said scanned area and means to subsequently illuminate at uniform intensity elemental portions of another elemental strip which overlaps at least one-half of said first mentioned strip.

39. In a television system, means to produce an image by scanning the entire field in elemental strips of width independent of tone value, including means for scanning the field in parallel

elemental strips distributed across the field transverse to the direction of scanning and means for scanning the field in elemental strips distributed across the field transverse to the direction of scanning parallel to said first strips each of which overlaps one of said first strips substantially uniformly throughout its length.

40. In a television system, means to produce an image by scanning the entire field in elemental strips of width independent of tone value, including means for scanning the field in parallel elemental strips distributed across the field transverse to the direction of scanning and means for scanning the field in elemental strips distributed across the field transverse to the direction of scanning parallel to said first strips each of which overlaps one of said first strips uniformly throughout its length by at least one-half its width.

41. In a television system, means to produce an image by scanning the entire field in strips of width independent of tone value, including means to scan the field in strips distributed across the field transversely to the direction of scanning and means to scan the field in other strips distributed across the field in a direction transverse to the direction of scanning each of which substantially overlaps a strip of said first scanning, the proportionate overlap of each pair of overlapping strips being uniform throughout their length.

42. In a television system, means to produce an image by scanning the entire field in strips of width independent of tone value, including means to scan the field in strips distributed across the field transversely to the direction of scanning and means to scan the field in other strips distributed across the field in a direction transverse to the direction of scanning each of which substantially overlaps a strip of said first scanning, the proportionate overlap of each pair of overlapping strips being at least one-half throughout the length of the strip.

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