

March 15, 1938.

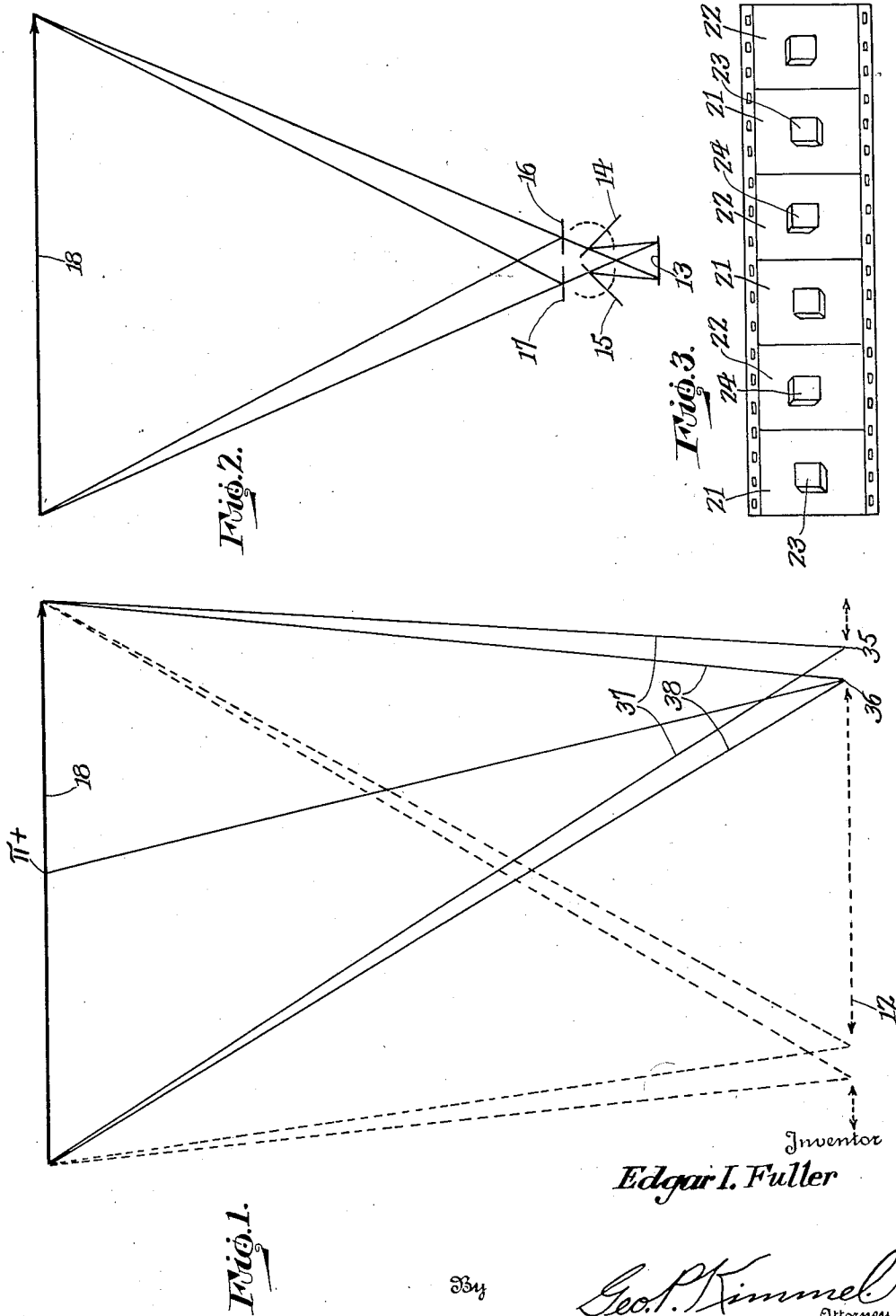
E. I. FULLER

2,111,445

METHOD OF PRODUCING MOVING PICTURES OF THE STEREOSCOPIC VARIETY

Filed May 20, 1935

5 Sheets-Sheet 1



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5 Sheets-Sheet 2

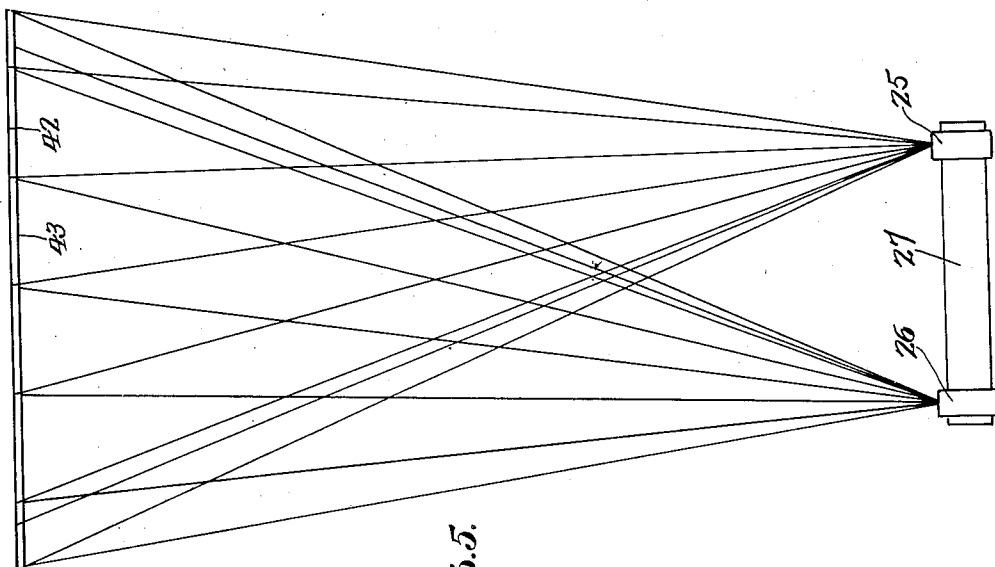


Fig. 5.

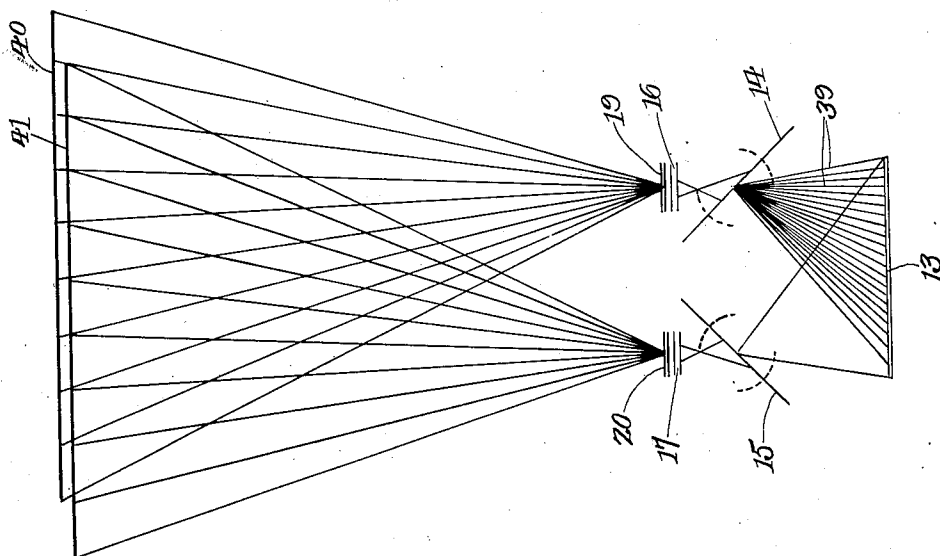


Fig. 4.

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5 Sheets-Sheet 3

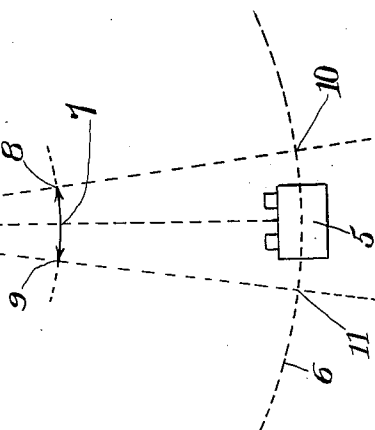
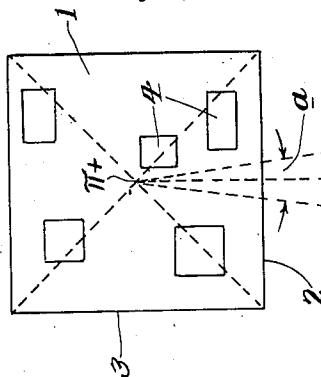
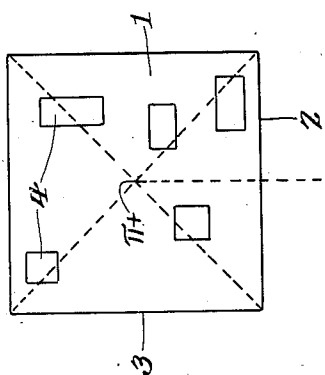


Fig. 1.

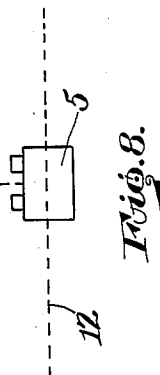


Fig. 2.

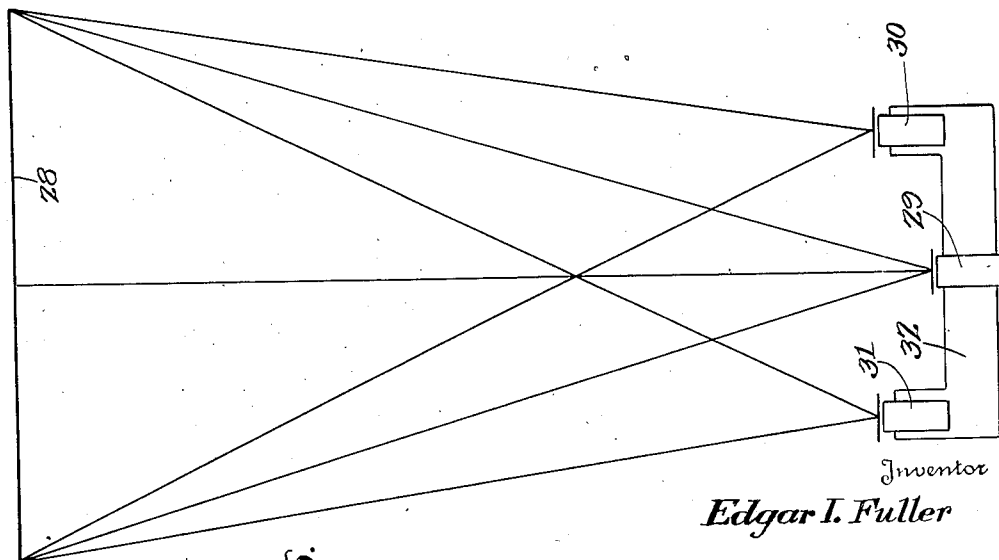


Fig. 3.

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5 Sheets-Sheet 4

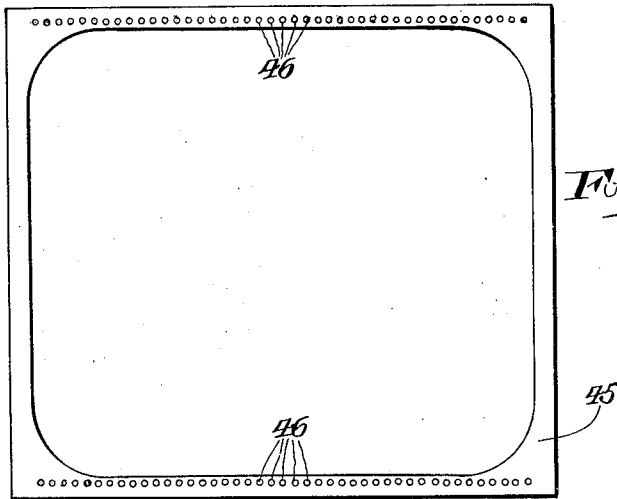


Fig. 9.

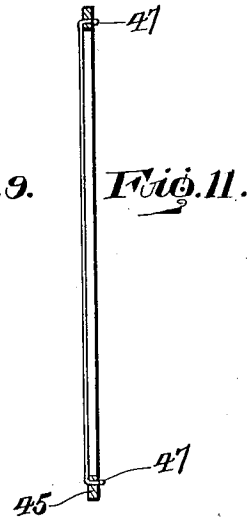


Fig. 11.

Fig. 10.

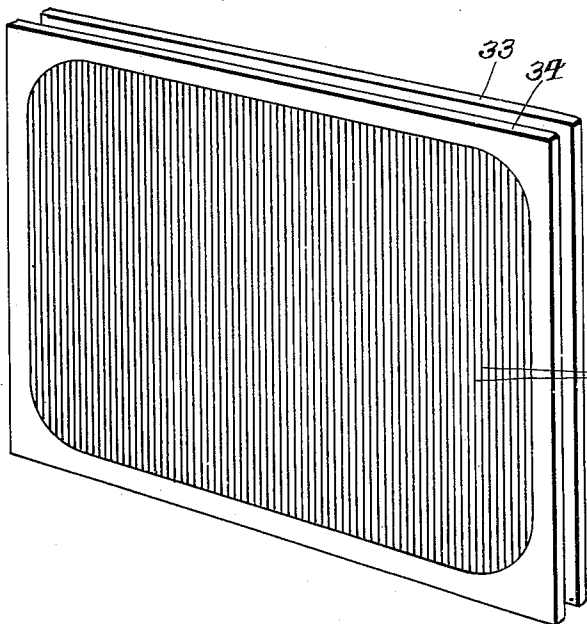
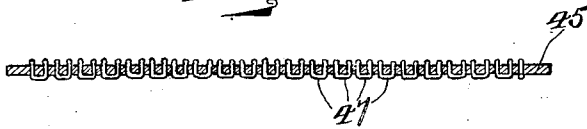


Fig. 12.

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METHOD OF PRODUCING MOVING PICTURES OF THE STEREOSCOPIC VARIETY

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Fig. 13.

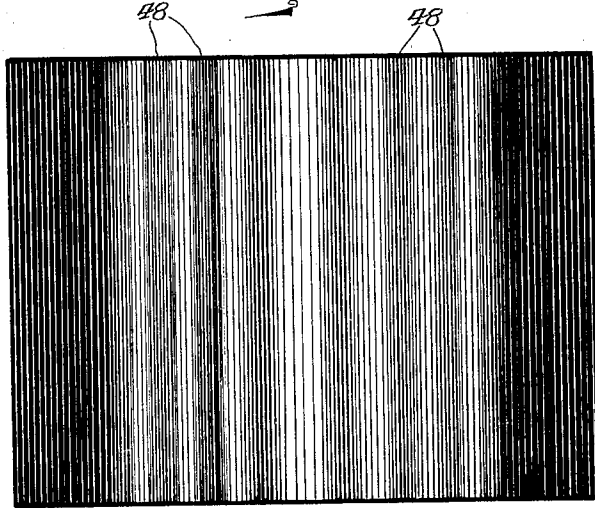


Fig. 14.

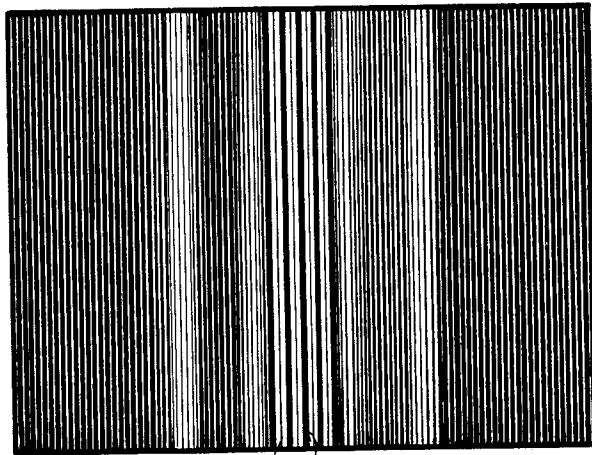
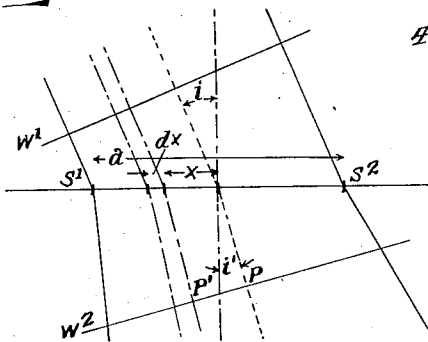


Fig. 15.



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UNITED STATES PATENT OFFICE

2,111,445

METHOD OF PRODUCING MOVING PICTURES OF THE STEREOSCOPIC VARIETY

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Application May 20, 1935, Serial No. 22,462

6 Claims. (Cl. 88—16.6)

This invention relates to a method of and apparatus for producing moving pictures of the stereoscopic variety.

It is a well known fact that either still pictures or moving pictures made with a single camera in a stationary position and reproduced in the ordinary manner do not have the appearance of depth, but rather have the appearance of being upon a flat surface as in fact they usually are.

Various attempts have been made both in the field of still pictures and in the field of moving pictures to reproduce scenes in such a manner as to give the observer the impression that the scene being viewed has depth. In the art of still pictures, it has for instance been suggested that if a plurality of views be taken of a scene through a vertical line screen, each view from a somewhat different angle, and these views combined into a single composite view, the resulting picture when viewed through a similar line screen would have the effect of giving depth.

Similarly, it has been proposed in moving pictures to take pictures by means of binocular cameras and to record the views taken through the different lenses on alternate spaces of a single film, this picture being afterwards printed and projected in the usual manner. Also, it has been proposed to move a monocular camera through an arc during taking of the picture so that it will produce views of the scene from different angles. In such instance, the pictures are taken through a line screen such as mentioned above and are projected through a similar line screen onto a screen of the ordinary type.

In order to convey a clearer conception of the problem to be solved and of the manner in which it is solved by the present invention, a brief discussion of natural binocular vision follows.

As we go up the scale of vertebrate animals, we find that there is a gradual change of the position of the eyes from the sides to the front of the head and a change of the inclination of the optical axes of the two eyes from 180 degrees to parallel. There is also evident gradual increase in the fineness of the bacillary layer of the retina from the margins toward the center, and, therefore, an increasing accuracy in the perception of form. This finally results in a highly organized central spot of fovea, which is possessed only by man and the higher monkeys.

Proceeding up the scale, we also find an increasing ability to converge the optic axes on a near point so that the images of the point may coincide with the central spots of both retinas.

These changes and others are closely associated with each other and especially with the development of the higher faculties of the mind.

Binocular vision in man and in the higher animals is the last result of the gradual improvement of the most refined sense-organ, adapting it to meet the requirements of highly complex organisms.

The normal position of human eyes is convergent or parallel, but it is possible to diverge the axes. The movement of the eyes is rather complex. When they move together to one side or the other up or down in a vertical plane there is no rotation of the optical axes—that is, no torsion. When the visual plane is elevated and the eyes move to the right, they rotate to the right; when they move to the left, they rotate to the left. When the visual plane is depressed and the eyes turn to the right, they rotate to the left; when they turn to the left, they rotate to the right. Through experience we unconsciously evaluate the muscular stresses, efforts and movements accompanying the motion of the eyes and thereby interpret much through visual perception in regard to such aspects of the external world as size, shape and distance of objects. Even this brief glimpse of the movements of the eyes indicates a complexity which suggests the intricacy of the explanations of certain visual phenomena.

The third dimension of space and of objects and other aspects of the external world are as follows:—(1) extent; (2) clearness or brightness and color as affected by distance; (3) interference of near objects with those more distant; (4) elevation of objects; (5) variation of light and shade on objects; (6) cast shadows; (7) perspective; (8) variation of the visor angle in proportion to distance; (9) muscular effort attending accommodation of the eye; (10) stereoscopic vision; (11) muscular effort attending convergence of the axes of the eye. The varieties of experiences may be combined in an almost infinite variety of proportion.

For every voluntary act of sight there are two adjustments of the eyes, namely, focal and axial. In the former case the ciliary muscle adjusts the lens in order to produce a defined image upon the retina. In axial adjustments the two eyes are turned by certain muscles so that their axes meet on the object looked at and the images of the object fall on the central spots of the retina. These take place together without distinct volition for each but by the single voluntary act of looking. Through experience the intellect has acquired a

wonderful capacity to interpret such factors as size, form, and distance in terms of the muscular movements in general without the observer being conscious of such interpretations. Objects at different distances cannot be seen distinctly at the same time but by interpreting the eye-movements as the point of sight is run backward and forward (varying convergence of the axes) the intellect practically automatically appraises the size, form and distance of each object. Obviously, experience is the prominent factor.

In natural binocular vision, a person determines depth in what he sees by a combination of several different functions of the two eyes working in unison, these functions being carried out automatically by the eyes without conscious effort on the part of the observer. One of these functions is the power of the eyes to focus upon a particular object and the power of the observer's mind to determine from what focus and from its previous experience in viewing other objects approximately the distance of the object viewed from the eyes. The two eyes working together also possess the power of convergence which enables the observer when looking at an object to interpret by the amount of convergence necessary to fix both eyes upon the object the approximate distance of the object from the eyes. The third function of the eyes, and the function which actually produces the depth effect is as above mentioned, a combination of the first two, and consists of constantly scanning a scene being viewed. That is, each eye automatically focuses alternately upon different points in a scene being viewed, and the two eyes likewise alternately converge upon different points, and through the changes in focus and convergence necessary to do this, they interpret for the observer the difference in distance from the observer of various points in the scene. It will readily be seen that this produces the depth effect, and is the result which must be obtained artificially in stereoscopic reproduction.

From the above, it will be seen that the problem in producing stereoscopic moving pictures is not simply a problem of photography, is not simply a problem of projection, and is not simply a problem of how the projected scene is to be viewed. Instead, it is a problem concerning all three of these factors, and unless all three are properly solved and co-related the full effectiveness of the stereoscopic reproduction cannot be obtained. In other words, it is not sufficient to take the pictures in such a way as to artificially perform the function above mentioned as being ordinarily performed by the eyes of an observer, and it is not sufficient after that to project the pictures in such a manner that this effect will be preserved in the projected scene, but after that it is necessary that the projected scene be viewed by the observer in such a manner that his eyes will not endeavor to perform this function which has already been performed for him by the camera.

It is therefore an object of this invention to provide for the production of stereoscopic motion pictures.

It is an object of this invention to provide a method of reproducing motion pictures in which normal functions of binocular vision will be artificially performed during the taking of the pictures, in which this effect will be preserved during the projection of the pictures, and in which the eyes of the observer will be prevented from trying to do a second time what has been

done for them artificially during the taking of the pictures.

It is a further object to provide an apparatus whereby the method above referred to may be carried out.

With the above and other objects in view, there are hereinafter set forth by way of example several embodiments of this invention, reference being had to the accompanying drawings wherein like numerals indicate corresponding parts throughout.

In the drawings:

Figure 1 is a diagrammatical illustration of the method of taking the pictures in accordance with this invention.

Figure 2 is a diagrammatical illustration of one method which may be used in the photographing to produce photographic variation on a single film.

Figure 3 is illustrative of a section of film produced by the method diagrammatically illustrated in Figure 2.

Figure 4 is a diagrammatic illustration of a camera which may be used in carrying out the method illustrated in Figure 2.

Figure 5 is a diagrammatic illustration of an arrangement whereby two cameras may be used simultaneously.

Figure 6 is a diagrammatic illustration showing the method of superposing the images taken by two cameras as illustrated in Figure 5.

Figure 7 is a view illustrating the method of calculating the appropriate speed of movement of the camera and for determining its path when the distance of the camera from the set is less than one hundred feet.

Figure 8 is a similar view illustrating the method of determining these factors when this distance is one hundred feet or greater.

Figure 9 is a view of a frame used in the construction of one form of vertical line viewing screen.

Figure 10 is a horizontal sectional view of a vertical line viewing screen using the frame illustrated in Figure 9.

Figure 11 is a vertical sectional view of the same screen.

Figure 12 is a perspective view showing the arrangement of the line screen with respect to the ordinary screen in projecting pictures according to this invention.

Figure 13 is a view illustrating the image which is formed on the background provided by the ordinary screen when the line screen is interposed in front thereof.

Figure 14 is a view similar to Figure 13 but illustrating the appearance of the image of Figure 13 when viewed through the vertical line screen referred to.

Figure 15 is a diagrammatic illustration of the deviation of a light ray passing through a slit.

In carrying out the method of this invention, the first step is to determine a position or point from which all measurements and calculations are to be made. In locating this point the set is squared, (see Figures 7 and 8) that is, a distance back is measured equal to the width of the front of the set, and the center of this square, from which measurements and calculations are made, is termed $w+$. It is noted that the sets cannot be "flat" sets as are frequently used in ordinary motion picture work, but they must have depth in order for any depth to be recorded in the final reproduction. In Figures 7 and 8 the sets are illustrated as having a depth 3 and provided with

various desirable properties and scenery such as 4.

After the position of $\pi+$ has been determined, the camera or cameras 5 are placed at the proper distance from $\pi+$ so as to obtain the degree of close-up or distance that may be desired, and while the picture is being taken the camera or cameras 5 are moved through an arc 6 having $\pi+$ as its center. When the camera position is 10 35 feet from $\pi+$, which point may be taken as the point 7 in Figure 7, its movement will be such that it will travel through an arc 8-9 one foot in length in the space of time required for 16 frame lines to pass the aperture of the camera. 15 When the position of the camera is more than 35 feet from $\pi+$ the speed of the camera along its arc is greater, although the extent of its movement is not necessarily greater. This speed is computed by laying off an arc 10-11 which would 20 subtend the same angle α at the camera position that a one foot arc 8-9 would subtend at 35 feet from $\pi+$, and moving the camera at such a speed that it would traverse the arc 10-11 laid off in the space of time required for 16 frame lines to pass 25 the aperture. In this instance, since the arc laid off will obviously be greater than one foot, the speed of the camera along its arc of oscillation must be greater in order that it may move fast enough to travel this arc in the same length of time that it would travel the one foot arc if it 30 were at the 35 foot point. This is clearly apparent from Figure 7. The extent of movement may be varied independently of the speed. An increase in the distance traveled by a camera along 35 its arc will increase the depth effect and decrease in the distance traveled will decrease the depth effect when the picture is reproduced. The movement may be either oscillatory or unidirectional about $\pi+$ as a center. When the camera is 40 further away than one hundred feet as shown in Figure 8, the same speed and the same extent of oscillation may be used as at one hundred feet. The path 12 of the camera will however be 45 straight instead of an arc because when the distance from camera to $\pi+$ is one hundred feet for greater, it is for practical purposes considered the same as being at infinity, and when the radius is infinite the arc will of course become a straight line.

When the camera is closer than 35 feet the speed of the camera along its path may be the same as at 35 feet, it being understood that at all times when the camera is less than one hundred feet from $\pi+$ its path will be along an arc 50 with $\pi+$ as a center.

In photographing, the method illustrated in Figure 2 may be followed. In this figure, the numeral 13 designates a sensitive film surface, 14 and 15 a pair of prisms or the like arranged in a well known manner for directing two objectives upon a single surface. Intermittent laterally spaced shutters 16 and 17 control the exposure 60 of the film surface 13. These shutters are so operated that the film will be exposed alternately through first one and then the other. The film is advanced intermittently so that alternate frames of the film will be exposed through one shutter and the remaining frames will be exposed through the other shutter to receive views of 65 the object 18 from slightly different angles. The resulting film will be similar to the section of film shown in Figure 3. A camera with two spaced lenses 19 and 20 such as illustrated diagrammatically in Figure 4 may be used in carrying 70 out this method. Shutters 16 and 17 are

provided for the lenses and prisms 14 and 15 or the like are provided so that the images from both lenses will focus on the single film 13. The shutters 16 and 17 operate alternately, so that one frame 21 on the film is exposed through one 5 lens, the next frame 22 through the other lens, etc., as illustrated in Figure 3. For purposes of illustration, the image of a cubical object is shown in the respective frames of the film in Figure 3, and the difference between the images 10 23, taken through one lens, and the images 24, taken through the other is exaggerated.

An alternate method is to mount two single cameras 25 and 26 upon a common support 27 for synchronized operation, to oscillate and operate 15 together and to take two separate pictures on separate films as illustrated in Figure 5. These films are then printed and simultaneously projected on the same screen 28, said screen being of a construction later to be described. The composite picture thus projected is photographed 20 from the screen with an ordinary camera 29 which may be in synchronism with the projectors 30 and 31 and which is preferably placed between them. The two projectors and the camera are 25 preferably mounted on a single rigid support 32.

The positive film which is produced by either method just described, is projected in the usual manner upon a screen which consists, as shown in Figures 9 to 12 inclusive, of the usual screen 30 33 for a background, with the addition of a grid 34 placed before it, i. e. between the background and the observer.

Referring now more particularly to the drawings, there is shown diagrammatically in Figure 1 35 the object which may be designated as 13. The points 35 and 36 represent the location of the two lenses of a binocular camera, or the two lenses of two single cameras mounted in fixed relation to each other. The solid lines 37 and 38 extending 40 from 35 and 36 to the opposite ends of the object 13 illustrate the manner in which the views taken through the respective lenses converge upon the object. This gives the effect of convergence which has been previously discussed in connection 45 with binocular vision, and greatly assists in producing the desired result. However, the two lenses, while in fixed relation to each other, are moved through a path which may be designated as 12 at a speed which is determined in accordance 50 with the rules hereinbefore set forth. This motion may be oscillatory, or the path may continue entirely around the object if so desired, the material point being that the cameras are moved at the specified speed through their path. While 55 Figure 1 shows this path as being straight, it will be appreciated that this will depend upon the distance of the camera from $\pi+$, the path being along the arc of a circle when this distance is less than one hundred feet as illustrated in 60 Figure 7.

In the camera illustrated in Figure 4 each lens 19 and 20 is provided with its own shutter 16 and 17 and these shutters operate so as to open the apertures of the respective lenses alternately. 65 Rearwardly of each lens there is provided a prism 14 and 15 or similar device for deflecting the light rays 39 so that the images from both lenses will fall upon a single strip of film 13 passing behind them. Such strip of film is diagrammatically 70 shown in Figure 3, in which alternate frames have been exposed through the respective lenses. Thus, frame 21 was exposed through one lens, 22 through another lens, 21 through the first lens, 22 through the second lens, etc. as pre- 75

viously described. When these are projected on the screen as hereinafter described, although they flash upon the screen views taken alternately through first one lens and then the other, the after image of the observer's eye will view them as a continuous picture and will blend or superpose the images on each other. In Figure 4, the two lenses of the camera are shown as being focused on slightly different points or parts 40 and 41 of the object. Such an arrangement provides a stereoscopic effect, but the sharpness of the images is not so acute as when the pictures are taken according to the diagram shown in Figure 2.

In Figure 5 there is illustrated the method of taking the pictures by means of two separate cameras 25 and 26 fixedly mounted with respect to each other on the support 27 but movable together in the same manner as described in connection with Figures 2 and 4. These cameras operate simultaneously and the images taken are printed upon separate films, after which they are superposed as illustrated in Figure 6 by being separately projected from the projectors 30 and 31 onto a screen 28 presently to be described, and retaken by a camera 29 preferably placed between two projectors. Like the two lenses in Figure 4, the two cameras in Figure 5 are shown focused on different parts 42 and 43 of the object. The screen referred to as 28 is the same as the screen which is subsequently used in the final reproduction of the pictures and as illustrated in Figures 9 to 12, it consists of the usual background 33 (see Fig. 12), with a vertical line screen 34 placed before it. This vertical line screen is made up of a series of opaque lines 44, the screen itself being spaced from the background 33 by a distance of about 1 millimeter. The composite screen must be disposed in a plane substantially at right angles to the axis of projection.

In order to provide a commercial construction for this screen and to guard against inaccuracies in its formation, it may be made up as illustrated in Figures 9, 10 and 11. In Figure 9 there is shown a frame 45 having a series of small holes 46 across the top and across the bottom thereof. It has been found that linen thread colored a dead black is quite suitable for the opaque lines. Such a thread 47 may be threaded through the holes 46 in the frame 45 as illustrated in Figures 10 and 11 so as to form the screen. Thus, the distance between the lines of the screen is fixed by the manufacturer and they cannot become shifted, and the device is at the same time capable of being assembled by any qualified technician.

The space between the lines of this line screen is determined by the angle of the lenses with which the pictures are taken and by the distance from the screen of the projector from which the pictures are to be projected. There is quite a wide tolerance in this spacing, and for ordinary theater projection a standard may be provided which has been found suitable for practically all ordinary operating conditions. Under this standard, the lines are made one millimeter in width, and the spaces between the lines one-half millimeter in width.

From the above, it will be appreciated that in carrying out this invention there is only one additional piece of equipment not included in ordinary theater equipment, which is necessary for the projection, namely the line screen which is described. This equipment is relatively inex-

pensive and this fact adds to the practicability of the invention for general use.

In theory, this invention is based upon the fact that rays of light passing by sharp opaque edges disposed at right angles to the rays of light do not move in accordance with the theory of rectilinear light wave motion. Instead, the rays immediately adjacent the edge are bent towards the edge. The effect of rays passing through an aperture between such edges is analogous to the passage of light through a concave lens. For example:

Suppose (Figure 15) a monochromatic plane wave to fall upon a screen at an angle of incidence i . This screen is pierced by a slit, whose edges s^1 and s^2 are perpendicular to the plane of incidence, which is considered parallel to the plane of the paper. In consequence of Huygen's principle, illumination may be observed from the other side of the screen in directions other than that of the incident light. Suppose an angle i' with normal to the screen and that w^3 is the diffracted plane wave observed. Let the width of the slit be a and dx be an element of width of the slit at a distance x from the center, the center being the origin of co-ordinates. Assuming the vibrations which constitute the advancing wave front to be simple harmonic, they may be represented by a point p on the central ray by the customary expression

$$\frac{2\pi t}{T}$$

multiplied by an appropriate amplitude constant, and similarly, for some other point p' of the same wave front, by the expression

$$ds = cdx \sin 2\pi \left(\frac{t}{T} - \frac{\delta}{\lambda} \right) \quad (1)$$

cdx represents an amplitude factor, where c is a constant depending upon the intensity of the source, and where dx is the width of the slit element whose effect is being investigated, ds represents that part of the total displacement, at any point, that is due to the element of width dx of the slit, λ represents the wave-length of the incident light, and δ the differences between the lengths of path of the central ray and of the one which traverses the element of width dx in travelling from their positions in the w^1 plane to those in the w^3 plane.

$$\frac{\delta}{\lambda}$$

therefore represents the phase of difference between the vibrations in the corresponding two points of the w^3 plane. From the figure

$$\delta = x(\sin i + \sin i') \quad (2)$$

$$\frac{\sin i + \sin i'}{\lambda} = \theta$$

Then Equation (1) takes the form

$$ds = cdx \sin 2\pi \left(\frac{t}{T} - \theta x \right) \quad (3)$$

considering the resultant light vibrations at the point where the image of the slit is being observed. The total displacement s^1 due to the whole slit-width will be given by integrating (3) between the limits

$$\pm \frac{a}{2}$$

with respect to the variable x . Result

$$s = ca \frac{\sin \pi a \theta}{\pi a \theta} \sin 2\pi \frac{t}{T} \quad (4)$$

This represents a simple harmonic vibration whose amplitude is

$$ca \frac{\sin \pi a \theta}{\pi a \theta} \quad (5)$$

Intensity, being proportional to energy, is proportional to the square of the amplitude of the vibration causing illumination. Hence the intensity at any point on the screen is given by

$$I = \left[ca \frac{\sin \pi a \theta}{\pi a \theta} \right]^2 \quad (6)$$

except for a proportionality factor, which we may consider to have been "absorbed" into c . This function of θ and therefore of i is the direction of the diffracted rays. (6) represents the intensity distribution as shown in Figure 13.

It is noteworthy that no line screen or equivalent is used in connection with the taking of the pictures as in previous efforts to solve this problem but that such a screen is used solely in front of the projecting screen. This line screen is employed for the purpose of maintaining the axes of the observer's eyes parallel, and thus preventing them from involuntarily trying to scan the depth of the projected picture. When the picture is projected through this screen, it produces a series of diffused images, of which Figure 13 of the drawings is illustrative, due to the bending of the light rays adjacent the opaque lines. Note that the shadow lines 48 are not clear and sharp but are diffused, while in Figure 14, the divisions between the highlights 49 and shadows 50 are comparatively sharp and clear. Thus, when these images are viewed through this line screen this effect is reversed and the eye sees a clear image which, due to the manner in which it was taken, gives to the observer the same effect that he would obtain from the eyes scanning the depth of a natural object. Thus the depth effect is produced and the line screen prevents the observer's eyes from scanning the depth and thus spoiling the illusion of depth. The line screen becomes invisible during the process of projection.

It will be appreciated that there has been set forth a method and apparatus, which, taken as a whole, will result in the reproduction of stereoscopic motion pictures and will accomplish all the objects sought to be accomplished by this invention in a practical and satisfactory manner. Having described my invention I claim:

1. The method of producing stereoscopic motion pictures which comprises forming two stereoscopic images of the scene from slightly spaced view points, recording the images separately and alternately on a film, forming a like series of images of the scene at a slightly different angle and recording said images alternately on the film, all of the images being taken at the same distance from the object but each at a different angle, and at a rate to provide persistence of vision, and projecting said images onto a screen and diffusing the projected image at the screen into small alternately, laterally and forwardly spaced line elements.

2. The method of producing stereoscopic motion pictures which comprises forming two stereoscopic images of the scene from slightly spaced view points, recording the images on a film, forming a like series of images of the scene at a slightly different angle and recording said images on the film, all of the images being taken at the same distance from the vertical median of the object but the consecutive images at a different angle, and at a rate to provide persistence of vision, and projecting said images onto a screen

and diffusing the projected image at the screen into small alternately, laterally and forwardly spaced line elements.

3. The method of producing stereoscopic motion pictures which comprises forming two stereoscopic images of the scene from slightly spaced view points, recording the images on a film, forming a like series of images of the scene at a slightly different angle and recording said images on a film, simultaneously projecting said images onto a screen to form a composite stereoscopic image and diffusing the projected image at the screen into small alternately, laterally and forwardly spaced line elements, forming a stereoscopic image of said projected composite image, recording this composite image on a film, and projecting said composite images onto a screen and diffusing the projected image at the screen into small alternately laterally and forwardly spaced line elements, all of the images being taken at the same distance from the object but each at a different angle, and at a rate to provide persistence of vision.

4. The method of producing stereoscopic motion pictures which comprises forming two stereoscopic images of the scene from slightly spaced view points, recording the images on a film, forming a like series of images of the scene at a slightly different angle and recording said images on a film, simultaneously projecting said images onto a film to form a composite stereoscopic image, and projecting said composite images onto a screen and diffusing the projected image at the screen into small alternately, laterally and forwardly spaced line elements, all of the images being taken at the same distance from the object but each at a different angle, and at a rate to provide persistence of vision.

5. The method of producing stereoscopic motion pictures which comprises locating the vertical median of the scene, forming two stereoscopic images of the scene from slightly spaced view points located on a line normal to a radius from the median as a center to the mid point of the line connecting the view points and recording the images alternately on a film, forming a like series of images of the scene at a slightly different angle and recording said images alternately on the film, all of the images being taken at the same distance from the vertical median of the scene but each at a different angle, and at a rate to provide persistence of vision, and projecting said images onto a screen and diffusing the projected image at the screen into small alternately, laterally and forwardly spaced line elements.

6. The method of producing stereoscopic motion pictures which comprises forming plural images of a scene from spaced view points, spaced normally with respect to a median optical axis extending radially from the vertical median of the scene as a center, said view points converging on said median while forming said images, recording said images alternately on a film, forming similar images from another angle and similarly recording said images, and projecting said images on a screen while diffusing the projected images on a series of uniformly and alternately, laterally and forwardly spaced line elements, said images being all taken at the same distance from the vertical median of the scene, at a rate to provide persistence of vision, the view points being moved along an arc with the vertical median of the scene as a center and at a rate of about 1.63 degrees per second.