

June 23, 1942.

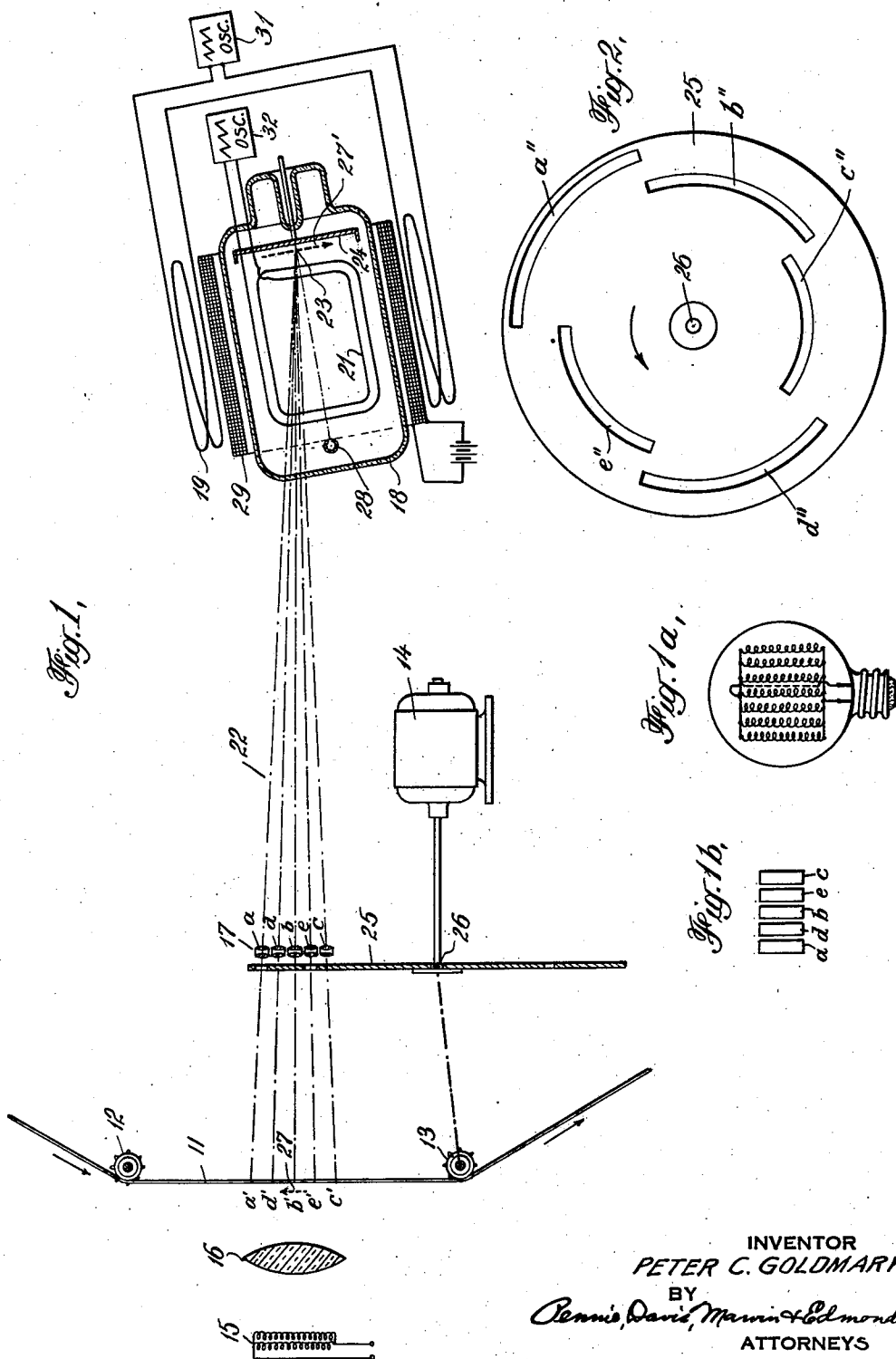
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2,287,033

METHOD AND APPARATUS FOR TELEVISION

Filed May 28, 1938

8 Sheets-Sheet 1



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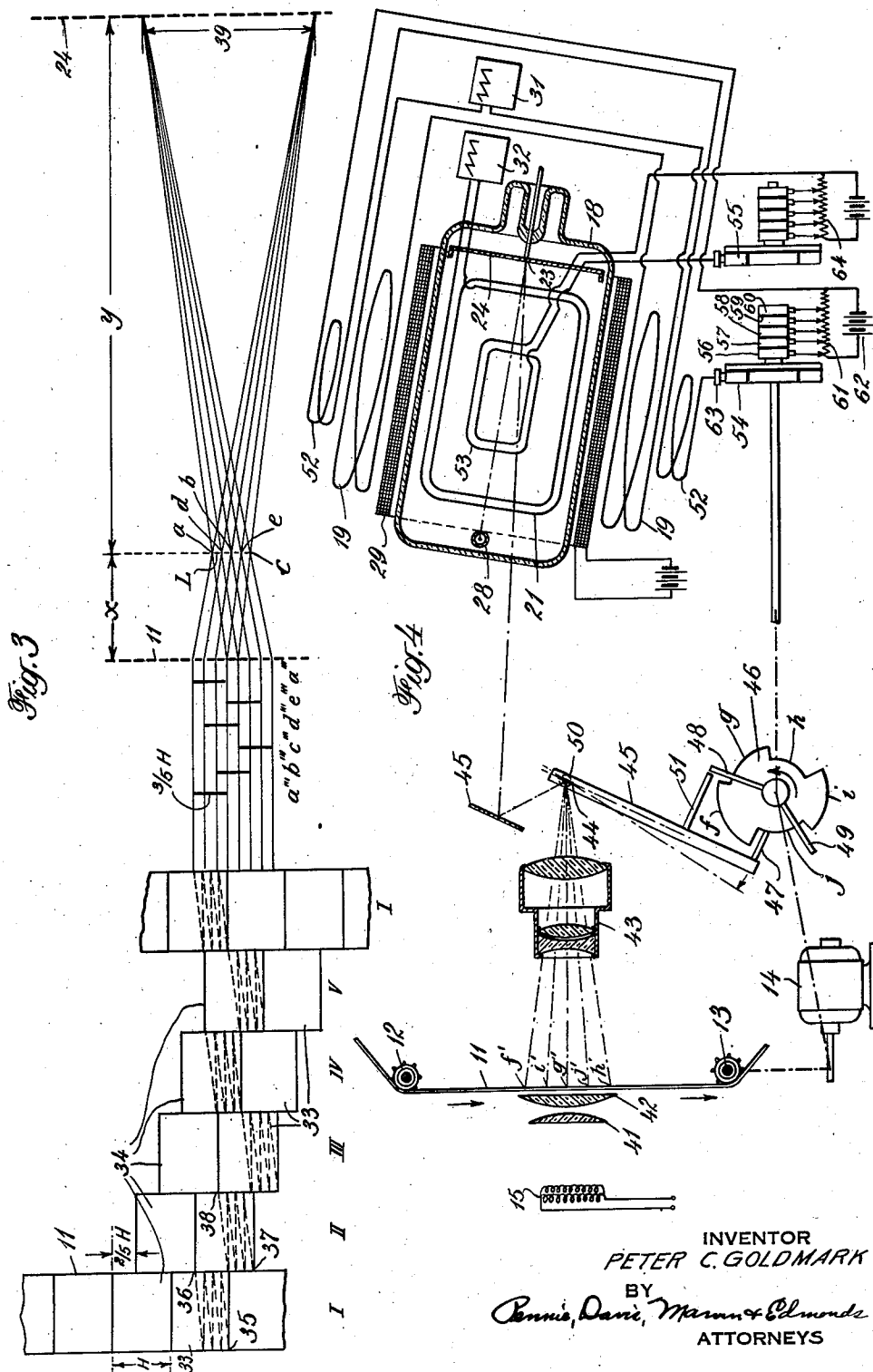
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METHOD AND APPARATUS FOR TELEVISION

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Fig. 5a

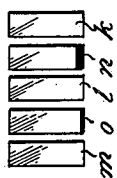


Fig. 6,

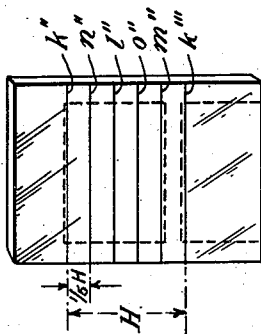
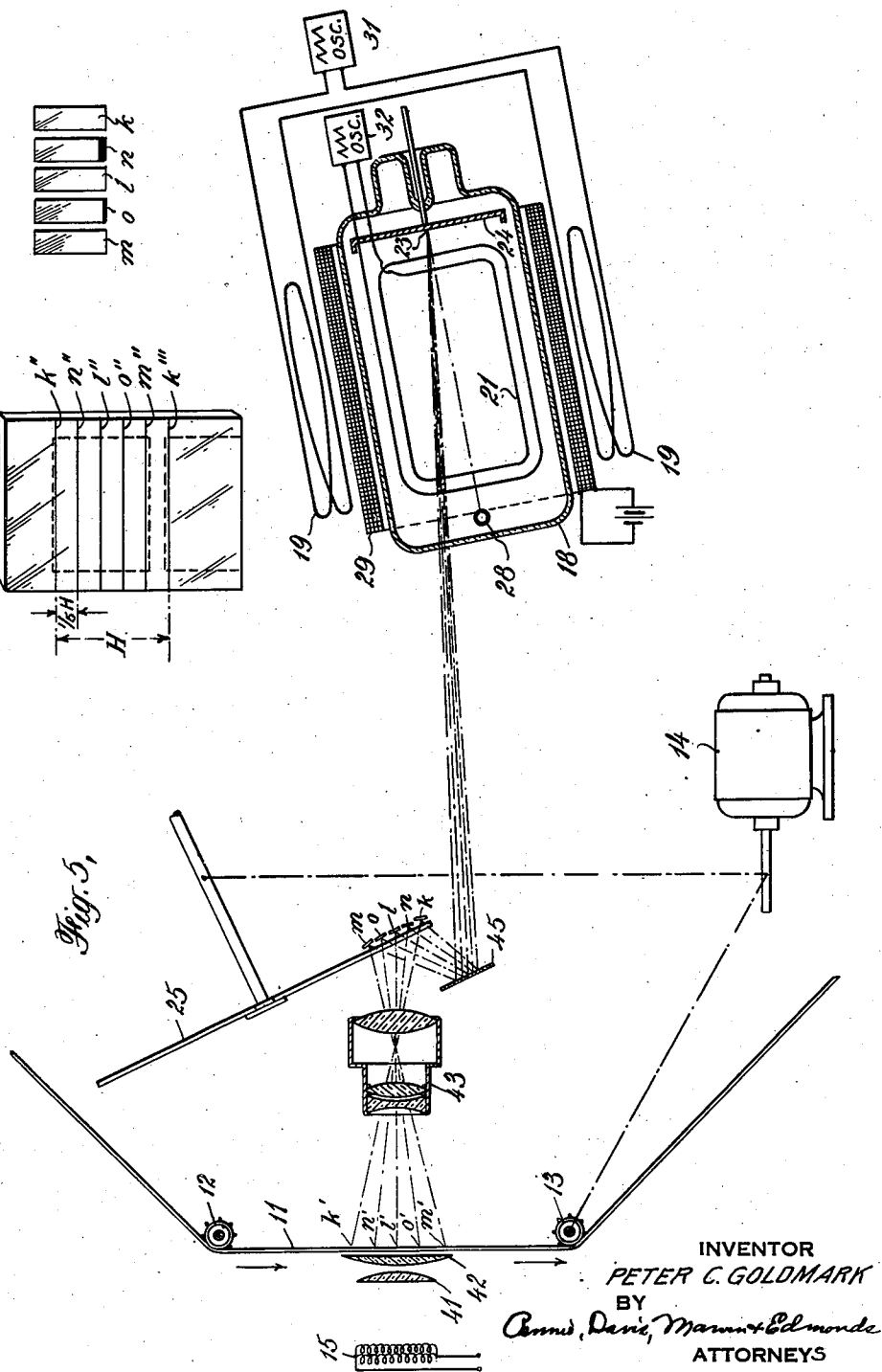


Fig. 5,



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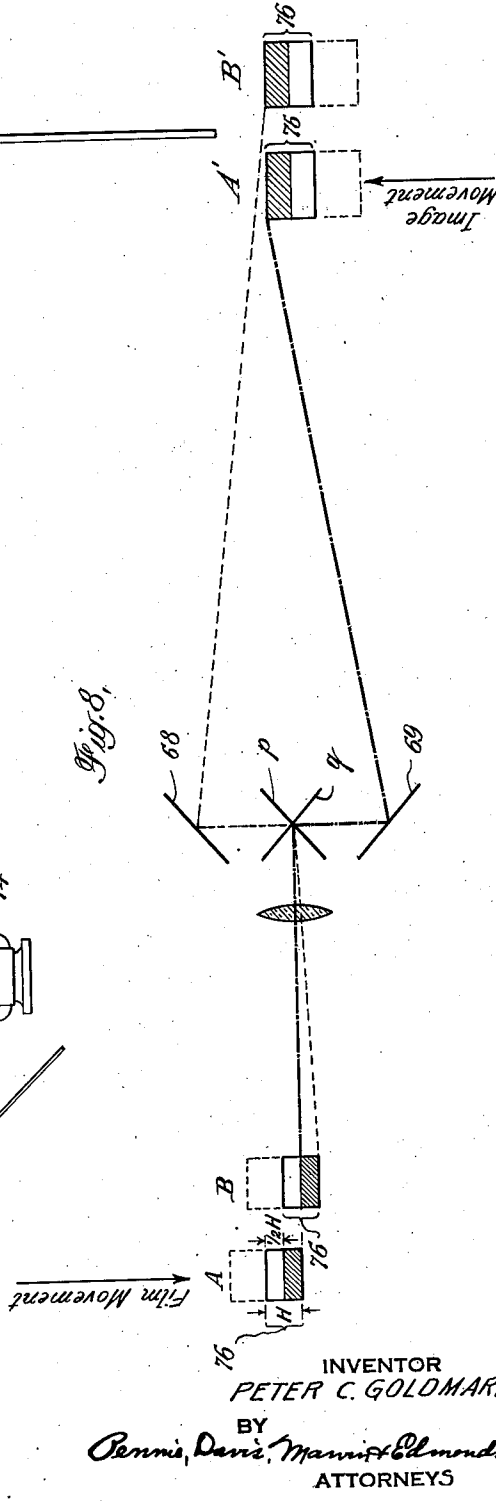
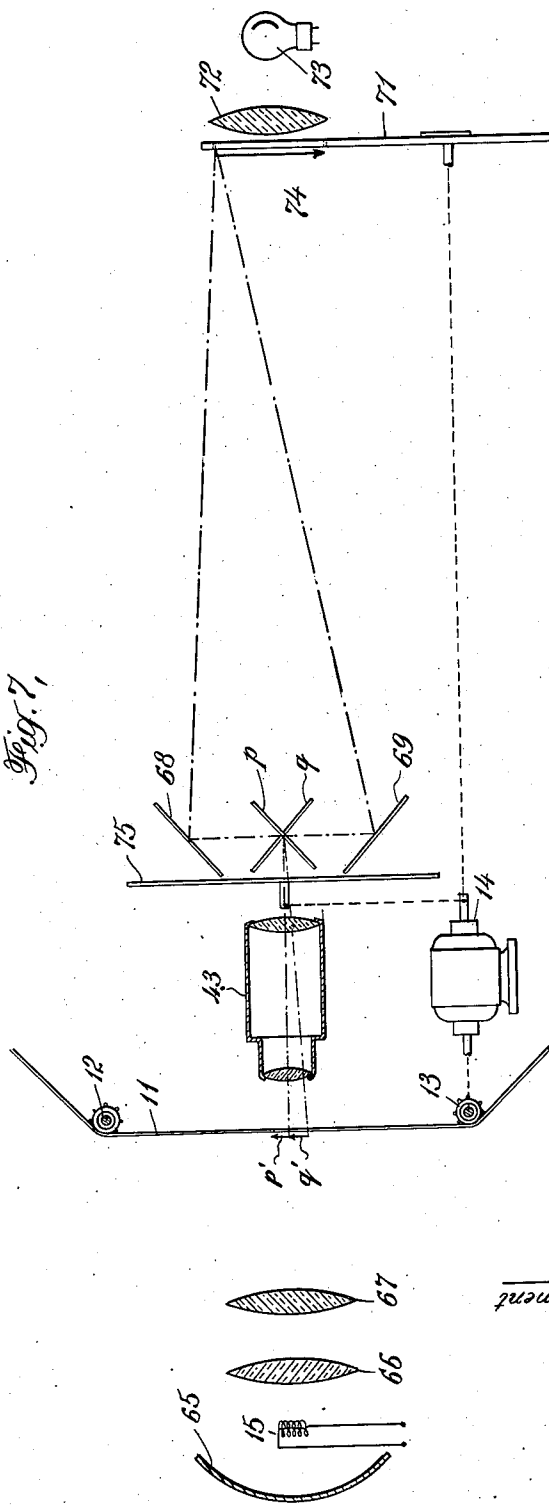
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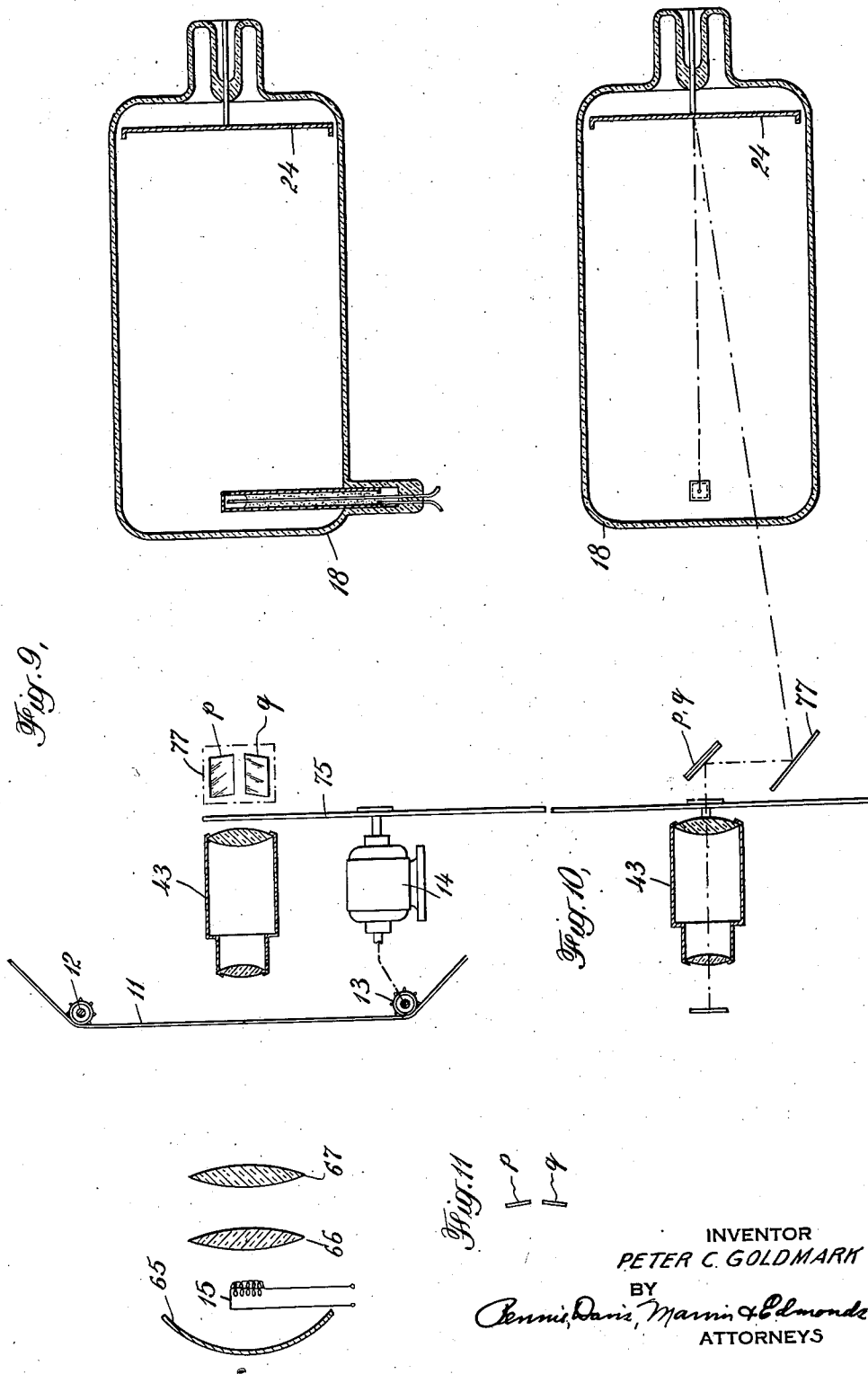
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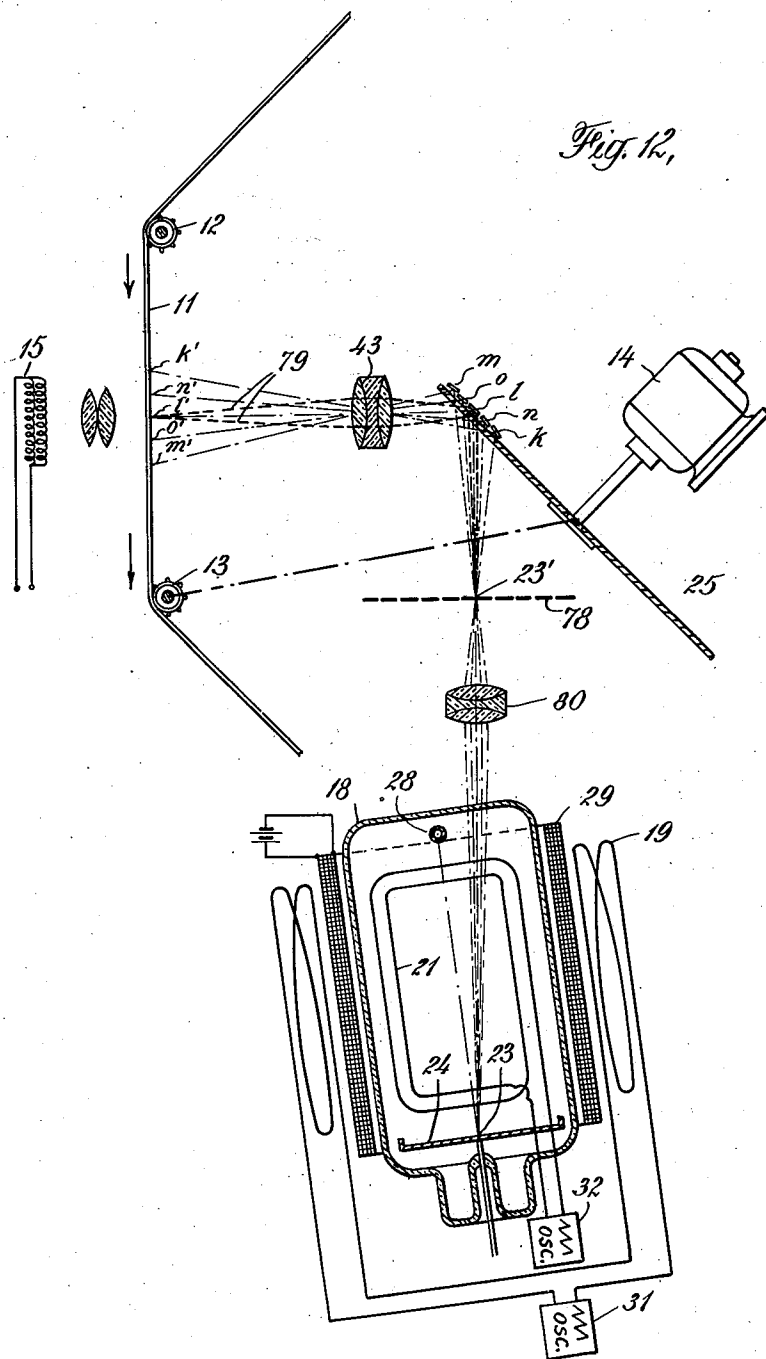
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Fig. 12,



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Fig. 13,

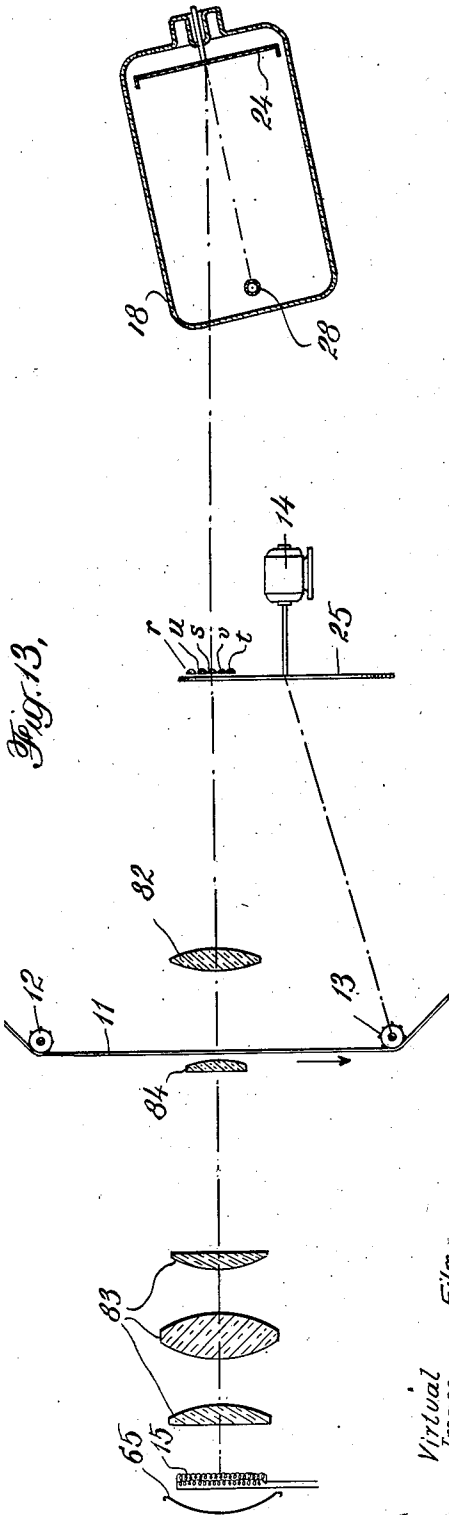
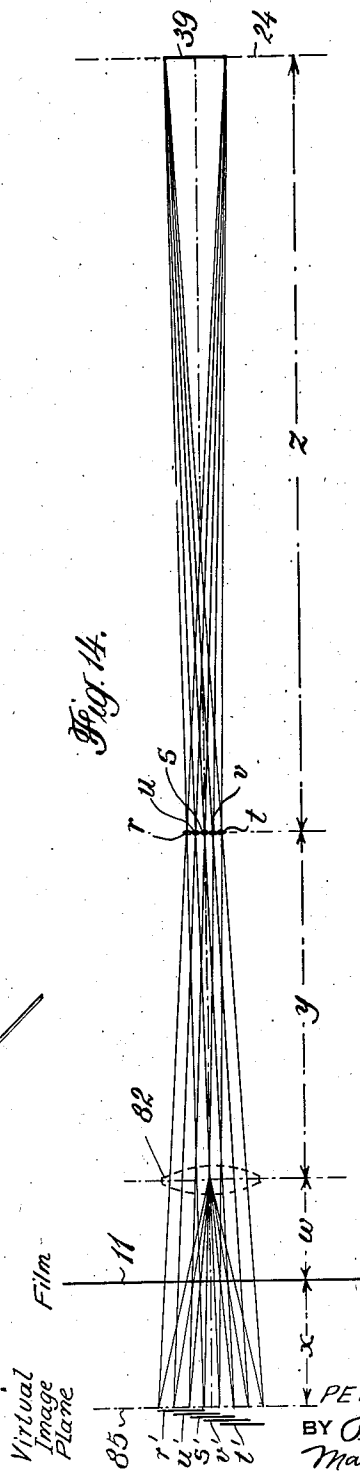


Fig. 14.



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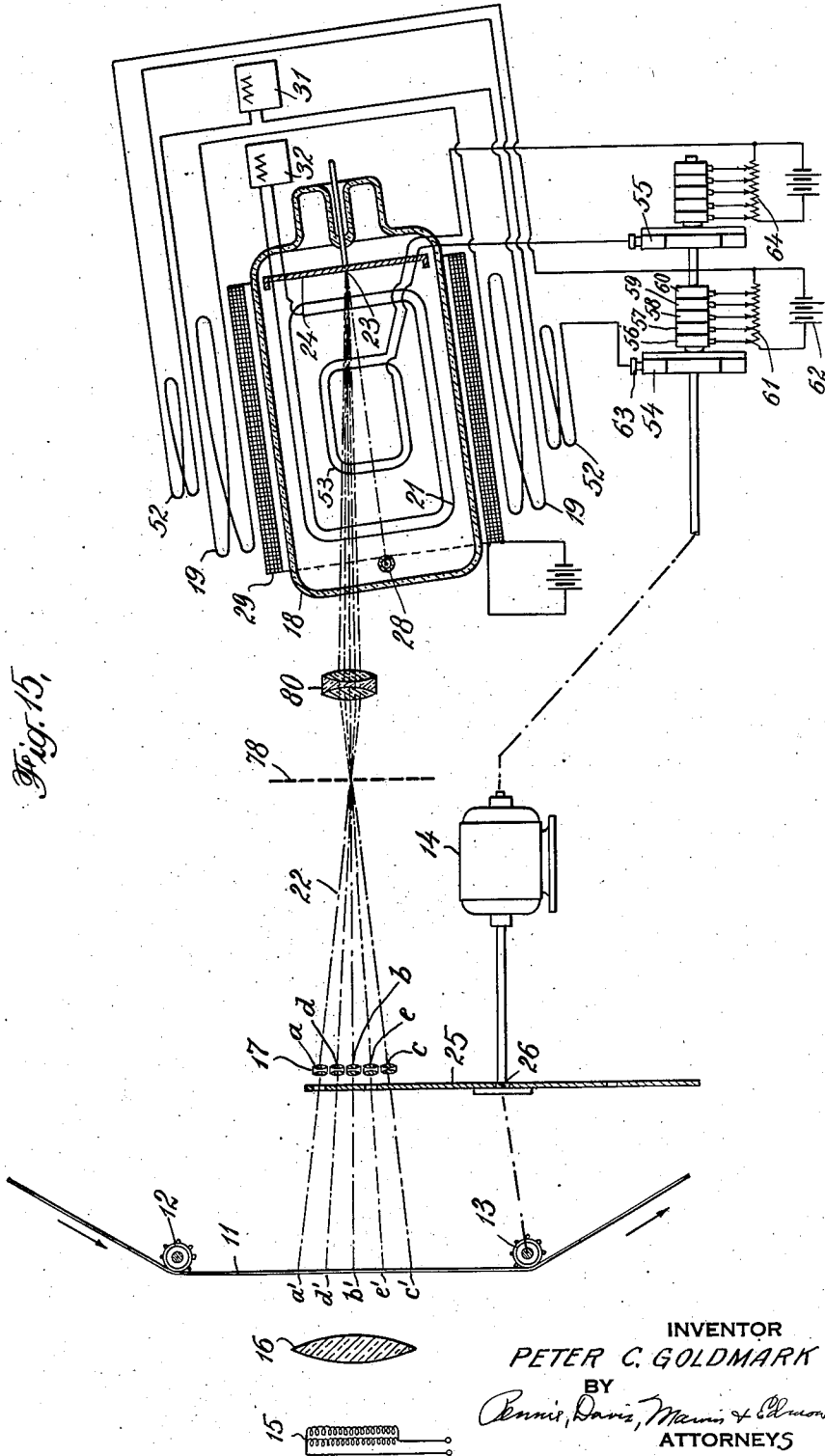
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UNITED STATES PATENT OFFICE

2,287,033

METHOD AND APPARATUS FOR TELEVISION

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Application May 28, 1938, Serial No. 210,607

19 Claims. (Cl. 178—7.2)

This invention relates to television scanning systems, particularly to film-scanning systems used in television transmitters. The invention especially relates to a method and apparatus for the scanning of a plurality of spaced areas lying in the path of travel of a film during its passage through the scanning apparatus. The invention particularly contemplates the scanning of a continuously moving film in which a single film-frame is scanned a plurality of times.

In the present state of the art, the televising of program material recorded on film is of considerable practical importance. This is true not only because of the possible extensive use of the so-called intermediate film process, but also because it is contemplated that, at least in the early stages of television broadcasting, and probably later on also, a considerable portion of the program material will be obtained from ordinary sound-motion-picture film, or from sound motion pictures especially recorded for television purposes.

The present television standards adopted in the United States require the transmission of images at the rate of 30 pictures per second, interlaced. Thus, the component scansions are produced at the rate of 60 scansions per second, two scansions for each picture transmitted. In motion picture practice, however, sound films are recorded and projected at the rate of 24 pictures per second. Thus, if standard sound motion pictures are employed in television, these two different standards must be coordinated, and since the periodicity of the scanning is not an integral multiple of the rate of movement of the film in frames per second, a special scanning scheme is required. Such coordination is highly desirable, since it renders the great libraries of ordinary sound-motion-picture film available for television purposes. Of course, the standards may be changed from time to time, but it appears likely that the rate of component scansions in television will be different from the rate at which sound motion pictures are recorded and projected.

Apparatus employed in televising motion picture material recorded on film may be classified into two general types. In one type the film is moved intermittently in a manner analogous to that employed in ordinary motion picture practice. In the other type the film is moved with continuous uniform motion.

Apparatus of the first type has been suggested, utilizing a tube of the iconoscope type. The film-frame, while stationary, is projected onto the mosaic of the iconoscope, the projection light

cut off, and the image on the mosaic scanned. Successive frames are scanned alternately 2 and 3 times at the rate of 60 scansions per second. In the frames which are scanned three times, the third scansion is a duplicate of one of the other two. Thus, 24 frames of the film are transmitted in a second, but 60 scansions are employed for doing so, thereby coordinating the motion picture and television standards. To accomplish this, however, it is necessary to move the film intermittently at the alternate rates of 30 frames per second and 20 frames per second, instead of moving the film intermittently at a uniform rate as in ordinary motion picture practice. Thus, the intermittent-feed mechanism is additionally complicated over that employed in ordinary motion picture projectors. Furthermore, owing to the very short period of exposure (of the order of $1/1000$ of a second), an intense source of light must be used.

Apparatus of the second type above mentioned, in which the film is fed with continuous uniform motion, and in which film-frames are transmitted at the rate of 24 pictures per second but with 60 scansions per second, have been disclosed in my prior copending United States applications, Serial Numbers 72,009 and 115,113. In the embodiments there shown, the scanning pattern of the scanning cathode-ray tube is displaced for successive scansions in such a manner that the film-frames are scanned alternately two and three times, thus scanning 24 film-frames with 60 scansions. This procedure gives the desired coordination between the motion picture and television standards.

The present invention is particularly concerned with apparatus of the second type in which the film is moved continuously. It differs from the systems in my prior applications above mentioned, however, in that the relatively large displacement of the scanning pattern of the scanning device is avoided, and the necessary displacement produced by optical means, the scanning pattern itself remaining stationary. This procedure has certain advantages as regards simplicity of equipment, reliability of operation, and quality of the reproduced pictures. A further difference is that in the apparatus described herein the images on the film are optically projected to the scanning device, instead of optically projecting a scanning spot of light to the film. Thus an adequate amount of light, which is important in television scanning, may be secured, and this light may be used efficiently. Furthermore, this procedure renders possible the use of electronic

scanning tubes such as those of the "image-dissector" type. Also, excellent contrast and detail may be obtained.

The invention is particularly advantageous in connection with present day electronic scanning tubes. In such tubes, for example, in tubes of the image-dissector type, for which the invention is particularly adapted, it is found that the deflecting fields in different parts of the tubes are not absolutely uniform. With pictures of the high definition now employed (441 lines per picture is the present standard), if two interlaced scansions of a single film-frame are produced in different parts of the scanning tube, such non-uniformity of the deflecting field in the two respective parts of the tube will prevent the precise interlacing of the two scansions, and hence will adversely affect the quality of the television image. Also, if two scansions of a single film-frame were each complete, rather than interlaced, the two images would not be identical, and hence would impair the received image. Still further, it is possible that in the development of the art it may become desirable to scan fewer pictures per second than are recorded on the film, so that individual film-frames would be scanned only once, but at different points in their path of travel. In such case, if successive film-frames were scanned in different parts of the scanning tube, non-uniformity of the deflecting field in the two respective parts would adversely affect the quality of the transmission since usually successive film-frames differ only slightly from each other.

By not displacing the scanning pattern, the present invention avoids the above difficulties. Furthermore, the required working area of the scanning tube is smaller than that required when the scanning pattern is displaced, for a given magnification between film-frames and scanning device. Even when it is desired to employ a mechanical rather than an electronic scanning device, for example, an apertured disc, using the scanning scheme described hereinbefore, the invention permits of the use of a simpler scanning device than would otherwise be the case.

In accordance with the invention, portions of a film lying at different separated areas in the path of travel of the film are successively projected and rendered in scanning relation with a substantially stationary scanning pattern produced by a suitable scanning device. More specifically, portions of a film lying at different separated fixed areas in the path of travel of the film are projected to substantially the same area of a selected image surface, usually a plane, and a scanning device is positioned with respect to the plane so as to scan the projected images of those portions of the film lying at the separated areas as they are projected to the same area of the selected plane.

Several forms of apparatus have been devised to carry out the above procedure, and will be described hereinafter. Although each of these forms is adapted to carry out the method of the invention, in general different forms possess somewhat different advantages from a practical standpoint, and therefore the particular form selected will be chosen in view of the particular conditions surrounding the application.

In general, a projection system is employed including optical means successively operative to project different relatively spaced areas in the path of travel of the film to the scanning device. For example, a plurality of successively operative

light-diverting elements, such as lenses or mirrors, may be employed.

One embodiment described hereinafter employs a plurality of projection lenses spaced apart in the direction of travel of the film. This embodiment is comparatively simple in design. The lenses will be ordinarily rather small, but should preferably be rather highly corrected. Furthermore, the several lenses should have the same focal length, unless some compensating means is employed. If desired, portions of highly corrected systems may be employed.

Embodiments employing a single projection lens, which may be of standard design, have also been devised. In general, these embodiments employ one or more light-diverting elements, for example, mirrors, for producing the relative displacement at the film. In one such design, a single mirror is employed, with a mechanism for intermittently changing the orientation of the mirror through a plurality of different orientations, thereby making efficient use of the light passing through the projection lens.

With relatively high frame frequencies, it may be difficult and expensive to construct apparatus to change the orientation of the mirror with the desired rapidity and precision. For such a case, apparatus has been devised employing a plurality of fixed mirrors whose orientations are such as to produce the desired separation of the areas of the film. In such a system the mirrors are relatively inexpensive and permit of a comparatively wide latitude of adjustment.

In the systems hereinafter more fully described, in which images on a continuously moving film are optically projected to the scanning device, it is contemplated that a single film-frame, ordinarily, will be successively projected a plurality of times and scanned each time. In view of present standards, the apparatus is designed to scan each film-frame a plurality of times, successive frame areas being scanned two and three times. If the standards are changed, or if for any other reason it is desired not to scan each film-frame a plurality of times, the apparatus of the invention may be changed accordingly.

Generally, the film-frame will be in a different position in its path of travel at the beginning of each scanion period. Also, since the film is moving during each projection, the image at the scanning device will be moving. In accordance with the method of the invention, at corresponding instants in the respective scanion periods the projected images of a given film-frame occupy substantially the same area of the scanning device. Thus, the projected images of a given element of the film-frame occupy substantially the same elemental area of the scanning device each time that particular element is scanned.

For convenience, it may be considered that at corresponding instants in the respective scanion periods the projected images of the same film-frame coincide at the scanning device. It will be understood that the images are not there at the same instant, but are there during their respective scanion periods.

Ordinarily, successive frames of a film will have the same dimensions and will bear images only slightly differing from each other. Therefore, at corresponding instants in the respective scanion periods, not only the several images of the same film-frame but also the images of successive film-frames are projected to the same area of the scanning device. Thus the scanning pattern may remain unchanged for successive

scansions of both the same and successive film-frames.

The invention may be more readily understood by a consideration of the specific embodiments shown in the drawings, and the following discussion thereof.

In the accompanying drawings:

Fig. 1 is a diagrammatic view, partly in section, of transmitting film-scanning apparatus employing a plurality of projecting lenses;

Fig. 1a is a front view of the projection lamp of Fig. 1;

Fig. 1b is a front view of the projection lenses of Fig. 1;

Fig. 2 is a front view of the shutter employed in Fig. 1;

Fig. 3 is a diagram illustrating the operation of the apparatus of Fig. 1, and also the general principles of operation of the apparatus shown in the remaining figures of the drawings;

Fig. 4 is a diagrammatic view, partly in section, of film-scanning apparatus employing an oscillating mirror;

Fig. 5 is a diagrammatic view, partly in section, showing film-scanning apparatus employing a plurality of fixed mirrors;

Fig. 5a is a front view of the plurality of mirrors of Fig. 5;

Fig. 6 illustrates a pattern useful in orienting the mirrors of Fig. 5;

Fig. 7 is a diagrammatic view of a modified apparatus employing fixed mirrors;

Fig. 8 is a diagram illustrating the operation of the apparatus of Fig. 7;

Figs. 9 and 10 are diagrammatic side and top views, respectively, of a further modification of apparatus employing fixed mirrors;

Fig. 11 is an end view of the pair of mirrors *p, q* of Figs. 9 and 10;

Fig. 12 is a diagrammatic view, partly in section, of a modified form of apparatus similar to that of Fig. 5; and

Figs. 13 and 14 are a diagrammatic view and explanatory diagram illustrating an embodiment similar to Fig. 1;

Fig. 15 is a diagrammatic view of an embodiment including the plurality of projection lenses of Fig. 1, the auxiliary deflecting means of Fig. 4, and the additional projection means of Fig. 12.

Referring now to Fig. 1, film 11 is fed with continuous uniform motion by a film-feeding mechanism including sprockets 12, 13 driven by motor 14. Additional mechanism may be employed, if desired, to insure absolute uniformity of motion. The film is illuminated by a suitable projection lamp 15 and condenser lens 16. The projection lamp may be a multiple coil tungsten projection lamp, such as illustrated, or other suitable projection source, such as an arc lamp. A front view of the lamp is shown in Fig. 1a. A plurality of fixed projection lenses, generally designated as 17, are interposed between the film 11 and a suitable television scanning device 18, here shown as a tube of the so-called "image-dissector" type. The image-dissector tube is provided with suitable longitudinal and transverse deflecting coils 19 and 21, respectively.

Projection lenses 17, here shown as five in number, designated *a, b, c, d* and *e*, respectively, are spaced apart longitudinally of the path in which film 11 is moved. Light rays 22 are drawn from the film through respective projection lenses to the same point 23 of cathode 24 of the image-dissector tube. From these rays it will be seen that light from the fixed longitudinally

separated points *a', b', c', d'* and *e'* in the path of travel of film 11 pass through the respective projection lenses and are superposed at point 23 of the cathode of the image-dissector tube, assuming for the moment that all the projection lenses are in operation at the same time. If the film 11 were considered to be stationary, the spaced points *a', b', c', d', e'* could be considered as being spaced points of the film itself. But since the film is continuously moving, the points of the film which lie at points *a' . . . e'* will be continuously changing, and therefore the points on the film which are superposed at point 23 will be continuously changing. However, the points of the film which are superposed for one position of the film remain superposed as the film moves, the point on cathode 24 at which they are superposed changing with the film movement.

Actually, in the operation of the apparatus, only one projection lens is operative at a time, and the lenses are made successively operative in the proper sequence by means of a continuously rotating shutter 25 driven by motor 14. Since motor 14 drives both the film-feeding sprocket 13 and shutter 25, the shutter may readily be properly synchronized with the film movement. A front view of shutter 25 is shown in Fig. 2. A plurality of arcuate slots *a'', b'', c'', d''* and *e''* are cut in an opaque disk 25 of suitable material. The arcuate slots are so spaced from the axis 26 of the disk as to uncover the respective lenses *a, b, c, d* and *e*. The order in which the slots are arranged around the disk, and hence the order in which the respective lenses are uncovered, is determined by the order in which it is desired to scan respective areas of the film 11. In general, successive slots are operative during successive scansion periods.

If desired, the shutter may be rotated intermittently, instead of continuously, to expose the lenses in proper sequence, thereby permitting the use of a smaller disc with shorter slots. Or, other suitable means, such as light valves, may be employed.

Each projection lens 17*a . . . e* projects an area lying in the path of travel of the film to a corresponding conjugate area of the cathode 24 of the image-dissector tube, rather than merely a point. Thus, if arrow 27 be considered to be an image recorded on film 11, a corresponding image 27' will be formed on the cathode 24 by projection lens *b*. The image-dissector tube may be skewed just enough so that all rays from the lenses pass by the scanning finger 28, thereby avoiding producing a shadow of the finger on the cathode. Of course, if the finger is placed at the side of the tube, or is located on the opposite side of the cathode, the skewing may be dispensed with.

In general, the image projected onto cathode 24 by a single lens will correspond to a film-frame of film 11, but since in Fig. 1 the film is continuously moving during scanning, the height of the projected area may be less than the height of a film-frame if the direction of the longitudinal scanning in the image-dissector tube is against the motion of the projected image. This will be more fully described hereinafter. The ratio of the distance from film to projection lens, and the distance from projection lens to cathode, may advantageously be chosen so as to produce an image on the cathode which is enlarged several times.

The image 27' causes the emission of photo-electrons from cathode 24 which are focused by

focusing coil 29 and form an electron image in the plane of the scanning finger 28. This electron image is deflected past the scanning finger by means of coils 19 and 21, and respective associated saw-tooth oscillators 31 and 32. The operation of the image dissector is well-known, and therefore need not be further described herein. The saw-tooth oscillator 32 and deflecting coil 21 scan the projected film image in a direction transverse of the film, at line-scanning frequency. The oscillator 31 and deflecting coil 19 deflects the electron image longitudinally of the film at frame-scanning frequency. The magnitude of the longitudinal deflection is such as to complete a scanning traversal of the moving image 27' on the cathode during the proper interval.

The specific apparatus shown in Fig. 1 is particularly designed for scanning a film moving at the rate of 24 frames per second by the interlaced method with component scansions occurring at the rate of 60 scansions per second. For a more complete understanding of the operation of the apparatus reference may be had to Fig. 3.

In Fig. 3 a fragment of film 11 is illustrated in the positions which it occupies at the beginning of successive scansion periods. With a film movement of 24 frames per second and a scansion rate of 60 scansions per second, it will be understood that two film-frames move past a given point in the path of travel of the film in the length of time it takes for five scansions. Therefore, the film moves a distance corresponding to $\frac{2}{5}H$, where H is the distance between successive film-frames, during a single scansion period. For this reason the film-frames 33 and 34 are shown successively displaced a distance of $\frac{2}{5}H$, at the beginning of corresponding scansion periods I, II, III, IV and V, respectively. The scansion periods are $\frac{1}{60}$ second in length, not taking into account the fact that the film-frames may not be quite contiguous to each other.

During scansion period I, the lower film-frame 33 is projected through projection lens *a* (Fig. 1) and scanned, the scansion beginning at the lower edge of the film-frame at point 35 and progressing upwards until it reaches point 36 at the end of the scansion period. Since the film-frame moves downward a distance of $\frac{2}{5}H$ during the scansion period, the scansion area need be only $\frac{3}{5}H$ in height in order to completely traverse the film-frame. It will be understood that although the scanning pattern is actually produced in the scanning tube, in Fig. 3 the dotted scanning pattern is represented as being at the plane of the film. Each scanning area at the film is fixed in space and the several scanning areas are scanned by a stationary scanning pattern at the scanning tube.

During scansion period II, the lower film-frame 33 is scanned a second time, by projecting it through lens *b* (Fig. 1) to the image-dissector tube. This is accomplished by means of shutter 25 which shuts off light through lens *a* at the end of the first scansion period, and renders lens *b* operative during the second scansion period. The scansion begins again at the lower edge of the film-frame at point 37 and progresses upwards until it reaches point 38 at the end of the scansion period. This is the same as in the first scansion period. For the selected film speed and scanning periods, shutter 25 will rotate at 720 R. P. M.

It is contemplated, at the present time, that the scansions of lower film-frame 33 performed

in scansion periods I and II will be interlaced scansions, each scansion producing approximately half the number of lines desired in the complete image. The interlacing may be accomplished in known manner by appropriate control of the saw-tooth oscillators. Or, the position of the lenses may be slightly altered to produce the desired interlacing. For example, lens *b* may be spaced from lens *a* so that the projected images of film-frame 33 occupy not quite the same area of cathode 24 at corresponding instants of scansion periods I and II, but are relatively displaced just enough to produce the desired interlacing. These different methods of interlacing may also be employed in the embodiments hereinafter described.

If desired, each scansion may be performed so as to produce the full number of lines desired in the final image.

During scansion period III the lower film-frame 33 is again rescanned, lens *c* being operative during this period. With interlaced scansion, the component scansion produced during period III may be a duplicate of the scansion produced in either of the preceding scansion periods.

During scansion periods IV and V, the upper film-frame 34 is scanned in the same manner as previously described for film-frame 33, lenses *d* and *e* being successively operative during these periods. The scansion begins at the lower edge of the film-frame during each scansion period, and progresses upward until it reaches the upper edge of the film-frame, the two scansions being interlaced if desired. The lower film-frame is scanned three times, whereas the upper film-frame is scanned only twice. Therefore, since a scansion period lasts $\frac{1}{60}$ second, two film frames are scanned in $\frac{1}{2}$ of a second, thereby scanning the film-frames at the average rate of 24 per second.

After the completion of the cycle of scansions shown in periods I . . . V, the cycle is repeated to scan the two film-frames next above 33 and 34, and the repetition continues until the desired length of film is transmitted.

From the positions of the film-frames and corresponding scanning areas shown in Fig. 3, it will be seen that the scanning area at the film is successively displaced longitudinally of the film for successive scansion periods. The longitudinal length of the scanning areas and the relative displacement thereof are shown at a''' , b''' , c''' , d''' and e''' . Each area is $\frac{3}{5}H$ in length, and areas a''' , b''' and c''' are successively displaced by $\frac{2}{5}H$. This corresponds to the displacement of the film at the beginning of the successive scanning periods. Scanning area d''' is displaced downwards from a''' by $\frac{1}{5}H$, since this is the position of the upper film-frame 34 at the beginning of scansion period IV. Scanning area e''' is displaced downward from d''' by $\frac{2}{5}H$, to allow for the film movement. It will be understood that the scanning areas a''' . . . e''' are all in the plane of the film 11 and are here shown as spaced apart from left to right for clearness only. The scanning areas are spaced apart longitudinally of the film movement, it being understood that the spaced areas overlap for the scanning procedure illustrated, and are not completely exclusive.

As previously stated, in order that the position of the scanning pattern produced by the image-dissector tube may remain unchanged for successive scansion periods, despite the

change in position of the scanning area at the film, the projection lenses *a*, *b*, *c*, *d* and *e* are so positioned with respect to the film that scanning areas *a'''* . . . *e'''* will be conjugate to the same area 39 of the cathode 24 of the image-dissector tube. The correct positioning is shown in Fig. 3 by drawing lines from the extremes of each scanning area *a'''* . . . *e'''* to the corresponding extremes of area 39. The projection lens corresponding to a given scanning area will be placed at the intersection of the lines drawn from that scanning area.

From geometrical considerations it will be seen that if the distance from the film 11 to the projection lenses is *x*, and the distance from the projection lenses to the cathode 24 is *y*, and it is desired to superpose on cathode 24 area which are spaced from each other by a distance $\frac{1}{2} H$ in the plane of film 11, as is the case here, successive lenses should be spaced longitudinally from each other by a distance *L* whose length is determined by the following equation:

$$L = \frac{1}{2} H \left(1 - \frac{x}{x+y} \right) \text{-----} (1)$$

Thus, the lenses are slightly closer together than the corresponding areas in the path of travel of film 11 which it is desired to superpose at the scanning tube.

Although the height of the scanning area need only be $\frac{3}{4} H$, and therefore the height of the scanning pattern produced by the image-dissector tube need only be $\frac{3}{4} H$ multiplied by the magnification, it will be understood that due to the motion of the film during the scanion period the entire height *H* will be scanned. Therefore the size of the elemental scanning area, which will be the size of the aperture of finger 28 in the case of an image-dissector tube, will be determined on the basis of an image of height *H*, rather than $\frac{3}{4} H$, in order that the entire area of the film-frame may be covered either by a single non-interlaced scanion, or by two interlaced scanions as is described herein.

From Fig. 3, as well as from Equation 1, it will be seen that the projection lenses 17 are quite small. In the illustrated embodiment, using standard motion picture film, they would be of the order of a few millimeters in width. To increase their light gathering power they may be made rather long, as shown in Fig. 1b. The lenses could conveniently be obtained by cutting central vertical slices from a corresponding number of standard lenses.

At the point where the operation is being transferred from one lens to another, the first lens will be gradually closed off and the second lens gradually opened by the respective slots of shutter 25. Therefore during this period the projected images will not have their full luminosity. This period may advantageously be used for blanking, so as to permit the electron beam in the scanning tube to retrace its path to the starting position, and to permit the transmission of frame-synchronizing signals. In practice, film-frames are often not quite contiguous to each other, and since this period comes between scanions of the same and successive film-frames, the complete, or very nearly the complete, height of the film-frames may be transmitted.

For simplicity, the space between film-frames has been usually disregarded in the explanations

given herein, since such details will be understood by those skilled in the art.

The specific embodiment shown in Fig. 1 employs five projection lenses for the scanning of motion picture film at the rate of 24 frames per second with scanion periods recurring at the rate of 60 scanions per second, so as to coordinate present motion picture and television standards. The spacing of the lenses and sequence of operation illustrated in Fig. 3 is thought desirable since it permits equal spacing of the lenses and the repeated scanions of a single film-frame are completed before the scanions of the next film-frame are begun. However, other spacings of the lenses and sequences of operation may be employed if desired.

Although the invention is especially concerned with coordinating existing motion picture and television standards, if it is desired to move the film at a rate other than the above, or to employ scanion periods other than the above, the apparatus can be modified accordingly. For example, the apparatus can be modified to transmit film-frames at the rate of 25 pictures per second, interlaced, as is customary in England, in which case only two lenses need be employed since each film-frame is scanned twice and the individual scanions recur at the rate of 50 scanions per second. In such case the film would move $\frac{1}{2} H$ during a scanion period, so that a single scanning area at the film need be only $\frac{1}{2} H$ in height.

Another example which might be mentioned is that of scanning film at the rate of 20 pictures per second with scanion periods of $\frac{1}{60}$ of a second. For this case 3 projection lenses would suffice, the film would move $\frac{1}{3} H$ in a scanion period, and a single scanning area at the film would be $\frac{2}{3} H$ in height. Each film frame would be scanned 3 times either by double interlacing with duplication of one scanion, or by triple interlacing.

With different film and scanion rates, including those just mentioned, the spacing of the lenses will be selected accordingly. When the successive scanion periods are equal and alike, the spacing of the lenses and the sequence of their use will in general be such that corresponding parts of the same and successive projected film-frames will coincide at the plane of the cathode of the image-dissector at corresponding instants in the respective scanion periods. Thus, at the beginning of any scanion period, the image of the film-frame being projected in that period should occupy the same area as that occupied by previous film-frame images at the beginning of their respective scanion periods. Stated somewhat differently, the spacing and sequence of use of the lenses should be selected so that corresponding elemental areas of the same and successive film-frames occupy substantially the same elemental area of the image-dissector cathode when they are scanned. For 25 pictures per second and 50 scanions per second, a spacing of the areas at the film of $\frac{1}{2} H$ may be employed. For the example mentioned in which 20 pictures per second are scanned with 60 scanions per second, a spacing of the areas at the film of $\frac{1}{3} H$ may be employed.

It is believed that the above discussion of several scanning procedures and rates will suffice to indicate how the apparatus can be designed for any particular set of conditions.

As previously stated, the projection lenses 17 of Fig. 1 are quite small. Various optical ex-

pedients may be employed in order to increase the spacing between the lenses, and hence permit the use of larger lenses. Also, a single auxiliary lens could be used for correction, if desired. However, it is advantageous to be able to use only a single projection lens, whose size can be increased as desired to collect a sufficiently large cone of light. Fig. 4 shows such a system. The system can be so designed that a standard highly corrected projection lens can be employed.

Referring now to Fig. 4, an embodiment of the invention is illustrated employing a single projection lens and an intermittently moving mirror, instead of the five projection lenses shown in Fig. 1. Film 11 is moved with continuous uniform motion by sprockets 12, 13 and motor 14, as in Fig. 1. Projection lamp 15 and lenses 41 and 42 illuminate the desired film area. Projection lens 43, oscillating mirror 44 and the stationary mirror 45 project an image of film 11 to the cathode 24 of the image-dissector tube 18, the intermittently moving and stationary mirrors being between the projection lens and the image-dissector tube, in an optical sense. The image-dissector tube is provided with focusing coil 29, deflecting coils 19 and 21, and associated saw-tooth oscillators 31 and 32, as in Fig. 1. The tube is also provided with auxiliary coils and associated mechanism, described hereinafter. The dissector tube is skewed with respect to the beam of light coming from mirror 45, so that the beam is not intercepted by the finger 28 of the tube.

Mirror 44 is preferably plane-faced, although it could be provided with a small curvature, if desired, and is successively oriented in a plurality of different angular positions so as to cause different areas in the path of travel of film 11 to be successively projected onto the same area of the cathode 24. To accomplish this, the mirror 44 is mounted on lever arm 45 which is pivoted at the mirror by pin 50. The angular position of mirror 44 is determined by cam 46, driven by motor 14. Cam 46 is provided with cam surfaces *f*, *g*, *h*, *i* and *j*, upon which pin 47, mounted on lever arm 45, rides. Each cam surface is an arc of a circle, the radii of the circles being selected in accordance with the desired scanning scheme.

If the scanning scheme is to be the same as that shown in Fig. 3, the radii would be selected so that mirror 44 successively assumes orientations such that rays from points *f'*, *g'*, *h'*, *i'* and *j'* (corresponding to points *a'* . . . *e'* in Fig. 1) are caused to impinge successively on the same point 23 of the cathode of the image-dissector tube. Of course, for each position of mirror 44, an area of the film 11, rather than a mere point thereof, will be projected onto the cathode of the image-dissector tube. For this scanning scheme the motor 14 will cause the cam to make one revolution during the interval in which two film-frames move past a given point in the film-feeding mechanism. For a film speed of 24 frames per second, the cam will rotate 12 revolutions per second.

Cam 46 rotates counterclockwise, as indicated. Thus pin 47 must be pushed outwards in passing from cam surface *j* to surface *f*, and also when passing from cam surface *h* to *i*. Projecting arms 48 and 49, mounted on the same shaft as the cam 46, but axially displaced therefrom, are provided for this purpose. These arms engage the pin 51, which is affixed to the lever

arm 45, and push the lever arm outwards at the proper times. Thus arm 48 engages pin 51 just before pin 47 reaches the junction point between cam surfaces *j* and *f*. The length of pin 51, its distance from the pivot point of lever 45, and the length of arm 48 should be so proportioned as to push the lever arm 45 outwards in a comparatively short period of time. For example, a length of time corresponding to about $\frac{1}{16}$ of a scanning period or less, is suitable, since this interval is commonly used for blanking purposes between scans anyway. Arm 49 engages pin 51 in a similar manner in order to move pin 47 outwards in passing from cam surface *h* to *i*.

The dimensions of the cam and the lever arm 45 have been greatly exaggerated in order to illustrate clearly the principles involved. It will be understood that the angles through which the mirror 44 is turned will ordinarily be quite small, of the order of one or two degrees. The exact angles to which the mirror must be turned will be determined by the dimensions of the apparatus and the spacing of the points *f'* . . . *h'* which it is desired to superpose at the image-dissector tube.

The lever and cam arrangement shown in Fig. 4 is one way in which the desired movement of mirror 44 may be obtained. Other means for oscillating the mirror may of course be employed, if desired. For example, electromagnetic means or piezo-electric means may be employed with more or less success.

The apparatus of Fig. 4 may of course be adapted for scanning schemes other than the one described, for example, those mentioned in connection with Fig. 1. In such case the use of two or three different orientations of mirror 44, instead of the five shown, would correspond to the use of two or three projection lenses in Fig. 1.

The purpose and operation of the auxiliary deflecting coils 52, 53, and their associated mechanism will now be described. It will be appreciated that the orientation of mirror 44 in each of its several positions must be quite precise in order to secure proper scanning of the film. This necessitates accurately designed and constructed cams and cam followers to produce the required motion. If other means for changing the orientation of the mirror are employed, they also must be quite precise. In practice, due to the difficulty or expense involved in making a very accurate cam, or due to wearing of the surfaces during use, the orientation of mirror 44 in each of its positions may not be precisely correct.

By slightly altering the position of the electron image with respect to the finger 28, in the image-dissector tube, any inaccuracies in the orientation of mirror 44 may be compensated for. Auxiliary coils 52, 53 permit of a comparatively quick and accurate adjustment of the position of the scanning pattern produced in the image-dissector tube during the scan periods.

The auxiliary coils are energized with a periodically varying electric wave by means of commutators 54 and 55, respectively, driven by motor 14. Each commutator has five segments, one for each scan period. The segments of commutator 54 are connected to conducting rings 56, 57, 58, 59 and 60, respectively, and each of the conducting rings is adjustably connected to a potentiometer 61 energized by battery 62. For a fuller description of the construction of the

commutator, reference may be had to my prior application Serial No. 115,113, filed December 10, 1936.

One end of coil 52 is connected to the potentiometer 61, and the other end is connected to brush 63 which rides on the commutator segments. It will thus be seen that the coil 52 may be successively energized with a succession of constant voltages obtained from the segments of commutator 54, each voltage lasting throughout a scanion period, and thus periodically deflect the scanning beam. The amount of deflection of the electron image during a given scanning period may be adjusted by adjusting the corresponding tap on potentiometer 61. The taps on potentiometer 61 should be arranged so that they may pass each other, so as to obtain any desired sequence of voltages for successive scanning periods.

Auxiliary deflecting coil 53 and its associated commutator 55 are constructed and operate in the same manner as coil 52 and commutator 54.

It will, therefore, be seen that if the projected image produced by mirror 44 in one of its positions should be slightly displaced from its correct position in a longitudinal direction, this displacement can be corrected by displacing the electron image corresponding to that area the proper amount in the opposite direction by adjusting the corresponding tap on potentiometer 61. Similarly, a displacement of a projected image in a direction at right angles to the film movement may be corrected by adjusting the corresponding tap on potentiometer 64.

Instead of using additional coils for the purpose just described, the several constant deflecting voltages might be applied to the regular deflecting coils, although the separate coils shown are preferred in order to prevent the auxiliary currents from affecting the regular deflecting currents. If a scanning tube were used which employed electrostatic deflection, the apparatus could be appropriately modified. Also, means other than commutators might be used to generate the required auxiliary voltages.

The arrangement of auxiliary coils and commutators shown in Fig. 4 may, of course, be applied to the apparatus shown in Fig. 1 to correct slight inaccuracies in the positioning of projection lenses *a*, *b*, *c*, *d* and *e*, and also to the embodiments shown in the other figures of the drawings. If it is desired to correct displacement in one direction only, only one auxiliary coil and one commutator need be employed.

Fig. 5 illustrates scanning apparatus which has been found to give good results. This system is similar to that of Fig. 4 in that only a single projection lens is employed, but differs in that instead of employing an oscillating mirror which is cyclically shifted through a plurality of different orientations, a corresponding plurality of fixed mirrors, whose orientations correspond to the several positions of the oscillating mirror, are employed. By this means, difficulties encountered in rapidly yet accurately changing the orientation of a single mirror, particularly in modern high-definition systems, are avoided. Other advantages, which in part will be obvious and in part will be pointed out hereinafter, are also present.

The various parts of the system, with the exception of the fixed mirrors and the shutter, have been described in connection with Fig. 4 and hence the description will not be repeated.

Plane mirrors, *k*, *l*, *m*, *n* and *o* are positioned

in the path of the rays through projection lens 43 and near the lens, and are spaced apart longitudinally with respect to the path of travel of film 11. The mirrors could be spaced apart laterally of the film, but this is not preferred for reasons given in connection with Figs. 7-11. Light rays impinging on these mirrors are reflected to the plane mirror 45 and thence to the cathode 24 of the image-dissector tube 18. The orientations of mirrors *k* . . . *o* are such that corresponding points *k'*, *l'*, *m'*, *n'* and *o'* in the path of travel of film 11 are caused to impinge on the same point 23 of the cathode of the image-dissector tube. Mirror 45 is advantageously positioned so that the light paths from the film to the image-dissector tube are the same for each mirror. Each mirror *k* . . . *o* reflects rays not only from the corresponding point in the path of the film, but rays from a corresponding area in the path of the travel of the film. The shutter 25 is similar to that shown in Fig. 2, and exposes the mirrors *k* . . . *o* in the proper sequence. The shutter is driven by motor 14 which also drives the film-feeding mechanism, and hence proper synchronization can be obtained.

The functioning of the apparatus is similar to that of Fig. 1, described more fully in connection with Fig. 3. Since, however, the projection of different spaced areas in the path of travel of the film to the same area of the image-dissector tube is accomplished by the use of a single projection lens with associated mirrors *k* to *o*, rather than a plurality of individual projection lenses, the positioning of the mirrors *k* to *o* is not as restricted as that of the projection lenses of Fig. 1. The mirrors may be adjustably mounted so that they can be precisely orientated to give the proper placement of the images in the image-dissector tube.

Usually, the orientation of the fixed mirrors in Fig. 5 will be such, as in the case of the previously described figures, that at corresponding instants in respective scanion periods the same portion of a given film-frame, or corresponding portions of different film-frames, will be scanned. Ordinarily, when each film-frame is scanned in transverse lines beginning at the bottom of the frame, the selected area of cathode 24 will be rendered successively conjugate to different longitudinally spaced areas whose separation is such that at the beginning of any scanion period the bottom of a frame is in position to be scanned. If the same film-frame is scanned a plurality of times, the separation of the corresponding scanning areas at the film will be the distance the film moves from the beginning of one scanion period to the beginning of the next. When two different film-frames are scanned, the corresponding scanning areas at the film will be separated by the distance between the film-frames as modified by the movement of the film between the corresponding scanion periods. In the embodiments described hereinbefore, the order of rescanning the same film-frame and of scanning adjacent film-frames has been chosen so that the separations between adjacent scanning areas at the film are all equal. Although this is advantageous, a scanning scheme might be selected in which this is not true, and the apparatus designed accordingly.

The proper orientation is facilitated by placing in the plane of the film 11 a glass plate which has lines of the desired spacing ruled thereon. Such a glass plate is shown in Fig. 6. The

space between lines is $\frac{1}{2} H$ to correspond to the distance between the scanning areas a''' , d''' , b''' , e''' , c''' (in the order given) of Fig. 3. The mirrors can conveniently be adjusted by rotating shutter 25 so that half of mirror k and half of mirror l are exposed, and then adjusting one or both mirrors so that the projected images of the corresponding lines k'' and l'' of the glass plate are superposed at the cathode 24 of the image-dissector tube, and are located at the proper place on the cathode. Then the shutter is rotated to expose half of mirrors l and m , and mirror m adjusted so that the image of its line m'' is superposed on that of l'' . Then mirrors n and o are successively adjusted in similar manner.

A front view of mirrors k to o is shown in Fig. 5a. The dimensions of the mirrors may be chosen in accordance with the other elements of the system. Mirrors $3\frac{1}{2}$ mm. in width and 10 mm. in height have been found satisfactory. In order that the projected image formed by each mirror may be of the same illumination, it may be necessary to slightly decrease the effective area of one or more of the mirrors. This may be conveniently done by masking off a portion of the lower part of the mirrors, as indicated in the case of mirrors n and o .

In order to secure efficient and even illumination over the entire area of a single image, it is advantageous to image the projection lamp 15 at the projection lens 43, or approximately at the plane of the mirrors, or at some plane in between. This may be accomplished by suitably designing and positioning the lenses 41 and 42. The image should of course cover all the mirrors. It is also advantageous to place the axes of the coils of the projection lamp 15 longitudinal with respect to the film 11, so that each of the mirrors k to o will receive light from each coil. Furthermore, it is advantageous to orient the mirrors so that the upper mirror corresponds to the lower area at the film, and the lower mirror corresponds to the upper area at the film, as is the case in Fig. 5.

The image-dissector tube may be skewed as in Fig. 1, to permit the light rays to pass the finger 28. If the finger 28 were behind the cathode, this skewing could be dispensed with, unless it should be desirable in order to equalize the light paths to various parts of the cathode, or for any other reason.

The operation of the apparatus of Fig. 5 will be understood from the description previously given for Figs. 1 to 4. Mirrors $k \dots o$ are rendered successively operative by shutter 23, and during the period a single mirror is operative the projected film-frame is scanned by the image-dissector tube. The lines of the scanion are transverse of the film, and the frame scanion begins at the bottom of the film-frame and proceeds toward the top at a rate which will scan the frame in the required time. Since the film is moving $\frac{1}{2} H$ during the scanion period, the height of the scanning pattern need be only $\frac{1}{2} H$ as magnified. This procedure will be understood by reference to Fig. 3 and the description of that figure.

The system of Fig. 5 can be adapted to scanning schemes other than that illustrated, as discussed in connection with Figs. 1 and 4. The number of mirrors employed, their orientation, and the order in which they are exposed will be selected in accordance with the selected scanning scheme.

The auxiliary deflecting coils 52 and 53 shown in Fig. 4, and their associated commutators, might also be used in the apparatus of Fig. 5, if desired. It will be appreciated that the accurate and precise adjustment of the orientation of the mirrors k to o is a rather delicate operation. Thus, if it should be discovered just prior to the broadcasting of a program that one or more of the mirrors is slightly out of adjustment, or, if by some accident during the course of broadcasting one or more mirrors is displaced, it might be difficult to readjust the mirrors in the short time available and without shutting down the apparatus. By slightly altering the position of the electron image with respect to the finger 27, by adjusting the proper taps on the potentiometers, any inaccuracies in the orientation of the mirrors may be compensated for. Of course, if desired, the auxiliary coils could be used to supply a more or less permanent correction for inaccuracies in mirror orientation.

Referring now to Fig. 7, apparatus is shown which is especially adapted for the scanning of film at the rate of 30 pictures per second, interlaced, with component scanions occurring at the rate of 60 per second. As in the previously described embodiments, a film 11 is fed with continuous uniform motion by means of sprockets 12, 13 and motor 14. In this figure, the projection lamp system comprises a projection lamp 15, a reflector 65 positioned behind the projection lamp, and a pair of lenses 66, 67. This system is so designed as to uniformly illuminate the desired area of film 11.

In the previous embodiments a scanning tube of the image-dissector type has been illustrated. Fig. 7 illustrates the use of a mechanical scanner comprising a scanning disk 71, a lens 72 and a photoelectric cell 73. Images of spaced areas in the path of travel of film 11 are projected to the same, or substantially the same, area in the plane of the scanning disk 71, by means of the projection lens 43, and the differently oriented mirrors p , q , and their respectively associated mirrors 68 and 69 positioned between the projection lens and the scanning disc, in an optical sense. This mechanical scanner can be employed in the other embodiments of the application, if desired, or other suitable scanning devices may be employed. However, it is preferred at the present time to employ a scanning tube of the image-dissector type.

The scanning disk 71 is provided with a suitable spiral of holes to repeatedly scan images projected to the plane of the disk. Light passing through the scanning holes is converged by lens 72 to the photoelectric cell 73, to produce corresponding electric signal waves.

In Fig. 5, the plurality of mirrors $k \dots o$ were spaced apart longitudinally of the film, and rays from each of these mirrors were diverted to the image-dissector tube by means of a single mirror 45. In Fig. 7, the mirrors p and q are separated transversely of the film, and are oriented so that mirror p reflects rays from the projection lens upwards to mirror 68, and the latter reflects the rays to the plane of the scanning disc 71. Similarly, mirror q reflects rays from the projection lens downwards to mirror 69, which in turn reflects the rays to the scanning disc. Mirrors p and 68 are so oriented with respect to mirrors q and 69 that the images of the corresponding longitudinally separated areas p' and q' in the path of travel of the film, are caused to coincide at the same area 74 of the plane of the scanning disc. Shutter 75 is provided for alternately ex-

posing mirrors p and q . This shutter may be similar to that shown in Fig. 2, but will be provided with two slots (or an even number of slots) instead of five.

The operation of the apparatus of Fig. 7 can be explained by means of a diagram such as that of Fig. 3. However, since the apparatus is somewhat simpler than that shown in the previous figures, it is feasible to illustrate the operation as shown in Fig. 8. Referring to Fig. 8, a single film-frame 76 is shown in the positions which it occupies at the beginning of two successive scan- sion periods. Since the film moves a half frame during a scan- sion period, the two positions are separated by $\frac{1}{2} H$. The scan- sion begins at the bottom of the frame and progresses upwards. Due to the film motion, the scanning area at the film need be only $\frac{1}{2} H$ in height, as shown by the shaded area of the film-frame. At the begin- ning of the first scan- sion period the film-frame at position A is projected by mirrors q and 69 to the position A' at the plane of the scanning disc. During this scan- sion period the area in the plane of the disc represented by the shaded area of A' is scanned. Since the image of the film-frame at A' is moving upwards, the scan- ning begins at the top of the shaded area and progresses downwards.

At the beginning of the second scan- sion period the film-frame 76 is at position B, and is projected by means of mirrors p , and 68 to the area in the plane of the scanning disc shown at B'. During this scan- sion period the shaded area is again scanned by the scanning disc, the scan- sion beginning at the top of the shaded area and progressing downwards.

It will be clearly seen from the diagram that although the shaded areas at A and B, repre- senting the areas in the path of travel of the film which are actually scanned, are longitudi- nally displaced, the shaded areas at A' and B' representing the areas in the plane of the scan- ning disc scanned during the respective scan- sion periods coincide at the scanning disc. Thus, the recurrent scanning pattern of the scanning disc is stationary. Successive film-frames are scanned in the same manner as film-frame 76.

Figs. 9 to 11 illustrate a further embodiment of the invention especially adapted, like that of Fig. 7, for the scan- sion of film for moving at the rate of 30 frames per second with component scan- sions recurrent at the rate of 60 per second. The apparatus of Figs. 9 to 11, however, possesses certain advantages over that of Fig. 7. In Fig. 7 it is found that the projected images are rather unevenly illuminated from left to right of the images, and that the relatively bright portions of the images formed by mirrors p and q are on op- posite sides of the respective images. This gives rise to a rather objectionable flicker from left to right of the images, unless additional means are employed for eliminating the flicker. The un- evenness of illumination over the area of a single image is probably due to the fact that the mir- rors are spaced somewhat from the projection lens, and therefore a single mirror p , for example, does not receive the same amount of light from each point in the corresponding area p' at the film.

In Fig. 9 the mirrors p and q extend trans- versely of the film, and are separated longitudi- nally thereof. Thus the centers of the utilized areas of the mirrors are separated in the direc- tion of motion at the mirrors of the rays forming the film images, but are not substantially sepa-

rated in the direction transverse thereof. Of course, no images of the film are formed at the mirrors, but the rays forming the film images at the dissector tube may be considered as moving at the mirrors.

In this case also, there is some unevenness of illumination of the projected images, but the images are evenly illuminated from left to right thereof and unevenly illuminated longitudinally thereof. Due to the fact that film-frames are usually wider than they are high, and further- more, due to the fact that the height of the scanning area at the cathode is only a fraction of the height of the projected film-frame, the scanning area at the cathode 24 may be illumi- nated more evenly. For this reason, an objec- tionable flicker is not produced.

As shown in Fig. 10, mirrors p and q are oriented so that the rays from the projection lens 43 are deflected transversely to a single mirror 77, and mirror 77 in turn reflects the rays to the plane of the cathode 24 of the image-dissector tube. As seen from the end view of the mirrors (Fig. 11), mirror p is tilted so as to slightly de- flect the rays from the lens downward, and mir- ror q is oriented so as to slightly deflect the rays upward. This causes two separated areas in the path of film 11 to coincide at the plane of the cathode 24.

Due to the fact that mirrors p and q are side by side in approximately a plane, and both reflect to the same mirror 77, the light paths from the film to the plane of cathode 24 may readily be made equal for the two mirrors. Also, consid- erably more latitude in the axial positioning of the scanning device is allowed since the beams from the two mirrors come to the scanning de- vice from very nearly the same direction, rather than intersecting at a considerable angle as in Fig. 7. These are further advantages of this embodiment over that of Fig. 7.

The operation of the apparatus of Figs. 9 to 11 is the same as that of Fig. 7 and hence will not be described again. It will be understood that suitable deflecting coils and circuits are provided for tube 18, as in previous figures, these being omitted here for simplicity.

Fig. 12 shows apparatus similar to that of Fig. 5, in which a plurality of fixed mirrors are posi- tioned between the projection lens and the scan- ning tube, in an optical sense. In this modifica- tion, however, the projected images formed by the projection lens 43 and mirrors k , l , m , n and o are formed in the plane 78. The formation of an image of l' in the plane of the film, at 23' in the plane 78, is illustrated by light rays 79. As shown, the light rays 79 are converged by pro- jection lens 43, and the converging rays are re- flected by mirror l to 23', at which point the rays meet and form the image. Each of the other mirrors k , m , n and o form images of points k' , m' , n' and o' , respectively, at points 23' in plane 78. Thus, the images formed in plane 78 cor- respond to those formed on the cathode 24 of the image-dissector tube in Fig. 5.

The images in plane 78 are projected by means of projection lens 80 onto the cathode 24 of the image-dissector tube 18, an image of point 23' being formed at point 23 on the cathode. The image-dissector tube may be skewed so that all rays from lens 80 pass the scanning finger 28.

The mirrors k to o are rendered successively operative in proper sequence by shutter 25, as in Fig. 5, and the corresponding moving images of the film 11 formed on cathode of the image-dis-

sector tube are scanned by means of deflecting coils 19 and 21, and their associated oscillators 31 and 32.

The embodiment of Fig. 12 has the advantage over that of Fig. 5 in that the cone of light passing the finger 28, for a given size image on cathode 24, is narrower. If desired, the additional lens 80 can also be employed in the other embodiments described hereinbefore, in which case the images formed by the plurality of projection lenses, the oscillating mirror, or the plurality of fixed mirrors, as the case may be, will be formed in a plane, such as plane 78, and then projected by the additional lens to the scanning device.

Referring now to Figs. 13 and 14, apparatus is shown similar to that of Fig. 1 in employing a plurality of small lenses r, s, t, u, v , but also employing an additional positive lens 82 which acts in conjunction with each of the small lenses to form images of corresponding spaced fixed areas in path of travel of film 11 at the same area of the scanning device, here shown as a tube 18 of the image-dissector type. The advantages of using this type of optical system in film-scanning apparatus of the kind herein disclosed are that the system can be designed so that the separation between adjacent lenses $r \dots v$ is greater than that of Fig. 1, and indeed, greater than the separation between successive areas at the film which are to coincide at the image plane of the scanning device, and also that the adjustments necessary to focus the film images sharply at the scanning device and to make the images corresponding to the several small lenses of precisely the same size are to a large extent separated.

The great separation is desirable in order to avoid the necessity for using very small lenses, or lens segments, which may be difficult to construct with suitable correction and which of course restrict the amount of illumination which can be utilized from a given source. The separate adjustability of focus and relative image size is also advantageous. In Fig. 1, any change in the positioning of one of the lenses to secure good focus at the same time changes the size of the image. Unless the lenses are precisely of the same focal length this may be serious, and in practice it is difficult and expensive to obtain corrected lenses of precisely the same focal length.

In Fig. 13, a mirror 65 is employed to collect light from the projection source, here shown as a filament projection lamp 15, from as large a solid angle as practicable. Lenses 83 are designed to collect light from the projection source and form an image of the source between lenses 83 and the field lens 84. Although any other suitable projection light system may be employed, if desired, this type is advantageous since the source 15 itself is removed from the vicinity of the film, thereby avoiding undue heating of the film, but the image of the source is close to the film, thereby securing efficient illumination. This image may in turn be focused at a suitable plane in the system, it being found advantageous to focus it between lens 82 and the small lenses, at a short distance from the latter.

Broadly stated, the projection system of Fig. 13 has means for forming an enlarged image of the film, and means for successively projecting images lying at spaced areas of the plane of the enlarged image to substantially the same area of a selected image plane at which the projected images are scanned. Although different

optical designs may be employed for forming the enlarged image, and for projecting different spaced areas thereof to the scanning device, the system shown is at the same time relatively simple, efficient and compact.

Calculations indicate that so long as the image which is utilized as an object by the lens segments is an enlarged image, the separation of the lens segments for a given over-all magnification of the film images will be greater than in the case of Fig. 1. In general, the greater the enlargement of the image used as object by the lens segments, the greater will be the separation.

Projection lens 82 is of such focal length and so positioned from film 11 that the film is inside the principal focus of the lens, so that an enlarged virtual image of the film is formed behind the film, for example at plane 85 of Fig. 14. Thus areas $a''', d''', b''', e''', c'''$ (Fig. 3) which are spaced apart, in the order given, a distance of $\frac{1}{2} H$ at the film, are spaced apart at the image plane 85 (Fig. 14) by a distance $\frac{1}{2} M \times \text{Mag.}$, where Mag. is the magnification between the film and the plane of the virtual image. The corresponding areas in Fig. 14 are indicated as r', u', s', v', t' , respectively.

The virtual images of the portions of the film at $r' \dots v'$ serve as objects for the respective lenses $r \dots v$. The latter lenses have such focal length and are so spaced longitudinally of the film movement that the images at the respective areas of plane 85 are projected to substantially the same area 39 of the cathode 24 of the tube 18. If another type of scanning device is employed, it will be so positioned as to scan the images projected to area 39 of image plane 24.

By suitably selecting the focal length and position of lens 82, the separation of the areas $r' \dots v'$ at the virtual image plane 85 may be made large enough so that with suitably selected focal lengths and axial positions of lenses $r \dots v$, the separation of the latter lenses longitudinally of the film movement may be greater than those in Fig. 1. Also, with suitable design it is found that the focusing of the film images at plane 24 may be primarily adjusted by moving lens 82 alone in the axial direction, while movement of lenses $r \dots v$ in the axial direction changes the focusing of the images to a much smaller extent than an equal movement of lens 82. However, movement of lenses $r \dots v$ in the axial direction will permit adjusting the relative sizes of their respective images. Thus the several projected images may be readily made of equal size, all in good focus. The size of the images can of course be simultaneously adjusted by moving lens 82, with appropriate change in the position of the scanning device if necessary.

It will of course be understood that in Fig. 13, as in Fig. 1, the lenses $r \dots v$ are successively operated by the shutter 25, and suitable scanning coils and circuits are provided for the tube 18, as in previous figures. Also, the apparatus can be adapted for other scanning procedures as previously pointed out.

As a further aid to the ready practice of the invention, the following details of a specific apparatus constructed in accordance with the foregoing description are given, it being understood that the specific details are given by way of example only, and that the invention is in no way limited thereto, since some or all of the details of the design may be changed by those skilled in

the art to meet the requirements of a particular situation, or as they deem advisable.

Lens 32	$f = 4.12$ in.
Lenses $r \dots v$	$f = 7.62$ in.
w	$= 2.31$ in.
x	$= 2.94$ in.

Mag. of $\frac{\text{Virtual image}}{\text{Film image}}$	$= 2.28$
y	$= 8.03$ in.
z	$= 17.9$ in.

Separation between areas at film ($\frac{1}{2}$ H) $= 0.15$ in.

Separation between adjacent lenses $r \dots v = 0.196$ in.

Mag. of $\frac{\text{Image at 24}}{\text{Film image}}$	$= 3.07$
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Lenses $r \dots v$ may be made about $\frac{1}{4}$ in. wide and $1\frac{1}{2}$ in. long in order to gather a comparatively large amount of light. Achromatic doublets may be used for these lenses, if desired. Lens 32 is preferably a rather highly corrected lens.

The embodiment of Fig. 13 has been found to have considerable advantages over that of Fig. 5 in ease and precision of adjustment, and also in ease of maintenance. Furthermore, the congruency of the several images at plane 24 is found to be more exact with the apparatus of Fig. 13, and loss of light is considerably reduced.

Fig. 15 is an embodiment of the invention including the projection lenses of Fig. 1, the auxiliary deflecting coils and commutators shown in Fig. 4, and the additional projection lenses 30 of Fig. 12. The operation of the apparatus will be clear from the discussion given hereinbefore, and therefore need not be described in detail here. The projection lenses 17 operate in the manner described in connection with Fig. 1 except that the successively superimposed images formed by lenses 17 are formed at plane 78, rather than at the cathode 24 of the scanning tube 10. The images at plane 78 are then projected to the cathode 24 by the additional projection lens 30, as described in connection with Fig. 12. The auxiliary deflecting coils 52 and 53, and their associated commutators 54 and 55 driven by the same motor 14 which drives the shutter 25 and the film moving mechanism 13, operate in the manner described in connection with Fig. 4. By the use of the auxiliary coils and commutators slight changes in the position of the scanning pattern during different scanning periods may be quickly and accurately made so as to compensate for slight inaccuracies in the positions of lenses 17.

It will now be apparent that this invention provides a method of scanning film which is particularly valuable in the scanning of a continuously moving film, and especially adapted for coordinating present day sound-motion-picture and television standards, and several forms of apparatus whereby this method can be carried out. In general it might be said that the several embodiments of the invention described herein each possess certain advantages over the others. The particular embodiment selected will depend somewhat upon the conditions under which the apparatus is to be used, and also upon individual judgment.

It will be apparent that many changes may be made in the details of the embodiments described herein without departing from the spirit

and scope of the invention. Also, features of several embodiments may be combined, if desired.

I claim:

1. Television film-scanning apparatus which comprises a film-feeding mechanism, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a projection system comprising a plurality of fixed projection lenses spaced apart in the direction in which said film is moved, said projection system being positioned and adapted to project film images lying in a plurality of areas separated in the direction in which the film is moved to substantially the same area of a selected image surface, the spacing of said lenses being selected so that said plurality of areas are separated by distances substantially different from the separation of film-frame areas of the film, a scanning device positioned and adapted to scan a projected image lying in said area of the selected image surface, and means for rendering said projection lenses operative successively one at a time.

2. In television transmission systems, apparatus for scanning a continuously moving film bearing motion picture film-frame images which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous motion, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a plurality of fixed projection lenses spaced apart in the direction in which said film is moved, said lenses being positioned and adapted to project film images lying in a corresponding plurality of longitudinally separated areas in the path of travel of said film to substantially the same area of a selected image plane, means for rendering said projection lenses operative successively one at a time, and a scanning device positioned and adapted to scan moving images of said film lying in said selected image plane; the rate of feeding the film, the spacing of said lenses, the means for rendering said lenses operative, and the period of the scanning device being correlated so that corresponding parts of the projected film-frame images are scanned at substantially the same part of the said selected image plane.

3. In television transmission systems, apparatus for scanning a continuously moving film bearing motion picture film-frame images, in which a film-frame is scanned a plurality of times, which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous uniform motion, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a plurality of fixed projection lenses spaced apart in the direction in which said film is moved, said lenses being positioned and adapted to project film images lying in a corresponding plurality of longitudinally separated areas in the path of travel of said film to substantially the same area of a selected image plane, the spacing of said lenses being selected so that said plurality of areas are separated by distances substantially different from the separation of film-frame areas of the film, means for rendering said projection lenses operative successively one at a time in a selected sequence, and a scanning device positioned and adapted to periodically scan moving images of said film lying in said area of the selected image plane and develop signals therefrom, the scanning of said area by said scanning device extending both longitudinally

and transversely of the projected images, the spacing of the lenses being correlated with the film speed and the longitudinal scanning period so that, when said lenses are operated in said selected sequence, longitudinally corresponding parts of the same and successive projected film-frame images substantially coincide at the said selected image plane when said parts are scanned in their respective scansion periods.

4. In television transmission systems, apparatus for scanning a continuously moving film bearing motion picture film-frame images, in which a film-frame is scanned a plurality of times, which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous uniform motion, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a plurality of fixed projection lenses spaced apart in the direction in which said film is moved, said lenses being positioned and adapted to project film images lying in a corresponding plurality of longitudinally separated areas in the path of travel of said film to substantially the same area of a selected image plane, a shutter positioned and adapted to render said projection lenses operative successively one at a time in a selected sequence, and a scanning device of the image-dissector type positioned and adapted to periodically scan moving images of said film projected to said area of the selected image plane and develop signals therefrom, said scanning device being provided with deflecting means for scanning said area both longitudinally and transversely of the projected images in lines extending transversely thereof, the shutter and the longitudinal scanning period being correlated so that the lenses are successively operative during respective successive longitudinal scanning periods, and the spacing of the lenses being correlated with the rate of film feed and the longitudinal scanning period so that, when said lenses operate in said selected sequence, longitudinally corresponding parts of the same and successive projected film-frame images substantially coincide at the said selected image plane at corresponding instants in their respective longitudinal scanning periods.

5. Television film-scanning apparatus for scanning a uniformly moving film having film-frames recorded thereon, in which the periodicity of scanning said film-frames is not an integral multiple of the rate of movement in frames per second, which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous uniform motion at a selected number of frames per second, a projection light source positioned to illuminate a film in said film-feeding mechanism, a plurality of fixed projection lenses spaced apart in the direction in which said film is moved, said lenses being positioned and adapted to project film images lying in a corresponding plurality of longitudinally separated fixed areas in the path of travel of said film to substantially the same area of a selected image plane, the spacing of said lenses being selected so that said plurality of areas are separated by distances substantially different from the separation of film-frame areas of the film, a scanning device positioned and adapted to periodically scan moving images of said film projected to said area of the selected image plane both longitudinally and transversely of the projected images in lines extending transversely thereof, the periodicity of the longitu-

dinal scanning being not an integral multiple of said selected number of frames per second, and means for rendering said projection lenses operative successively one at a time in a selected sequence, said means and the longitudinal scanning period being correlated so that the lenses are successively operative during respective successive longitudinal scanning periods, and the number and spacing of said lenses and their sequence of operation being selected with respect to the rate of film feed and the periodicity of longitudinal scanning so that longitudinally corresponding parts of the film-frame images projected to said image plane occupy substantially the same part of said plane at corresponding instants in their respective longitudinal scanning periods.

6. Television film-scanning apparatus which comprises a film-feeding mechanism, a projection system optically arranged and adapted to render a plurality of relatively separated selected areas in the path of travel of a film in said film-feeding mechanism successively conjugate to substantially the same area of a selected surface, an electronic scanning device provided with means for deflecting an electron beam in said device to develop a scanning pattern, said electronic scanning device being positioned with respect to said selected surface so as to scan the portions of the film lying at the said selected areas in the path of travel of the film when those areas are rendered conjugate to the said area of the selected surface, and means for periodically deflecting said electron beam through a plurality of deflections each of which is substantially constant throughout the scansion of at least one of said areas rendered conjugate to said selected plane, the magnitudes of said plurality of deflections being adapted to compensate for lack of coincidence at said selected plane of the selected areas successively rendered conjugate thereto.

7. Television film-scanning apparatus which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous motion, a projection system including optical means successively operative to render a plurality of relatively separated selected areas in the path of travel of a film in said film-feeding mechanism successively conjugate to substantially the same area of a selected plane, an electronic scanning device positioned with respect to said selected plane so as to scan the portions of the film lying at the said selected areas in the path of travel of the film when those areas are rendered conjugate to the said area of the selected plane, said electronic scanning device being provided with means for deflecting an electron beam therein to develop a recurring scanning pattern to repeatedly scan said area of the selected plane, and means correlated with the successive operation of said optical means for periodically deflecting said electron beam through a plurality of deflections each of which is substantially constant throughout the scansion of at least one of said areas rendered conjugate to said selected plane, the magnitude of said plurality of deflections being adapted to compensate for lack of coincidence at said selected plane of the selected areas successively rendered conjugate thereto.

8. Television film-scanning apparatus for scanning film-frame areas of a film which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with

continuous uniform motion, a projection system including optical means successively operative to render a plurality of longitudinally separated fixed areas in the path of travel of a film in said film-feeding mechanism successively conjugate to substantially the same area of a selected plane, an electronic scanning device positioned with respect to said selected plane so as to scan the portions of the moving film lying at the said fixed areas when those areas are rendered conjugate to the said area of the selected plane, said electronic scanning device being provided with means for deflecting an electron beam therein to develop a periodically recurring scanning pattern to repeatedly traverse said area of the selected plane both longitudinally and transversely of the film images rendered conjugate thereto in lines extending transversely thereof, the separation of said longitudinally separated areas being selected with respect to the rate of film feed and the longitudinal scanning period so that corresponding transverse line elements of respective film-frame areas are conjugate to substantially the same elementary area of the selected plane when the respective line elements are scanned, and means for compensating for lack of desired coincidence of the said corresponding line elements at said selected plane when they are scanned including a source of a periodically varying electric wave, and means for applying said electric wave to deflect the said electron beam in the scanning device, said source being correlated with the successive operation of said optical means and adapted to provide an electric wave which periodically deflects said electron beam through a plurality of deflections each of which is substantially constant throughout the scan of at least one of said areas rendered conjugate to said selected plane.

9. Television film-scanning apparatus for scanning a film having film-frame images recorded thereon which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous uniform motion, a projection light source positioned to illuminate a film in said film-feeding mechanism, a projection system including optical means successively operative to render a plurality of spaced substantially fixed areas in the path of travel of a film in said film-feeding mechanism successively conjugate to substantially the same area of a selected image surface, whereby images of the portions of said film lying at said fixed areas may be successively projected to said image surface, an electronic scanning device positioned and adapted to periodically scan moving images of said film projected to said area of the selected image surface both longitudinally and transversely of the projected images in lines extending transversely thereof, the longitudinal scanning period being correlated with the successive operation of said optical means so that images successively projected from different fixed areas are scanned during respective different longitudinal scanning periods, the separation of said fixed areas being correlated with the longitudinal scanning period and the rate of film feed so that corresponding transverse line elements of respective film-frames successively projected to said image surface substantially coincide at said surface at corresponding instants in their respective scanning periods, and means for compensating for lack of desired coincidence of said line elements at said image surface at said instants including a source of periodically vary-

ing electric wave, and means for applying said electric wave to deflect the electron beam in the said electronic scanning device, said source being correlated with the successive operation of said optical means and adapted to provide an electric wave which periodically deflects said electron beam through a plurality of deflections each of which is substantially constant throughout the scan of at least one of said areas rendered conjugate to said selected image surface, the magnitudes of said plurality of deflections being adapted to provide said compensating.

10. Television film-scanning apparatus which comprises a film-feeding mechanism, a projection system optically arranged and adapted to successively project images lying in a plurality of different areas in the path of travel of a film in said film-feeding mechanism to substantially the same area of a selected image surface, second projection means optically arranged to project images lying at said area of the selected image surface to a second selected image surface, and scanning means having a restricted aperture positioned and adapted to receive and scan the images projected to said second selected image surface, said second projection means providing a smaller cone of light impinging on said second image surface than on the first-mentioned image surface, whereby the cone of light can enter said aperture more effectively.

11. Television film-scanning apparatus which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally, a projection system optically arranged and adapted to successively project images lying in a plurality of longitudinally separated substantially fixed areas in the path of travel of a film in said film-feeding mechanism to substantially the same area of a selected image plane, second projection means optically arranged to project images lying at said area of the selected image plane to a second selected image plane, and a scanning device of the image-dissector type positioned and adapted to receive and scan the images projected to said second selected image plane.

12. Television film-scanning apparatus which comprises a film-feeding mechanism, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a projection system comprising means for forming an enlarged image of said film at a selected image surface and means including a plurality of projection lenses optically arranged to project images lying at a corresponding plurality of spaced areas of said selected image surface to substantially the same area of a second selected image surface, a scanning device positioned and adapted to scan a projected image lying in said area of said second selected image surface, and means for rendering said projection lenses operative successively one at a time.

13. In television transmission systems, apparatus for scanning a continuously moving film bearing motion picture film-frame images which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous motion, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a projection system comprising optical means for forming an enlarged image of said film at a selected image plane and means including a plurality of fixed projection lenses having their optical axes spaced apart longitudinally of the film images at said image plane and optically arranged to project images lying

at a corresponding plurality of longitudinally separated areas of said image plane to substantially the same area of a second selected image plane, means for rendering said projection lenses operative successively one at a time, and a scanning device positioned and adapted to scan moving images of said film lying in said area of the second selected image plane.

14. In television transmission systems, apparatus for scanning a continuously moving film bearing motion picture film-frame images, in which a film-frame is scanned a plurality of times, which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous uniform motion, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a projection system comprising a positive lens optically arranged to form an enlarged virtual image of said film at a selected image plane and a plurality of fixed projection lenses spaced apart in a direction longitudinal of the film images at said image plane and optically arranged to project film images lying at a corresponding plurality of longitudinally separated areas of said image plane to substantially the same area of a second selected image plane, means for rendering said projection lenses operative successively one at a time in a selected sequence, and a scanning device positioned and adapted to periodically scan moving images of said film lying at said area of the second selected plane and develop signals therefrom, the scanning of said area by said scanning device extending both longitudinally and transversely of the images projected thereto, the spacing of said plurality of projection lenses being correlated with the film speed and the longitudinal scanning period so that, when said lenses are operated in said selected sequence, longitudinally corresponding parts of the same and successive projected film-frame images substantially coincide at the said second image plane when said parts are scanned in their respective scanion periods.

15. Television film-scanning apparatus which comprises a film-feeding mechanism, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a projection system optically arranged and adapted to successively project images lying in a plurality of different areas in the path of travel of a film in said film-feeding mechanism to substantially the same area of a selected image surface, said projection system comprising a plurality of projection lenses spaced apart in the direction in which said film is moved, second projection means optically arranged to project images lying at said area of the selected image surface to a second selected image surface, an electronic scanning device provided with means for deflecting an electron beam in said device to develop a scanning pattern, said electronic scanning device being positioned with respect to said second selected surface so as to scan the portions of the film lying at the said selected areas in the path of travel of the film when those areas are rendered conjugate to the said second selected surface, and means for periodically deflecting said electron beam through a plurality of deflections each of which is substantially constant throughout the scanion of at least one of said areas rendered conjugate to said selected plane, the magnitudes of said plurality of deflections being adapted to compensate for lack of coincidence at

said selected plane of the selected areas successively rendered conjugate thereto.

16. Television film-scanning apparatus which comprises a film-feeding mechanism constructed and adapted to feed a film longitudinally with continuous motion and selected film-frame frequency, a source of projection light positioned to illuminate a film in said film-feeding mechanism, a projection system comprising a plurality of fixed projection lenses spaced apart in the direction in which said film is moved, said projection system being positioned and adapted to project film images lying in a plurality of fixed areas separated in the direction in which the film is moved to substantially the same area of a selected image surface, the spacing of said lenses being selected so that said plurality of areas are separated by distances substantially different from the separation of film-frame areas of the film, a scanning device positioned and adapted to scan projected images lying in said area of the selected image surface at a field-scanning frequency different from said film-frame frequency, and means for rendering said projection lenses operative successively one at a time.

17. Television film-scanning apparatus which comprises a film-feeding mechanism, a scanning device, a projection system between the film-feeding mechanism and the scanning device comprising a plurality of longitudinally spaced projection lenses, said projection system being positioned and adapted to render a plurality of longitudinally separated areas in the path of travel of the film conjugate to substantially the same area at said scanning device, the spacing of said lenses being selected so that said plurality of areas are separated by distances substantially different from the separation of film-frame areas of the film, and means for rendering said lenses operative successively one at a time so that the portions of the film lying at said longitudinally separated areas are scanned successively.

18. Television film-scanning apparatus which comprises a film-feeding mechanism for feeding a film longitudinally with continuous uniform motion and selected film-frame frequency, a scanning device adapted to provide a two-dimensional scanning pattern of field-scanning frequency different from said film-frame frequency, a projection system between the film-feeding mechanism and the scanning device comprising a plurality of longitudinally spaced fixed projection lenses, said projection system being positioned and adapted to render a plurality of longitudinally separated fixed areas in the path of travel of the film conjugate to substantially the same area at said scanning device, and means for rendering said lenses operative successively one at a time in selected sequence, the spacing of said lenses being selected so that said plurality of areas are separated by distances substantially different from the separation of film-frame areas and correlated with the film feeding and field frequency so that longitudinally corresponding parts of the film-frame areas occupy substantially the same part of the area at said scanning device at corresponding instants in their respective field-scanning periods.

19. Television film-scanning apparatus which comprises a film-feeding mechanism for feeding a film longitudinally with continuous uniform motion and selected film-frame frequency, a scanning device adapted to provide a two-dimensional scanning pattern of field-scanning fre-

quency different from said film-frame frequency, a projection system between the film-feeding mechanism and the scanning device comprising optical means for forming an enlarged image of the film at a selected plane and a plurality of longitudinally spaced fixed projection lenses optically arranged to render a plurality of longitudinally separated fixed areas of said plane conjugate to substantially the same area at said scanning device, and means for rendering said lenses operative successively in selected sequence, the longitudinal spacing of said lenses

being selected so that the plurality of longitudinal fixed areas in the path of travel of the film which are conjugate to the said fixed areas of said plane are separated by distances substantially different from the separation of film-frame areas and correlated with the film feeding and field frequency so that longitudinally corresponding parts of the film-frame areas occupy substantially the same part of the area at said scanning device at corresponding instants in their respective field-scanning periods.

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