

April 5, 1949.

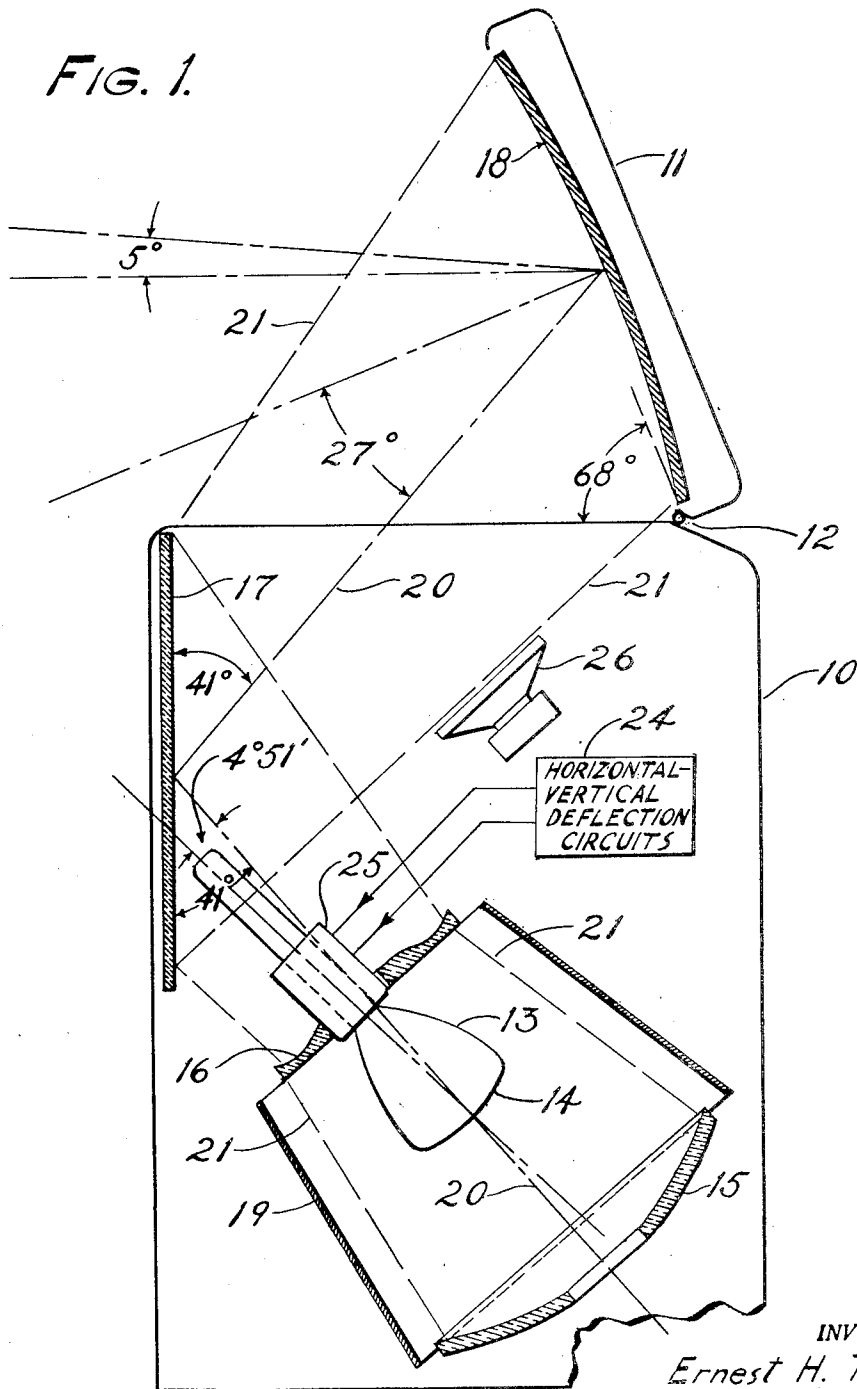
E. H. TRAUB
SKEWED SCHMIDT TELEVISION PROJECTOR
WITH DIRECTIVE SCREEN

2,466,338

Filed Feb. 21, 1946

2 Sheets-Sheet 1

FIG. 1.



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2 Sheets-Sheet 2

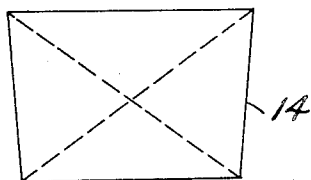


FIG. 2.

FIG. 3.

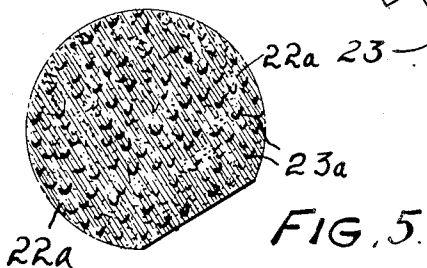
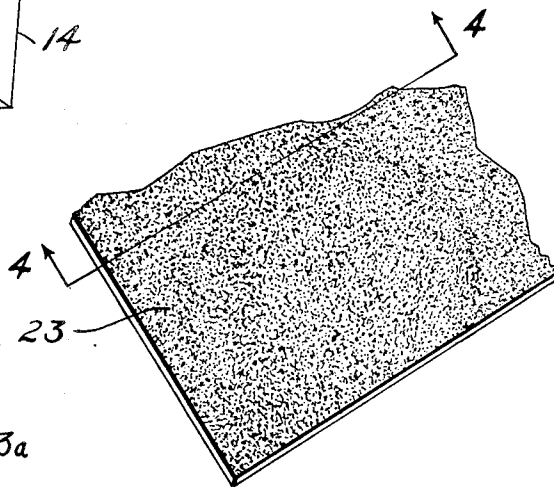


FIG. 5.

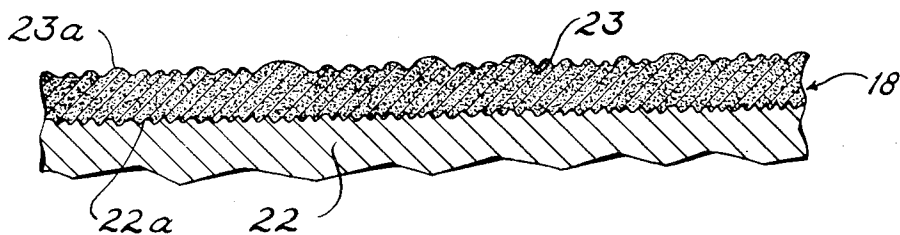


FIG. 4.

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2,466,338

SKEWED SCHMIDT TELEVISION PROJECTOR
WITH DIRECTIVE SCREENErnest H. Traub, Philadelphia, Pa., assignor, by
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Philadelphia, Pa., a corporation of Pennsylvania

Application February 21, 1946, Serial No. 649,359

5 Claims. (Cl. 88—24)

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The present invention relates to projection type image-forming optical systems and, more particularly, is concerned with projection television receivers.

A number of different types of optical systems have heretofore been proposed for use in television receiver picture projection systems, but all have left much to be desired from the standpoint of the image size and brightness required for satisfactory viewing, especially when the receiver is used in a lighted or an only semi-darkened room. Primarily, such difficulties have arisen by virtue of the fact that the brightness of the primary picture on the fluorescent screen of the picture tube is subject to certain practical limitations, because light losses in the optical system and in the viewing screen lower the brightness of the image resolved on said screen, and because room illumination—incident upon the screen—is generally reflected back through the system, resulting in reduction in contrast.

Attempts have been made to increase the brightness and effectiveness of the image on the screen by the utilization of reflective optical systems of the so-called "Schmidt"-type (which are inherently of high optical efficiency) in association with highly diffusing screens. Such apparatus, however, has of necessity wasted a considerable proportion of the available light in the diffusion and, in addition, receivers employing these concepts have frequently proven to be of such large dimensions as to be difficult to house in cabinets of pleasing and satisfactory proportions. Furthermore, the resultant devices have not solved the problem arising from susceptibility to room lights and other "stray" illumination.

In addition, an annoying defect resulting from vertical non-uniformity of the apparent brightness of the viewing area, fully explained in my copending application, Serial No. 599,927, filed June 16, 1945, has not been overcome in available apparatus.

Screens having directional characteristics, intended to restrict and direct the available light to the viewing area, have also been developed, and while certain of these are beneficial, no really satisfactory complete system employing such screens has heretofore been developed. Primarily, such is the case because there has been no recognition of the existence of a cooperative

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effect between the design of the optical projection system and the design of the screen, per se.

With the foregoing premises in view, an important object of the present invention resides in the provision of a television receiver which overcomes the aforesaid difficulties and disadvantages, and in which the image resolved on the screen is of exceptional brightness, contrast, and uniformity of illumination, the apparatus further being of such a nature as to be substantially immune to room lights.

The invention also has as an object the provision of television projection apparatus characterized by the attainment of the aforesaid advantages without sacrifice of compactness and pleasing appearance.

In the achievement of the aforementioned objects and advantages, and in accordance with an important feature of the invention, my novel apparatus contemplates the use of a reflecting screen which is so constructed and arranged as to be substantially immune to room illumination (said screen having high light directional characteristics, serving to reflect the major portion of the incident light in a beam limited both as to vertical height and horizontal width) in novel combination with a large-aperture (Schmidt-type) optical system. As will be fully set forth hereinafter, such apparatus is particularly advantageous in that, by virtue of the large aperture employed, light is incident upon each elemental area of the screen from widely divergent angles, thereby avoiding elemental areas of over- and under-illumination which would otherwise result with certain known directional screens. Also, the device of my invention overcomes, by novel means, that deficiency in uniform screen illumination which arises from the central blanking or vignetting occasioned by the location of the projection tube in the Schmidt system.

Further, in accordance with a feature of the invention, the directional characteristics of the screen and its angular disposition with respect to the observer, cooperate in providing the aforementioned freedom from room light interference.

Preferred embodiments of my invention include a Schmidt-type large aperture optical system, in combination with a directional viewing screen, the face of which is obliquely angled with respect to the optical axis of said system, where-

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by the system would normally be subject to key-stone distortion and out-of-focus effects; and it is an additional object of the invention to provide novel and highly effective correction for such effects.

Further and more detailed objects and advantages of the invention will be evident from a consideration of the following description, in conjunction with the accompanying drawings, in which:

Figure 1 is a somewhat diagrammatic vertical sectional view illustrating a television receiver in accordance with the present invention;

Figure 2 is a diagrammatic representation of the fluorescent screen, or target area, of the picture tube;

Figure 3 is a view in perspective, showing a fragmentary portion of the viewing screen employed in the apparatus of the present invention;

Figure 4 is a sectional view through the screen, said view being on a greatly magnified scale and being taken as indicated by the line 4—4 applied to Figure 3; and

Figure 5 is an elevational view illustrating, on a magnified scale, a fragmentary portion of the screen surface shown in Figure 3.

Referring to Figure 1, there is shown a picture projection system for a television receiver, the parts of which are housed within a cabinet shown in general outline at 10, and having a lid 11 hinged to the cabinet along the rear edge thereof, as indicated at 12. The projection system includes a picture tube 13 having a fluorescent screen or target area 14, spherical mirror 15, an aspherically configured correction plate 16, a plane reflector 17 supported upon the upper inside surface of the front portion of the cabinet, and a viewing screen 18. The tube, correction plate and spherical mirror, are arranged as a unitary assembly surrounded by a dust-resistant housing, represented at 19, it being understood that any convenient mounting means may be employed to support this assembly within the cabinet.

In operation, a small primary image is formed on the tube screen 14, which image is projected by the optical system and resolved as a magnified image on the viewing screen 18, carried by lid 11. The correction element or plate 16 compensates for the spherical aberration introduced by the mirror 15, said correction plate being positioned substantially at the center of curvature of the mirror. The above-mentioned components of the optical system define the optical axis, indicated at 20, a pair of representative limiting rays being shown at 21—21.

Since this Schmidt-type reflective system is known, a detailed discussion of its operation and application to the television art, is deemed unnecessary to a clear understanding of the present invention, which is concerned with utilization of the system in novel association with other elements of the apparatus. However, dimensions of a representative embodiment which has proven highly satisfactory, will facilitate a clear understanding of the invention. These dimensions are as follows:

The radii of the tube face and the spherical reflector are equal to 7.25 and 13.7 inches, respectively, the tube having a diameter of 5 inches and the mirror diameter being 14 inches. The effective diameter of the correction plate is equal to approximately 8.3 inches, and the general plane of the viewing screen is angled upwardly 68°, with respect to the horizontal, the screen itself being curved cylindrically (as will be brought out more

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fully hereinafter) about a radius equal to 60 inches. The distances, (a) from the center of the tube face to the center of the spherical reflector, and (b) from the spherical reflector backwardly along the optical axis 20 to the central portion of the screen 18 (which are the conjugate distances of the system) are equal to 7.526 inches and 50.074 inches, respectively.

The plane reflector, mounted in the forward portion of the cabinet, is trapezoidal in shape, the width of the upper edge being 16 inches, that of lower edge being equal to 11 inches, while the height is 17 inches. Further, as designated in Figure 1, the lower portion of the optical axis 20 has an angularity of 41° with respect to the surface of the reflector 17, which, of course, results in the upper portion of said optical axis making an equivalent angle with the face of the reflector. The mirror 17 is mounted vertically. It should also be noted that the angle of tilt of the screen is so arranged as to result in a slight upward slant (5°) of the principal direction of the light coming from the screen, with respect to the horizontal. This feature enables viewers sitting close to the screen (at a distance, for example, of 10 feet) to see the picture under optimum illumination conditions while seated, and at an eye level of from 45 to 50 inches. Also, viewers standing at the back of the room, at a distance of possibly 20 feet, will see the picture equally well at eye levels lying between 60 and 70 inches.

As has been mentioned, directional screens, per se, are of advantage in that they direct substantially all the incident projected light to a viewing area of predetermined optimum location and dimensions. In the embodiment illustrated, and as will be referred to more fully in what follows, the projected light incident upon the screen is compressed into a region subtending a total vertical angle of about 20° and a horizontal angle of the order of 60°. These angles are known as the angles of vertical and horizontal "scatter," respectively. Any viewer whose eye level falls within this region, and who is positioned at the proper distance from the screen, will see the image with proper intensity. That is, directional screens may be so designed as to result in a broad, generally rectangular viewing area to which substantially all the light reflected from the screen is limited.

Previously, systems utilizing directional screens have been unsatisfactory. Deleterious effects arise from the fact that some screens, in order to have the desired directionality, were provided with a great number of minute optical elements, or lenticular features, across the surface thereof. Furthermore, if large aperture projection systems are attempted with known directional screens, the distribution of illumination in the viewing plane tends to become increasingly non-uniform as the aperture is increased, which limits the practical utility of such systems. With other screens a still further defect became apparent when the Schmidt type of large aperture projection system was used, which defect appeared as a marked lack of illumination in the center of the viewing area. In systems employing directional screens in accordance with prior developments, these effects are highly objectionable.

While, as aforesaid, the angular disposition of the screen plays an important part in lowering the susceptibility of the system to room lights, or other stray illumination, for best results in minimizing this susceptibility it is also highly desirable that the screen have directional character-

istics. The use of a properly designed directional screen, in combination with the other components of the system of the present invention, results in three primary advantages. Firstly, the light directing and conserving properties of a reflective directional screen may be utilized without elemental areas of over- and under-illumination appearing on said screen, providing that the proper type of directional screen is utilized and in combination with a large aperture light source, such for example as the Schmidt system here illustrated. Secondly, the directional characteristics of the screen and its angular disposition with respect to the observer, cooperate in providing the above-mentioned freedom from room light interference. Thirdly, and as fully set forth hereinafter, apparatus according to my invention provides uniform illumination throughout the viewing area, overcoming the area of under-illumination introduced by the central vignetting of the Schmidt system. These facts have not been previously recognized, and the reasons therefor will appear in what follows.

I have discovered that by the proper selection of the nature and optical features or elements of the screen, full advantage may be taken of the high optical efficiency of the Schmidt system without the introduction of any of the aforesaid defects.

An example will illustrate the reason for the first of the three primary advantages just outlined. Assume that a narrow beam or "pencil" of light, arising from a small aperture (for example, refractive) light source, falls upon an elemental section of one of the lenticular elements, which section has substantially zero slope with respect to the plane of the screen. This light may be reflected directly back to the eye and produce an unpleasant bright spot in the picture. Similarly, a relatively narrow beam of light, from the same source, falling upon a sharply sloped zone of an element, may be so reflected that substantially all of it is lost to the observer, with the result that said zone is under-illuminated when compared with other surface portions of the screen. When a screen, selected as an appropriate component of an embodiment of the present invention, is used with a large aperture light source, on the other hand, light is incident upon all of its minute optical features from widely divergent angles and, as a consequence, substantially all points on the screen provide a close approach to the desired amount of illumination at the eye of the observer.

Referring now to the second of the above-noted primary advantages, i. e., the manner in which the screen angularity and directionality contribute to provide substantial immunity to room lights, it will be evident, that the cone or sector of directionality is reversible optically. In other words, no stray illumination incident upon the screen from points lying outside of the cone of directionality will be reflected back to the picture tube. Such reflection, of course, would result in a reduction in picture contrast. The forward inclination of the screen further contributes in attaining this immunity, by virtue of the fact that only lights located relatively near the floor of the room, and forwardly of the screen surface, could provide direct apparent illumination upon the screen. However, in the particular embodiment of my invention which is shown in Figure 1, by virtue of the disposition of the mirror, and the front wall of the cabinet 10, practically no stray light is collected by the screen.

It will be apparent that light from virtually any source in a room, may reach the face of a screen mounted vertically, as has been common in prior practice.

Because the advantages available from the selection of the proper screen, for use in novel association with the large aperture system, are so substantial and unexpected, it is desirable to describe the screen structure and analyze its operation in some detail, prior to a full consideration of the third primary advantage, that is, the elimination of under illumination due to central vignetting.

Although in the broad aspect of my invention, other screens having certain required optical characteristics may be used—in combination with the large aperture light source shown—I have illustrated and prefer to employ a screen of the type disclosed and claimed in my copending application, Serial No. 651,064, filed March 1, 1946.

Such a screen employs a specularly reflective concave member having a large number of minute random parallel grooves in its reflecting surface. The construction is such that the concavity of the screen renders it directional in the vertical sense, while the grooves render it directional horizontally, by effecting a horizontal diffusion of the incident light.

As is illustrated in Figures 3, 4 and 5, such a screen comprises two surfaces, 22 and 23, having different optical properties, surface 23 being disposed in front of surface 22. The reflective member 22 is cylindrically concave, with its axis of curvature horizontal, as appears in Figure 1. Its radius of curvature is preferably selected according to the formula:

$$R = \left(2 \frac{u \cdot v}{u + v} \right)$$

where R is the radius of curvature, u is the distance between the exit pupil of the projection lens system and the screen, and v is the distance between the screen and the desired viewing point. The grooves in surface 22 may be approximately semi-circular or of other convenient cross-sectional shape, and should preferably be of random spacing and length. Their purpose is to diffuse the reflected light and to produce broad, but controlled, horizontal light distribution over a sector, e. g. 50° to 80° in subtense. A way in which the screen may be made is brought out in the copending application identified. By reason of its concavity and its strong diffusive power horizontally, member 22 has the above-described directional characteristics in the vertical and horizontal directions.

Surface 23 may conveniently comprise the front surface of a transparent refractive film or sheet, the elemental areas of which have relatively weak diffusing power in the vertical direction.

While it is of importance that this film have the desired relatively weak diffusion in the vertical sense, in the embodiment illustrated, and for convenience in manufacture, such diffusion is also present in the horizontal sense. As set forth later, this incidental horizontal diffusion is not objectionable.

Preferably, sheet 23 consists of a film of flat lacquer which is so constituted and applied as to distort or wrinkle during drying, whereby to form the desired lenticular surface. It is to be noted that the random surfaces 22a of the grooves in member 22 have average angularity of greater

slope than the curved elemental areas 23a of surface 23. Figure 5 represents a fragmentary portion of the composite screen, in which figure the vertical grooves have been shown (as they would appear under a strong magnification) at 22a and the small lenticular features at 23a. One purpose of the surface 23, that is, of the small randomly disposed lenticular elements 23a, is still further to reduce the areas of over- and under-illumination, referred to above.

The above description of the screen, per se, is sufficient for the purposes of the present invention, and for further and more detailed description, reference may be had to the copending application above identified.

Previously, known directional screens have commonly been of the lens-mosaic type, that is of the type having precisely formed, optically effective surfaces, comprising minute individual lenses or mirrors. These determine the solid angle to be illuminated, by their size and focal length. They must be of exceedingly small size and, as will be appreciated, screens of the lens-mosaic type have been of prohibitive cost. As a consequence, the provision of a satisfactory system which includes—as a component—a relatively inexpensive directional screen, has been a long standing problem. Cylindrically curved screens having a certain amount of horizontal diffusion have also been suggested and, while much more attractive than the lens-mosaic screen, from the cost standpoint, would not lend themselves well to association in satisfactory projection optical systems.

Operation of these known screens, in combination with projection lenses, will be described with reference to both small and large apertures, so that the advantages of the unique combination of the present invention may be manifest. Considering a vertical section of a small aperture projection apparatus employing a known cylindrical screen, that is, the section in which the screen has curvature and optical power, the source of screen illumination is, in effect, magnified by the power of the screen to provide a magnified region of illumination, here termed the viewing area. The magnification will depend on the relative distances between the screen and the correcting plate, on the one hand, and the screen and the viewing area, on the other hand. Because of practical dimensional limitations, the effective magnification will be relatively small and, if the source of light were only two or three inches in vertical height, the viewing area would have an impractically small vertical dimension. This result will now be contrasted with the result available from a lens-mosaic screen using a similar small aperture source of light. In such latter case the magnification depends on the individual magnification of the lenticular elements of the screen and it may thus be very considerable, within a quite limited distance. For this reason, the lens-mosaic screen can provide a substantial viewing height even when used with a small aperture light source. However, the screen itself cannot be produced economically, and certain of the defects brought out, supra, remain.

Turning now to the case of a light source having a large vertical dimension, it will be apparent, initially, that either the lens-mosaic screen or the cylindrical screen will provide a vertically large viewing area. However, upon investigation, it has been determined that while the illumination of the center of the viewing area will increase when a large source is used with the lens-mosaic

screen, the illumination becomes so badly distributed and diminishes so rapidly—as the center of the area is departed from—that to the observer it appears that the viewing area is of very restricted height. This is true even though the projected image is visible over a very large vertical range, it being in only the center of the range that the picture appears to have substantially full and uniform intensity.

If a cylindrical screen be used, the above-mentioned effect does not occur to any appreciable extent, when a source having a large vertical dimension is used. This is because the magnification of the size of the light source is provided only by the power of the screen itself. When possible practical embodiments of the inexpensive curved screen with the large aperture source are considered, however, difficulties are discovered. Most known practical examples of sources having a large area utilize reflective elements, of which the Schmidt system is typical. It is characteristic of such devices that the apparatus producing the picture to be projected comes between the mirror and the correction plate in such a way as to block out the central area of the correction plate, so far as effective light transmission is concerned. This effect may be referred to as "central vignetting." I have discovered that this defect may be overcome, while still employing the more practical cylindrical type of screen, by the provision of a second diffusing surface having a low degree of diffusing power, at least in the vertical direction, said surface being located in the vicinity of the cylindrical screen, or forming a part thereof. The position and configuration of the two diffusing surfaces are interrelated, and a highly satisfactory arrangement for providing the desired result has been hereinbefore specified.

From an understanding of the purpose of this diffusing surface the extent of the effect which it is required to produce will be recognized. The extent of the diffusion must be sufficient to provide that light originating outside the vignetted central area of the correction plate will be diverted so as to illuminate the central portion of the viewing area, where the illumination had been deficient due to the central vignetting of the light source. It will be recognized that the diffusion thus provided will have no effect on the shape of the image on the screen, but that it will redistribute the available light within the viewing area. If the slight diffusion thus provided is of greater degree than required for the intended purpose, light which would normally fall along the outer margins of the viewing area will be wasted by being diffused outside of the useful area. Given the results to be obtained, the proper degree of diffusion may readily be achieved experimentally, in any particular apparatus.

The foregoing considerations are concerned only with the vertical section of the device. Considering the plane which includes the optical axis and the central horizontal incremental area of the cylindrical screen, it will be seen that the screen has no optical power in this plane, and that, therefore, the defect resulting from central vignetting does not occur. However, the parallel vertical features of the screen are depended upon to provide diffusion in the horizontal plane, thereby causing light from all points on the screen to be directed to the useful viewing area. The amount of diffusion required for this purpose is so much larger than that introduced by the slightly diffusing auxiliary surface that the effect of said slightly diffusing surface may be ignored,

in designing for the primary horizontal diffusion. Nevertheless, the slightly diffusing structure provides a valuable adjunct to the vertical features of the screen, in that it permits larger and more practical vertical grooves to be used, than would otherwise be possible.

Considering the ultimate illumination of the viewing area, as it is controlled by the width of the light source (in contrast to its vertical dimension), it will be seen that while the general level of illumination in the viewing area will increase directly with the width of the light source, the characteristics of the illumination in the viewing area are not so dependent on the width of the light source as they are on its vertical dimension. For this reason, if other practical considerations are not more important, it may be desirable to use a light source having a large vertical dimension and a relatively small horizontal dimension, rather than a circular light source having the same equivalent area, and the term "large aperture" should be understood to have a broad connotation in this regard.

In considering the intensity of illumination in the viewing area, the "light source" should be understood to be the "object," whose "image" is formed, in the viewing area, by the cylindrical reflector. This "object" is not the same as the picture on the projection tube, but is the relatively uniformly illuminated area in the region of the aperture-stop of the projecting system. In the Schmidt system, for example, the correcting plate provides the aperture-stop or exit pupil for the image projection; and the image of the relatively uniformly illuminated correcting plate serves to define the viewing area.

It has been set forth, supra, that the directional viewing screen is angled with respect to the optical axis of the Schmidt system illustrated, which angularity would normally cause the apparatus to be subject to keystone distortion and out-of-focus effects. In another aspect, it is an important feature of the invention to provide optical and electrical means novelly cooperable to correct for such effects.

The system of projection illustrated in Figure 1 would produce a trapezoid on the screen (assuming a rectangular primary image) rather than the desired rectangle, but if the primary image on the tube screen is predistorted trapezoidally, the desired rectangular shape may be projected upon the screen. Such keystone predistortion and correction involve the fulfillment of three conditions: (1) trapezoid predistortion of the primary image, (2) vertical distribution predistortion of the lines scanned in the primary picture, and (3) focus correction. With low aperture systems (such as the refractive systems commonly employed) considerable latitude is allowed the designer in the correction for the trapezoid or keystone effect, due to the relatively great depth of focus inherent in such systems. However, in large aperture systems of low f number (such as the Schmidt system shown) the depth of focus is slight and this has created certain problems solved by the present invention.

In order to focus correctly upon the angled screen, the face 14 of the tube and the surface 18 of the image screen are so placed that $\tan \beta$ is equal to $m \tan \alpha$, where m is the reciprocal of the magnification, and the angles β and α represent the angle between the normal to the optical axis and the face 14 of the viewing tube, and the angle between the normal to the optical

axis and the surface 18 of the image screen, respectively.

In the system of the present invention, α is equal to 27° , β is equal to $4^\circ 51'$, and m is equal to 6. Angles equal to angles α and β are shown in Figure 1. The former is shown as the angle between the optical axis and the normal to the image screen 18, and the latter is indicated as the angularity between the longitudinal axis of the tube and the optical axis of the system. In other words, in the apparatus shown and described, the required rotation of the tube about the center of the tube screen, as the center of rotation, is equal to $4^\circ 51'$. Such angular displacement is sufficient to provide a satisfactory focus upon the screen 18.

With respect to the trapezoidal predistortion of the image on the screen, and with reference to Figure 2 of the drawings, for the system specified the lower edge of the primary image has a width of approximately $3\frac{3}{8}$ inches, the upper edge a width of about $3\frac{7}{8}$ inches, the height of the image being about $2\frac{1}{2}$ inches. Such dimensions produce an appropriate rectangular image on the screen, the vertical height of which is equal to approximately 18 inches, while its width is equal to 24 inches. The slant height of the screen is approximately equal to $19\frac{1}{4}$ inches.

In Figure 2, the geometric center of the trapezoid is represented by the intersection point of the two diagonals applied to the figure. This geometric center will occur in the final image as the actual center of the picture on the screen. Since the primary picture is composed of a large number of horizontally scanned lines, it is necessary to preadjust the normal vertical distribution of the lines scanned on the tube screen so that rays coming, for example, from the center of the trapezoid, will also coincide with the center of the picture to be projected. Since the intersection point of two diagonals is not equidistant from the top and bottom edges of the picture, an equal number of scanned lines must be provided upon the tube screen both above and below said geometric center.

As represented at 24 in Figure 1, the apparatus includes the usual horizontal and vertical deflection circuits which, further, are so constructed as to effect the trapezoidal predistortion and the vertical distribution adjustment, aforesaid. These circuits are connected with suitable deflecting coils 25, associated with the neck of the picture tube, as will be understood. Whereas the invention contemplates the use of such circuits in novel cooperative association with the optical means providing focus correction, the circuits, per se, are not included within the scope of my invention. These circuits may take a number of different known forms such, for example, as those described at pp. 471, et seq., in the 1940 edition of "Television," by V. K. Zworykin and G. A. Morton. Detailed description is not necessary herein.

As will be evident, the television receiver will also include various video and sound receiving and reproducing apparatus (not shown). A loudspeaker 26 is shown positioned just outside the optical path and in a location close to the screen. The television signal receiving circuit may be mounted in the cabinet in locations disposed laterally with respect to the plane of Figure 1.

From the foregoing, it will be appreciated that the concepts of the present invention not only provide a television receiver having substantial immunity from room light interference, but fur-

ther, these concepts have accomplished this advantageous result in an apparatus which, for the first time, makes it possible to utilize the advantages inherent in certain types of directional screen.

While I prefer to employ the Schmidt system shown, certain very large aperture refractive optical systems have been developed, such, for example, as that disclosed and claimed in the copending application of W. E. Bradley, Serial No. 627,334, filed November 8, 1945. In the broader aspect, the present invention contemplates the utilization of refractive systems having such large apertures. However, it will be understood that changes and modifications may be made in the illustrated embodiment, within the scope of the appended claims.

I claim:

1. Projection television apparatus comprising, in combination: a Schmidt type image projector system having an optical axis and including a substantially spherical image-forming mirror and a primary image source, said source including a surface disposed in confronting relation with respect to said mirror and reducing light transmission in a zone within the boundary of the path of light projection, the length of the path of light from said source to said mirror being equal to one conjugate distance of the system; a viewing screen spaced from said mirror and disposed at the other conjugate distance of the system, said viewing screen being cylindrically concave about a horizontal axis extending at right angles with respect to the optical axis of the system and providing vertical compression of the projected light, said screen having a plurality of generally parallel grooves extending in the direction of curvature thereof and effective to spread said light through a substantial angle in the horizontal sense; and a coating of transparent material on said screen forming a multiplicity of random sized and randomly-disposed weakly diffusing lens elements effective to spread the projected light slightly in at least the vertical direction, both said lens elements and said grooves being of such small size that they are beyond the resolving power of the eye at the minimum proper viewing distance.

2. Projection television apparatus comprising, in combination: a Schmidt type image projector system having an optical axis and including a substantially spherical image-forming mirror and a primary image source, said source including a surface disposed in confronting relation with respect to said mirror and reducing light transmission in a zone within the boundary of the path of light projection, the length of the path of light from said source to said mirror being equal to one conjugate distance of the system; a viewing screen spaced from said mirror and disposed at the other conjugate distance of the system, said screen having light-directing surface portions variously sloped with respect to the optical axis of the system and imparting converging power effective to provide compression of the projected light in one of two rectangularly related coordinate senses, a plurality of strongly diffusing elongated elements on the screen extending generally in the direction in which said screen has slope and spreading said light through a substantial angle in the other of said two coordinate senses; and a transparent material on said screen providing a multiplicity of weakly diffusing lens elements effective to spread the projected light slightly in at least the first-men-

tioned coordinate sense, both said strongly diffusing elements and said lens elements being of such small size that they are beyond the resolving power of the eye at the minimum proper viewing distance.

3. Projection television apparatus comprising, in combination: a Schmidt type image projector system having an optical axis and including a substantially spherical image-forming mirror and a primary image source, said source including a surface disposed in confronting relation with respect to said mirror and reducing light transmission in a zone within the boundary of the path of light projection, the length of the path of light from said source to said mirror being equal to one conjugate distance of the system; a viewing screen spaced from said mirror and disposed at the other conjugate distance of the system, said screen including light-directing surface portions variously sloped with respect to the optical axis of the system and imparting converging power effective to provide compression of the projected light in one of two rectangularly related coordinate senses; and a multiplicity of weak light-diffusing convex lens elements at said screen, said lens elements being operative by refraction to diffuse and spread the projected light slightly in at least the first-mentioned coordinate sense, said lens elements being of such small size that they are beyond the resolving power of the eye at the minimum proper viewing distance.

4. Projection television apparatus comprising, in combination: a Schmidt type image projector system having an optical axis and including a substantially spherical image-forming mirror and a primary image source, said source including a surface disposed in confronting relation with respect to said mirror and reducing light transmission in a zone within the boundary of the path of light projection, the length of the path of light from said source to said mirror being equal to one conjugate distance of the system; a viewing screen spaced from said mirror and disposed at the other conjugate distance of the system, said viewing screen including light-directing surface portions variously sloped with respect to the optical axis of the system and imparting converging power effective to provide vertical compression of the projected light, a plurality of strongly diffusing generally parallel elongated elements on the screen extending in the direction of slope thereof and effective to spread said light through a substantial angle in the other of said two coordinate senses; and said screen being covered with a multiplicity of individual weakly diffusing means effective to spread the projected light slightly in at least the vertical direction, both said strongly diffusing elements and said means being of such small size that they are beyond the resolving power of the eye at the minimum proper viewing distance.

5. Projection television apparatus comprising, in combination: a cabinet having opposed walls; an image projector system disposed within said cabinet and including a concave image-forming mirror, a lens for correcting aberration arising in said mirror, and a primary image source having a surface disposed in confronting relation with respect to said mirror and reducing light transmission in a zone within the boundary of the path of light projection, the length of the path of light from said source to said mirror being equal to one conjugate distance of the system, and said mirror and lens defining an optical axis disposed obliquely with respect to the major axis of said

cabinet whereby light from said projector is directed toward a region of one wall of the cabinet; a reflector disposed in said region; a viewing screen associated with an opposite cabinet wall and spaced from said mirror—along the said optical axis—a distance equal to the other conjugate distance of the system, said screen being obliquely inclined with respect to said optical axis and being forwardly inclined toward the viewing area to prevent light—from sources exterior to said apparatus—from being reflected into the viewing area, said screen including light-directing surface portions variously sloped with respect to the optical axis of the system and imparting converging power effective to compress light in one of two rectangularly related coordinate senses; a plurality of strongly diffusing generally parallel elongated elements on said screen extending in the direction of slope thereof and effective to spread the projected light through a substantial angle in the other of said two coordinate senses; and a multiplicity of weak light-dispersing lens elements at said screen operative to diffuse and spread the projected light slightly in at least the first-mentioned coordinate sense, both said diffusing elements and said lens elements being of such small size that they are beyond the resolving power of the eye at the minimum proper viewing distance.

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