Sept. 14, 1954 E. GRETENER 2,689,298

MEANS FOR OBTAINING EVEN ILLUMINATION FROM A SINGLE SOURCE

Filed Sept. 1, 1948 2 Sheets-Sheet 1

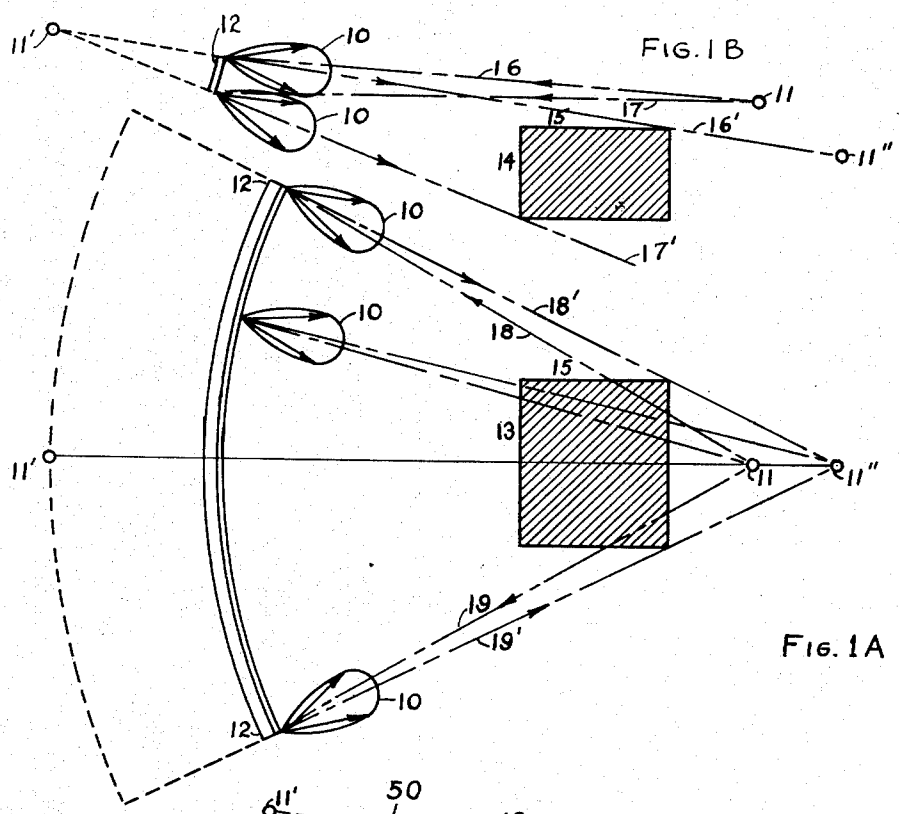


FIG. 1B

FIG. 1A

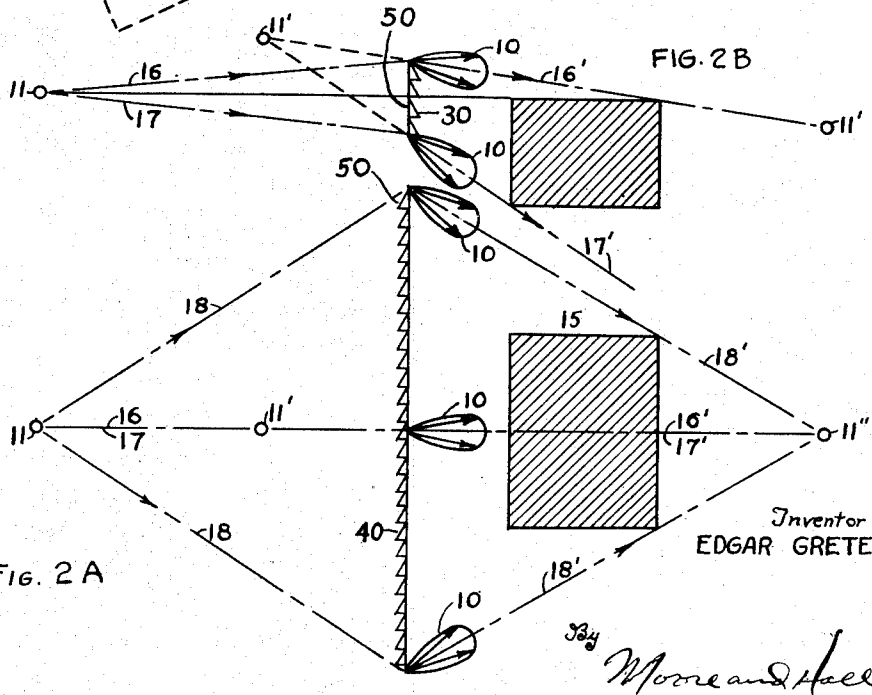


FIG. 2B

FIG. 2A

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Sept. 14, 1954 E. GRETENER 2,689,298

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Filed Sept. 1, 1948 2 Sheets-Sheet 2

Fig. 3.

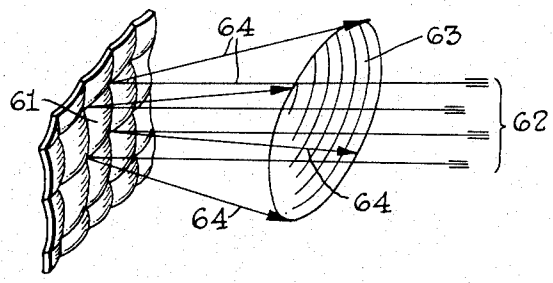


Fig. 4.

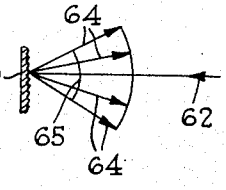


Fig. 5.

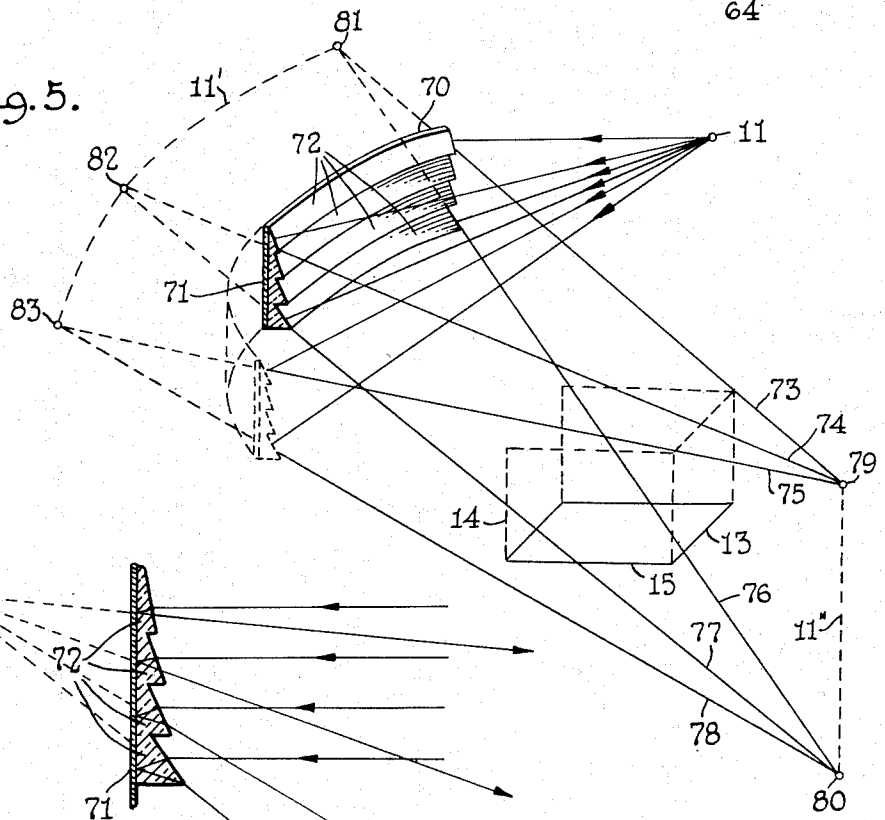


Fig. 6.

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MEANS FOR OBTAINING EVEN ILLUMINATION FROM A SINGLE SOURCE

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10 Claims. (Cl. 240—3)

1

The present invention relates to illumination and particularly concerns the even illumination of a space of substantial dimensions by a single light source. Reference is made to my British Patent No. 664,250 cognate with the present application. The invention comprises an optical device for obtaining uniform illumination of a given space of predetermined dimensions by means of a single light source, characterized by the use of a light reflecting or refracting surface in conjunction with the light source and in which said surface reflects or refracts the light rays emanating from said source in such a way, that all reflected or refracted rays disposed in a common vertical plane intersect at or near one common point in front of the space to be illuminated, whereas all reflected or refracted light rays disposed in a common horizonal or approximately horizontal plane intersect at or near one common point at the rear of said space to be illuminated.

The fundamental idea of the invention is that homogeneous illumination of a selected space may be obtained if this space is illuminated by a light beam, the sectional area of which is approximately of equal size all through this space. As the same light flux passes through each sectional area and is uniformly distributed over each of these areas and as the intensity of illumination is equal to the quotient of the light flux divided by the sectional area of the beam, intensity of illumination will thus be equal for any sectional area. A light beam having this property is obtained by causing the beam to converge in horizontal sections and diverge in vertical sections. This divergence and convergence is achieved by a deflector device having a form such that all rays reflected by points lying on common horizontal sections through said device unite in common points, respectively, in front of the device, and that the elongations of all rays reflected by such points as lie in common vertical sections through said device unite in common points, respectively, to the rear of said device. The uniting points in front of the device, the "real images," are located on a practically perpendicular line and the uniting points to the rear of said device, the "virtual images," are located on a horizontal line rearward of the surface. The space to be illuminated is located in that part of this light beam where convergence and divergence just compensate each other, thus keeping the sectional area constant. This means that the space to be illuminated must be located in between the reflector surface and the

2

real image of the light source. The area to be illuminated must be interposed into the beam of reflected rays between the said device and the locus of said uniting points in front of said device.

These objects may be achieved only if the reflector surface as a whole is given a toroidal shape, i. e., convex in vertical sections and concave in horizontal sections, or is provided with Fresnel-lenses or prisms of equal effect.

It is an object of the invention to provide an arrangement to illuminate a selected area evenly from a concentrated light source by employing a light spreading area which forms a real image of the light source in horizontal planes by main rays uniting in points behind the space to be illuminated and also forms a virtual image of the same light source in vertical planes by main rays uniting in points in front of the space to be illuminated.

The even illumination of a space in length, breadth and height such as a stage presents a problem of illumination technique which is of especial practical importance in the illumination of studio sets or other scenes for motion picture photography, television and the like. Evenness of lighting is important not only in color work but also in black and white.

The use of a single light source to obtain the necessary illumination is most desirable so as to minimize the trouble and expense of operation and maintenance and maximize control for given equipment. We are here concerned with even illumination commonly referred to as the "key-light" of a stage, studio, or scene which should not only have a homogeneous distribution, but is preferably white light having a continuous spectrum. Additional lighting is obtained from other light sources such as spot-lights with or without colored filters to produce any special effects which may be desired. This special lighting is not to be confused with key lighting.

The homogeneous distribution of light throughout a space is now obtained in practice by using either a distant source of light to reduce the contrast caused by the operation of the inverse square law or a light source which extends over a relatively large area.

According to the present invention a light spreading surface which may be either a reflector or refractor or combination of the two is provided with suitably shaped optical surfaces constructed in such a manner that image of the light source is formed behind the space being illuminated by all rays reflected by points of said

surface lying in a common horizontal plane and a virtual image of the light source is formed in front of said space by all rays reflected by points of said surface lying in a common vertical plane.

The light source may consist, for example, of a single arc lamp or an aggregation of such lamps which are combined to form a single source of light. It is preferred, in the practice of the invention, that a cylindrical rather than a point source of light is formed. An elongate fan shaped beam is best suited for the illumination of the reflecting, refracting or combination light spreading surface. The disclosure in my copending U. S. Patent No. 2,621,284, filed July 14, 1947, for carbon arcs, may be employed as a suitable cylindrical source.

The accompanying drawings are intended to be taken as illustrative of three forms the invention may take and are not to be taken as limiting. Like numerals refer to like elements throughout.

Fig. 1A is a sectional plan view of a schematic construction using a reflector incorporating the invention.

Fig. 1B is a sectional elevation of Fig. 1A.

Fig. 2A is a sectional plan view of a schematic construction using an echelon lens of the type developed by Fresnel, incorporating the invention.

Fig. 2B is a sectional elevation of a vertical Fresnel lens embodying the invention.

Fig. 3 is a fragmentary elevation of a lenticulated lens according to the invention.

Fig. 4 is a fragmentary section of one of the lens elements of Fig. 3 with an elemental ray diagram.

Fig. 5 is a sectional perspective view of a Fresnel type lens embodying the invention.

Fig. 6 is a vertical section of the structure of Fig. 5.

Referring to Figs. 1A and 1B, 11 indicates a cylindrical light source having its longitudinal axis vertical and is preferably of the arc-lamp type mentioned above. A light spreading optical device 12 comprising a doubly curved reflecting surface made up of a portion of a toroid surface having different radii of curvature about sections normal to each other, specifically the horizontal and vertical sections. The curvature in horizontal sections is concave as is shown in Fig. 1A and the curvature in vertical sections is convex as is shown in Fig. 1B. The resulting toroid surface presents a shape similar to that of a saddle. The structure of element 12 may be formed of metal such as aluminum, copper or the like, polished or plated so as to have high reflecting characteristics. Elements 12 may also be made of glass on which a layer of metallic silver has been deposited. Coated plastics can be used.

The space under illumination is taken to be a cube having a length 13, a height 14 and a breadth 15 representing a set in a motion picture film studio, the stage of the theatre or a set to be televised. The last perhaps has the most exacting illumination requirements.

The main rays 16 and 17 in elevation view Fig. 1B and 18 and 19 in plan view Fig. 1A from light source 11 are reflected and reoriented by light spreading surface 12 to form individual well-defined polar diagrams 10 the central rays of which are represented by the corresponding reflected beams 16' and 17' in the vertical plane and 18' and 19' in the horizontal plane. As the ray analysis is independent of the particular outline of polar diagrams 10 it is sufficiently accurate in the interests of simplicity to consider only main rays 16, 17, 18 and 19 coming from light source 11 and deviated by reflector 12 as rays 16', 17', 18' and 19'.

The practical homogeneous or even distribution of light within the space 13—14—15 requires that the following conditions be fulfilled:

First, the main rays 16 and 17 coming from light source 11 toward reflector 12 in vertical planes be deviated by reflector 12 so that a virtual image 11' of source 11 is formed by the reflected main rays 16' and 17' in front of the space 13—14—15 as shown at 11' in Fig. 1B.

Second, the main rays 18 and 19 coming from light source 11 toward reflector 12 in horizontal planes be deviated by reflector 12 so that a real image 11'' of the light source 11 is formed by rays 18' and 19' behind space 13—14—15 as shown at 11'' in Fig. 1A.

Third, light intercepting objects within the space 13—14—15 should be small compared with the dimensions of the space. Should a single solid light impervious object fill a half or two-thirds of space 13—14—15 there would probably be shadows depending on the contour of the object which would interfere to a greater or less degree with the even distribution of light in space 13—14—15.

Fourth, the brightness of reflecting surface 12 must be substantially a constant over the area of the surface. This requires that the reflection characteristic over the surface 12 and the brightness level over the surface of light source 11 are constants or that they compensate each other, whereby the resultant reflected light level in space 13—14—15 is made constant.

The even distribution of light within the space 13, 14, 15 is obtained by reason of the fact that the luminous area of the surface increases proportionally with the distance of the view point from the said surface provided that the brightness of the surface is made constant.

For practical purposes the bringing of rays 16', 17' and 18', 19', and all other rays lying in the same vertical or horizontal plane, respectively, to a sharp focus is unnecessary as only a limited concentration is needed to produce the effect desired and the soft lighting effect of relatively large areas of diffusion may in some cases be desirable. In other words image points 11' and 11'' need not be sharp.

For practical purposes the distribution of illumination over the spreading surface is advantageously made homogeneous in every vertical section through the light source and the spread surface.

Surface 12 may be white such as coated plastic. When it is desired that polar diagrams 10 be of any special shape, reflector 12 as shown by Figs. 3 and 4 is composed of a large number of individual light spreading elements 60 such as miniature concave or convex mirrors or reflectors formed in or on the material from which the light spreading reflector 12 is made. These miniature reflectors preferably form a regular pattern. The curvature of the individual elements is chosen in such a way, that the light impinging upon the reflecting surface of an individual element or in the direction of arrows 62 is reflected to fill a given solid angle 63 with a prescribed distribution of intensity, which may be indicated by the length of arrows 64, the points of which form the distribution curve. In a particular case as shown in Fig. 4, light is reflected with homogeneous intensity into a certain angle 65, whereas

no light is reflected beyond the angle. Where the individual reflectors are very small and form a deposited mosaic regularity of pattern is of less importance and may be neglected.

Figs. 2A and 2B show a form of invention in which the light spreading device **50** comprises two crossed echelon lens systems of the Fresnel type. Fig. 2B shows an elevation of a horizontal Fresnel lens grid system **30** forming one part of lens **50** and Fig. 2A shows a plan view of a vertical Fresnel lens grid system **40** completing lens **50**.

In Fig. 2B Fresnel lens grid system **30** forms a virtual image **11'** of light source **11** in front of space **13—14—15** as shown by the ray construction **16, 17** and refracted rays **16', 17'**.

In Fig. 2A Fresnel lens grid system **40** forms a real image **11''** behind space **13—14—15** as shown by the ray construction **18, 18** and refracted rays **18', 18'**.

For clarity the horizontal lenticulations **30** of Fig. 2B have been omitted from Fig. 2A and vice versa. The embodiment illustrated in Figs. 2A and 2B has the disadvantage that it occupies more space which in devices of this type is at a premium.

In most cases of practical application the reflector type **12** is preferred particularly where the illuminating equipment is to be portable.

As described above the light spreading device such as reflector **12** comprises a toroid shaped reflecting surface having different radii of curvature in the vertical and horizontal sections, the vertical extent being of considerably smaller dimension than the horizontal one as is seen in Fig. 1B and Fig. 1A respectively. For certain applications a single curved surface combined with a Fresnel mirror or prism grid system may be used as shown by Figs. 5 and 6.

Fig. 5 schematically shows in a perspective view an embodiment of the invention and Fig. 6 a section view thereof. Elements corresponding to elements shown in Figs. 1A and 1B are given identical reference numerals. The light coming from a source **11** impinges upon a refractor **70** which is cylindrical i. e. concave in horizontal sections and straight in vertical sections. The reflecting surface **71** supports circular Fresnel prisms **72**. Light coming from source **11** traverses the prisms **72**, is reflected by the underlying surface **71**, traverses the prisms a second time and is thus reflected downwards to greater or lesser extent, as the deflecting power of the Fresnel prisms increases from the top towards the bottom. It is to be understood that in realty the dimension of the prisms are much smaller and have been enlarged in the drawings only for the sake of clarity. The rays impinging upon the reflector are deflected in such a way that all rays, e. g. **73—74—75** or **76—77—78**, reflected by points on the reflector that are disposed in common horizontal section thereof converge due to the curvature of the reflector surface **71** towards a common point respectively, **79** or **80**. All such points are disposed on line **11''**. All rays reflected by points that are disposed in common vertical sections, e. g. **73—76** or **74—77** or **75—78**, due to the effect of the Fresnel prisms diverge, so that their rearward elongations intersect in a common point, respectively e. g. **81, 82** or **83**, rearwards of the reflector. All such points are disposed on a line **11'**. The entire light beam, defined in the drawing by rays **73, 75, 76** and **78**, diverges in one e. g. the vertical direction, and converges in the other, e. g. the horizontal direction. The space **13—14—15** to be illuminated

is interposed into this beam in between reflector **71** and the locus of intersection of the reflected rays, i. e., the locus of the real images of the light source. With this construction a virtual light source image is formed in front of the space **13—14—15** by the horizontal Fresnel mirror system by all rays reflected by points of said surface lying on a common vertical section thereof, respectively, and another real image is formed by all rays reflected by points of said surface lying on a common vertical section thereof, respectively behind the space by the cylindrical reflecting surface. The term front as here used refers to the left side of space **13—14—15** in the drawing.

The Fresnel lens **50** may be made translucent or transparent depending upon the softness of key lighting required. Lens **50** may be a flat spread surface, the focusing being done by the lenticular elements.

I claim:

1. An illumination system comprising a compact light source, a single unbroken light spreading surface having two fixed radii of curvature about two different axes in respect to a relatively large solid region to be illuminated, the curvature of said surface about one axis producing a real image of said source on one side of said region and removed from said surface a distance of at least a meter, the curvature of said surface with respect to the other axis being such as to produce a virtual image of said source on another side of said region whereby said region is evenly and homogeneously illuminated.

2. An optical system comprising a compact cylindrical light source, a light spreading surface of a toroid shape, the curvature in a substantially vertical section of the surface producing a virtual image of said source and the curvature in a substantially horizontal section of the surface producing a real image of said source, the longitudinal axis of said cylindrical source being substantially vertical with respect to the curvatures of said surface, said images being on different sides of said surface whereby even illumination is produced over a selected area of at least a square meter in extent interposed between said surface and the locus of said real images.

3. The combination set forth in claim 1, said light spreading surface being a reflector having a concave curvature about one axis thereof and a convex curvature about another axis.

4. The combination set forth in claim 1, said light spreading surface comprising an echelon lens having elemental lens portions on opposite sides thereof.

5. The combination set forth in claim 1, said light spreading surface comprising a curved reflector with a Fresnel mirror.

6. The combination set forth in claim 5, said light spreading surface comprising a reflecting surface curved in the horizontal plane and a Fresnel mirror whereby the real image is formed by said reflecting surface and the virtual image is formed by said Fresnel mirror.

7. An illuminating system for the production of homogeneous illumination of a region, said system comprising a compact cylindrical light source, a single light spreading reflecting surface illuminated by said source, every horizontal section of said surface being an unbroken concave configuration and causing the light rays from said source to converge in horizontal planes, every vertical section of said surface being an unbroken convex configuration and causing the

light rays from said source to diverge in vertical planes, whereby said region is illuminated in effect by two images of said source, said cylindrical light source being centrally located with respect to the area of said reflecting surface and said source having its longitudinal axis substantially vertical with respect to the said surface.

8. An illumination system for illuminating a solid area with an even distribution of light, comprising a compact cylindrical light source facing the forward surface of a reflector device, said reflector device deflecting the light rays emanating from said source and comprising a concave configuration in all horizontal sections so that all rays reflected by points lying on common horizontal sections through said device unite in common points, respectively, before said forward surface, said deflector device comprising a convex configuration in all vertical sections so that the elongations of all rays reflected by such points as lie on common vertical sections through said device unite in common points, respectively, behind said forward surface, said area to be illuminated being interposed into the beam of reflected rays in a space measuring at least a meter between the forward surface of said device and the locus of said uniting points before said forward surface, the longitudinal axis of said cylindrical light source being substantially vertical with respect to the said horizontal and vertical sections of said reflector device.

9. The combination set forth in claim 8, the radius of curvature of said reflector in said vertical sections being substantially smaller than the radius of curvature in said horizontal sections said light source comprising an arc-lamp device centrally positioned before said forward surface.

10. An optical system for providing substantially uniform illumination of a selected region of substantial macroscopic dimensions, a light source, a light deflecting device having as a whole a toroidal shape effectively convex in vertical sections and concave in horizontal sections thereof, a single illuminating beam from said source for illuminating said region, said beam being convergent in horizontal sections and divergent in vertical sections, the rays of said beam affected by points lying on common horizontal sections of said device, uniting in common points, respectively, in front of said device to form real images removed from said device a distance of not less than the order of a meter, said selected region being positioned between said device and said real images in the area in which the horizontally convergent sections of the single illuminating beam and the vertically divergent sections of the beam mutually compensate to produce substantially uniform illumination.

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