Oct. 27, 1964 R. G. McPHAIL ETAL 3,154,254

STREET LIGHT REFRACTOR

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Fig. 1A.

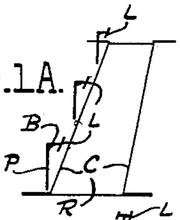

Fig. 1B.

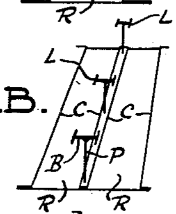

Fig. 1C.

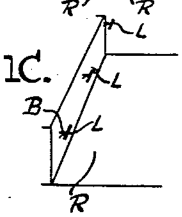

Fig. 2.

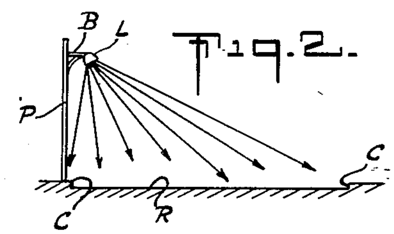

Fig. 3.

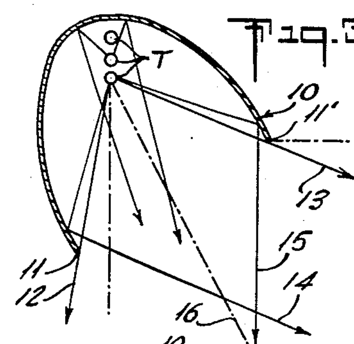

Fig. 5.

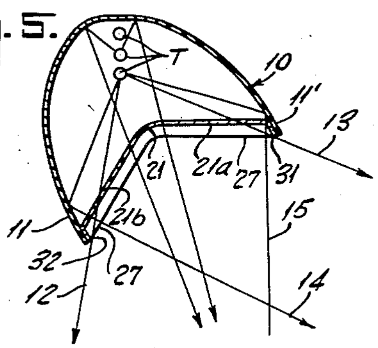

Fig. 4.

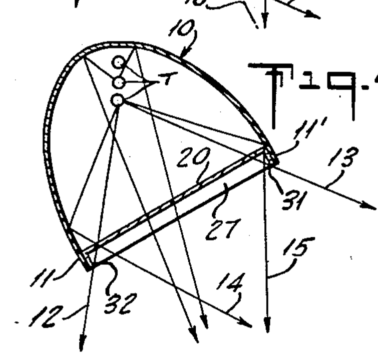

Fig. 6.

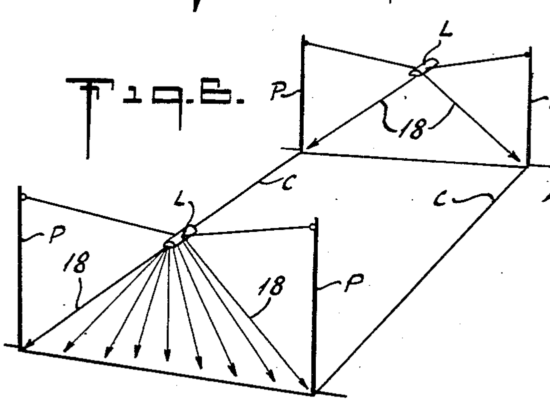

Fig. 7.

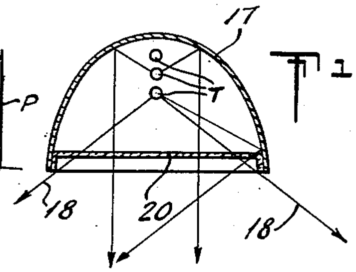

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Fig. 8.

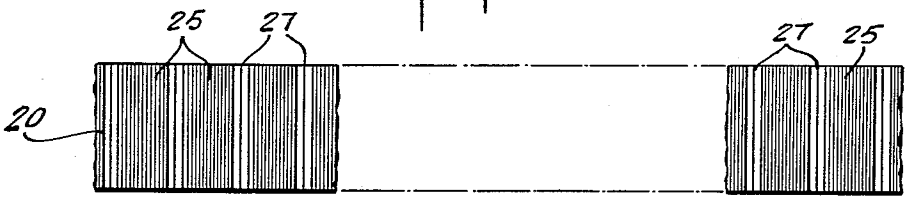


Fig. 9.

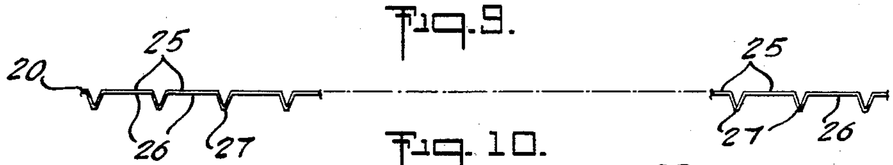


Fig. 10.

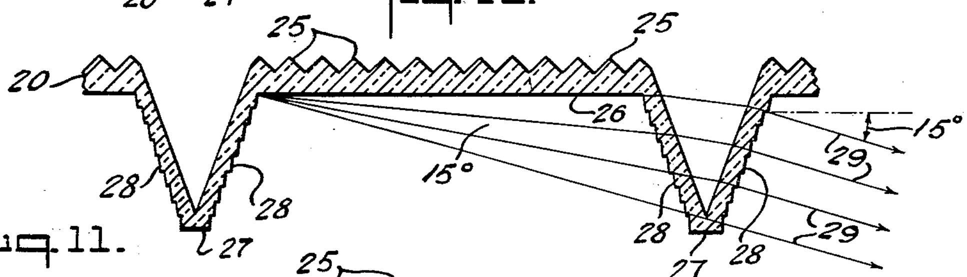
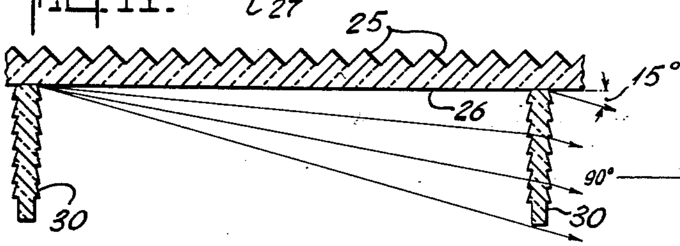


Fig. 11.



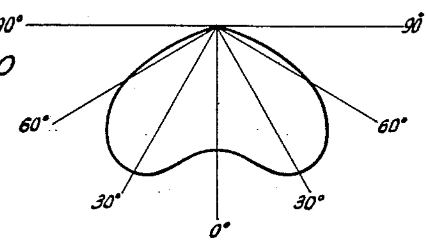


Fig. 13.

Fig. 12.

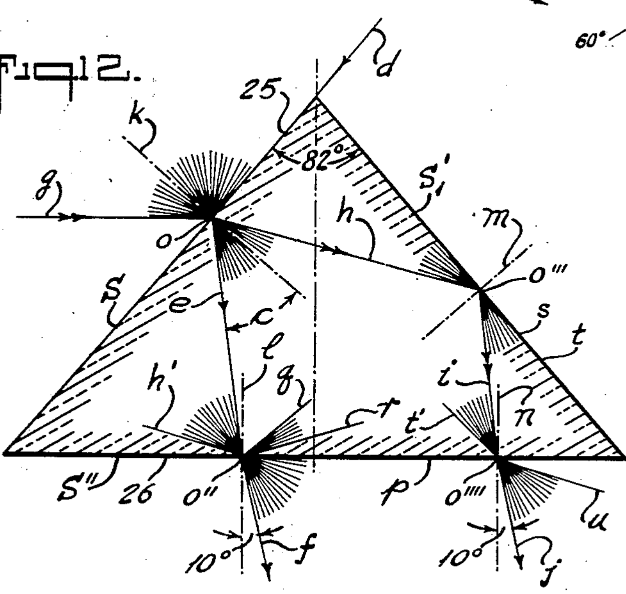


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Fig. 11B.

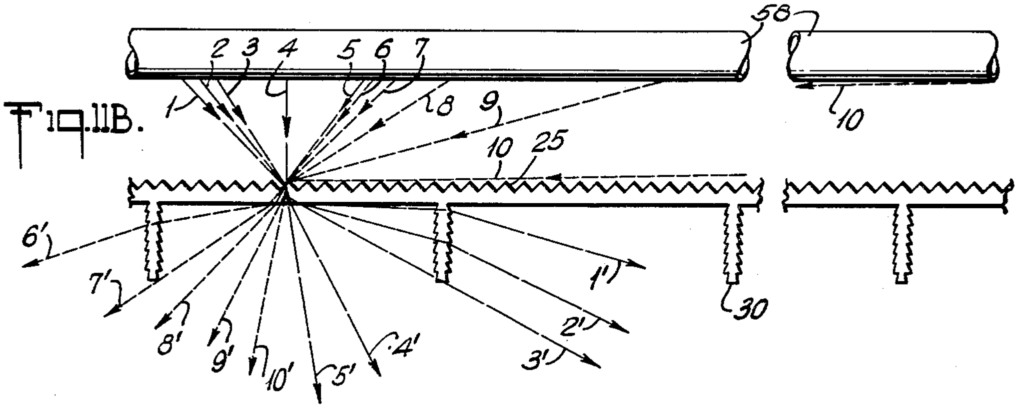


Fig. 13A.

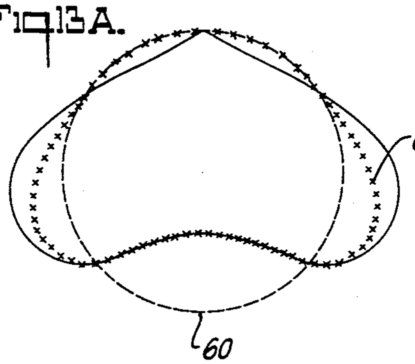


Fig. 13B.

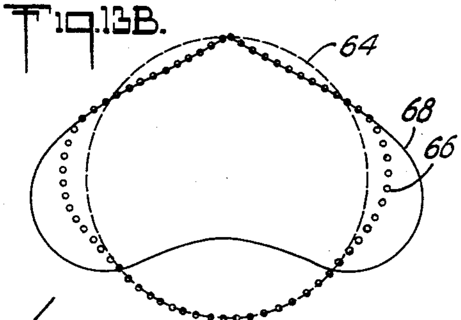
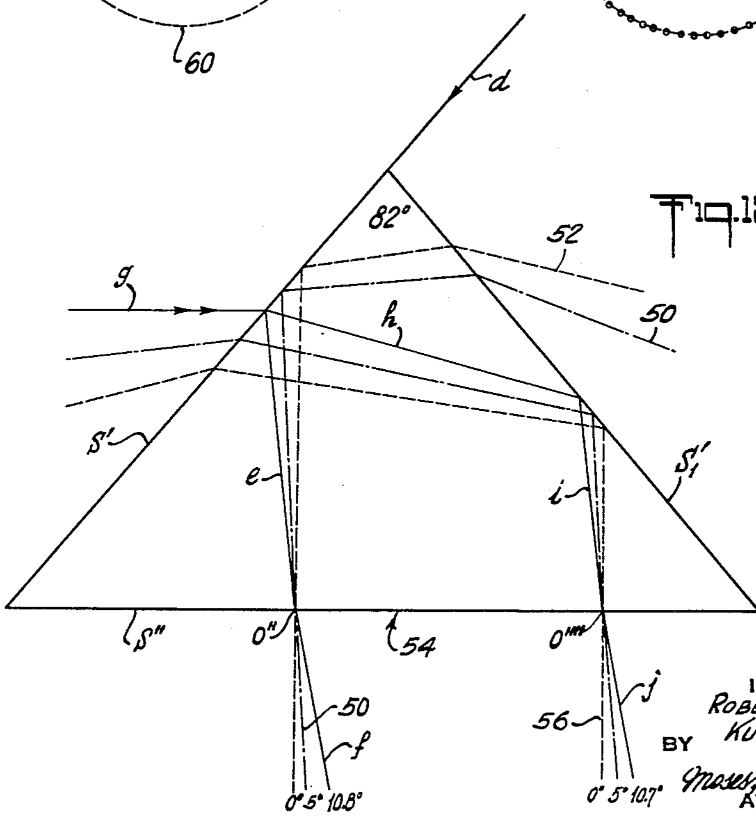


Fig. 12B.



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3,154,254

STREET LIGHT REFRACTOR

Robert G. McPhail, deceased, late of Newark, Ohio, by The Park National Bank of Newark, Ohio, executor, and Kurt Franck, Newark, Ohio, assignors to Holophane Company, Inc., New York, N.Y., a corporation of Delaware

Filed Jan. 2, 1959, Ser. No. 784,776
7 Claims. (Cl. 240—106)

This invention relates in general to luminaires and in particular to a new and useful luminaire having an elongated light source such as a fluorescent light and including an improved refractor to control the distribution of light over extended areas such as a street and to avoid excessive brightness and glare at high-angle longitudinal directions and directly beneath the luminaire on the surface of the area being lighted.

Fluorescent light sources are more efficient in the output of light than incandescent light sources, but such lighting equipment is necessarily large. The natural distribution of light from fluorescent sources is such that either the light is allowed to escape without control, or the conrolling equipment used has to be large and may be cumbersome.

The present invention contemplates improved fluorescent lighting luminaires for the lighting of extended areas adapted to be mounted over and to one side of the center of such an area, for example, near the curb, or over the center of the street, and having reflectors which determine the transverse light pattern and confine the light output to a band or strip of predetermined width such as street or roadway. This is accomplished by suitably reflecting the light rays from lamps arranged parallel with the street direction. Such reflectors afford mechanical and weather protection for the lamp carriers, but effect no control of light in the longitudinal or street direction. Such open reflectors are also subject to rapid deterioration on account of the accumulation of dirt on the reflecting surfaces.

The present invention is an improvement over prior art constructions, particularly in the prevention of glare directly beneath and at high-angle longitudinal directions in a luminaire having an elongated light source such as a fluorescent light. The invention includes an improved reflector and refractor construction in which the light rays are dispersed laterally and longitudinally and in which the light rays emanating from the light source are prevented from being emitted in directions essentially straight down or at high angle longitudinal directions up to around fifteen degrees below the surface of the refractor.

The present invention was discovered in consideration of the known optical axiom that light ray paths are reversible. It is possible to trace the course of a light ray not only from the light source to the work plane or human eye, but also in a reverse direction from a work plane back to the light source. Based on this axiom it was conceived that in order to find a prism which would not permit light from an extended fluorescent lamp of such laminaires to be sent in directions essentially straight down, an analysis might be made to determine the kind of prism which would not let light rays, entering in directions essentially straight up, strike the lamp, but instead, such rays would be turned downward again. These considerations had to take into account the horizontal elongation of the fluorescent light source whereas previously only point light sources had to be dealt with.

Accordingly it is an object of this invention to provide an improved refractor for a luminaire having an elongated light source.

A further object of the invention is to provide a luminaire including an elongated light source such as a fluorescent light and having means for controlling the distribution of the light emitted therefrom over an extended surface area to be lighted, including means to prevent light from the fluorescent lamp from being emitted straight down.

A further object of the invention is to provide a refractor for use with a luminaire having an elongated light source including prims arranged to reduce the light falling on the street surface close to and below the luminaire and to divert the light away from the nadir in longitudinal directions to build up the illumination at more distant regions and prevent light rays from emanating at high-angle longitudinal directions.

Accordingly, the present invention also contemplates the provision of suitable closures for the mouths of the reflectors so that entrance of dirt to impair the reflecting surfaces is avoided, and so that light emitted at high angles in longitudinal directions is suppressed to avoid high brightness in the region of the horizontal.

As the natural distribution of the trough-shaped reflector about an elongated source is such as to build up the maximum light output opposite the middle of the lighting unit, such open reflectors tend to produce excessively high street surface brightness close to the luminaire.

The present invention contemplates incorporating into the closure light splitting prisms arranged to reduce the light falling on the street surface close to the luminaire and divert the light away from nadir in longitudinal directions to build up illumination at more distant regions.

A further object of the invention is to provide a luminaire which is simple in design, rugged in construction, and economical to manufacture.

Other objects of the invention will become apparent as the description proceeds.

The accompanying drawings show, for purposes of illustrating the present invention, two embodiments, together with modification of certain parts, in which the invention may take form, it being understood that the drawings are illustrative of the invention, rather than limiting the same.

In the accompanying drawings:

FIGS. 1*a*, 1*b* and 1*c* are diagrams illustrating the installation of the luminaires along the side of a street, the middle of a parkway or the side of a building.

FIG. 2 is a cross section showing the transverse spread of the light as limited by the reflector of a luminaire mounted at the side of the street;

FIG. 3 is a cross sectional view of the luminaire without a closure;

FIGS. 4 and 5 are cross sectional views of the luminaire with two forms of light transmitting closure;

FIG. 6 is a cross sectional view showing the transverse spread of the light as limited by the reflector of a luminaire mounted over the center of the street;

FIG. 7 is a cross sectional view of the luminaire of FIG. 6;

FIG. 8 and 9 are diagrammatic top plan and profile views of a light transmitting closure at a small scale constructed in accordance with invention;

FIGS. 10 and 11 are enlarged, longitudinal sectional views through two forms of refractor with light splitting prisms and light suppressing elements for cutting off high angled light and lowering it constructed in accordance with the invention;

FIG. 11*b* is a view similar to FIG. 11 but indicating the elongated fluorescent tube light source and the redirecting of the light therefrom by the improved refractor constructed in accordance with the invention;

FIG. 12 is a diagram showing the optics of the preferred form of light splitting prism;

FIG. 12*b* is a diagram showing the optics considerations to achieve the prisms of FIG. 12;

FIG. 13 is a photometric diagram illustrating the type of longitudinal light distribution obtained by the luminaire; and

FIGS. 13*a* and 13*b* are photometric diagrams similar to FIG. 13 indicating the improved lighting effected by the individual refractor srtuctures.

In FIGS. 1*a*, 1*b*, 1*c* and 2 the elongated surface to be lighted is indicated by the letter R with the curb lines at C, C. the luminaires L may be mounted on brackets B on poles P along the side (or sides) of the street or on the side of a building. The brackets B extent over the surface. The placing of the luminaire partway across the street permits relatively steep rays toward the near curb and relatively high angle light directed toward the further curb. Suitable angular values in the plane of FIG. 2 are approximately 10° to the left of nadir, and near 70° to the right of nadir. These indicate a mounting height of approximately 30 feet over a street surface 75 feet wide.

The light source employed preferably has a plurality of fluorescent tubes T, of a type suitable for street lighting. In the drawings they are shown mounted one above the other, but they may be in a cluster. The reflector for enclosing the light source and effecting the transverse light control is indicated at **10**.

The reflector for side of street mounting is asymmetric. To effect a continuous change in angle of reflected light, the left lower edge **11** is so placed as to provide the desired curb side cut off angle, typically 10° to the left of nadir, as indicated by the ray **12** and its upper right edge **11'** is so placed as to provide the desired cut off angle, typically 70° to the right of nadir, as indicated by the ray **13** to confine the directed light to the width of the street surface. Near the lower edge **11** the reflector is designed to reflect the highest angled light ray **14** in directions substantially parallel with ray **13**, while near the upper edge **11'** the reflector is designed to reflect the highest angled light ray **15** into the directions substantially parallel with the ray **12**. All these rays cross the median plane **16—16** of the reflector before reaching the street surface. Owing to the physical size of the light source there will be considerable spread of the reflected light. The top of the reflector is flattened so as to keep the reflected light off the tubes.

FIGS. 6 and 7 show a luminaire L mounted over the center of the street in the conventional manner, care being taken to orient it lengthwise of the street. Here the reflector **17** is symmetric and has an angle of cut off suitable to confine the light to the desired street width as illustrated by limiting rays **18—18**, and a profile to keep the reflected ray within approximately the same angle of spread.

While the reflectors above described effect a very desirable distribution of light in transverse plane and could be employed where an open fixture and high luminaire brightness lengthwise of the street at angles near the horizontal were acceptable, it is preferable to provide the luminaire with optical means for redirecting the light in longitudinal directions for optimum distribution.

In the transverse planes of FIGS. 4 and 7 the control is effected by a generally flat light transmitting closure generally indicated at **20**, while in FIG. 5 it is effected by a closure **21** with a reentrant angle so that each half **21*a*** and **21*b*** has a higher average angle of incidence for reflected rays than the corresponding portions of the flat closure **20**, and hence higher efficiency.

The closure **20** is preferably made of transparent material of a width to extend across the mouth of the reflector and a length (for example, two feet) so that several molded units will close off the mouth of the long reflector. The dominant portion of the upper or light incident surface of these light transmitting units is occupied by a series of continuous light splitting ribs or prisms **25** opposite a smooth, light emergent surface **26**. Such ribs tend to divert light from the nadir, as will be more

fully explained below, but the smooth surface **26** opposite them permits light rays to escape up to 90° from the nadir, or the horizontal.

To intercept this high angle, longitudinally emitted light from the bottom surface **26**, the closure plates of FIGS. 8–10 are provided with V-shaped ribs **27** preferably of a depth and spacing to intercept all light within 15° of the horizontal and provided with prisms **28**, **28** to deviate the intercepted light so that it is emitted at angles of 15° below the horizontal, as shown by rays **29**. These ribs are symmetrical about the median plane as they have to handle light coming from the right or the left. They are thin walled, as shown, to facilitate pressing.

The modified form of closure in FIG. 11 has thin prismatic ribs **30** at spaced intervals and integral with or suitably secured to the flat plate. The closures may be provided with side flanges indicated at **31** and **32**.

As the light splitting prisms **25** receive light from the left as well as from the right, the prisms should by symmetrical about vertical planes through their apices. Each side face of such a series of prisms will receive from above a zone of light extending from the horizontal up to the cutoff line provided by the prisms surface. (Such a prism is shown at enlarged scale in FIG. 12. The light rays farthest to the right from zenith, i.e., those grazing the left incident surface S of the prisms, will be refracted into the critical angle *c* for the medium and again refracted by the emergent surface S'' (**26**). The horizontal limiting rays will be refracted by surface S', reflected by the other S_1' of the prism and refractively transmitted by the emergent surface S''.

The path of the limiting grazing ray with 90° angle of incidence at the point *o* is indicated in FIG. 12 by the single arrowed line *d, e, f*. The path of the originally horizontal ray which is refracted, reflected and again refracted, is indicated by the double arrowed line *g, h, i, j*. The normals to the surfaces are indicated by the lines *k, l. m* and *n*, respectively.

The bundle of rays in the sector between *d* and *g* is refracted into a narrower bundle of rays in the sector between *e* and *h* with ray *e* at the critical angle *c* from the normal *k* and the ray *h* deviated an amount corresponding with the angle of incidence *g, o, k* of the ray *g*.

A portion of the rays in sector *e, o, h* falls on the lower or emergent surface S'' at *o''*, as indicated by the sector *e, o'', h'*, and is refractively transmitted into the sector *f, o'', p* and the other rays are totally reflected, as indicated by the sector *q, o'', r*. The other portion of the rays in sector *e, o, h* falls on the surface S_1' of the other side of the prism in a sector indicated at *h, o''', s*, and are totally reflected as indicated by the sector *i, o''', s*. This light falls on the emergent surface S'' at *o''''* in sector *i, o'''', t'* for transmission to sector *j, o'''', u*.

As the surface directly underneath the luminaire is closest to the luminaire and receives the light at high angles of incidence, it is desirable to spread the light away from the nadir to reduce brightness of the street surface in this region.

If one were to select a slope for the incident surface S' of the prism **25** such that the ray *e* were normal to the emergent surface **26** or S'', light in ray *e* would be vertically downward and the two-sided prism would permit transmissioon of light down to nadir from both the right and the left. With such a prism the sector of light totally reflected by the surface S_1' would be narrower and have greater angles of incidence on the surface S'' and an angle of refraction for the ray *j* of about 18°. By making the sides S', S_1' steeper, the rays *e, f* may be made to slope toward the right and reduce illumination in the region of nadir. With a prism with such steeper sides the angle of ray *h* is raised and that of rays *i* and *j* is lowered. When the prism slopes are adjusted to an amount such that the slopes of rays *f* and *j* are the same, the least possible amount of light is emitted at or near the normal to the lower surface of the prism.

To determine the optimum slope angle (or apex angle of the prism, one may make assumptions of these values and find out where the limiting rays go, or may make the determination by the solution of trigonometric equations based on optical laws. In either case the result is the same; namely, an apex angle (to the nearest degree) of 82° for the prism, and a deviation from the vertical of 10° for both rays *f* and *j*—this based on an index of refraction of 1.50, that of the usual refracting media. While there is no split for prisms with apex angles less than 74° or greater than 96° to achieve suitable dimunition of light toward nadir the angle of the prisms should be between 79° and 86°. (See FIG. 12.)

Referring to FIG. 12*b* it can be seen how the lens of FIG. 12 was achieved by reasoning from the optical axiom that light ray paths are reversible. Considering that ray **50** is a light ray beneath a fluorescent lamp positioned above the lens structure generally designated **54**, the ray **50** goes straight up and enters the prism at surface S″ at the location *o″* and strikes the prism surface S′ at the interior of the prism for a total reflection within the prism and then strikes the prism surface S_1'. It is reflected internally for transmission in a slightly downward direction. Such a ray will enter the next prism in the row and will be lowered further until it will eventually be again emitted in a downward direction without ever striking the extended fluorescent lamp which is located above the arrangement of prisms.

A ray **56** which is directed upwardly straight to the surface S″ at *o''''* strikes prism surface S_1' internally for total reflection, then strikes prism surface S′ for transmission into air, again at an angle below the horizontal direction, that is slightly downward. Ray **56** will again be directed further downwardly when entering the adjacent prism and will be emitted in downward directions to the bottom surface S″ of the prismatic arrangement, without striking the fluorescent lamp positioned above the arrangement of prisms. Similar conditions exist for the ray striking the prisms at substantially vertical directions to those falling in-between as limited by the rays *f* and *j* which are shown at 10.8 degrees and 10.7 degrees, respectively.

Since all rays entering the prism surface S″ in directions between straight up and limiting directions *f* and *j* are eventually turned down without ever striking the lamp, this process was reversed in accordance with the present invention to provide a prismatic construction to prevent light rays from emanating from an elongated fluorescent lamp in directions between straight down and limiting direction of rays *f* and *j*. In actual application, therefore, the zone between zero degrees and approximately 10.5 degrees, as indicated by the limiting rays *f* and *j*, remain dark, producing the desired reduction in candle power straight down and evening out the uniformity of illumination of the street surface.

FIG. 11*b* indicates the overall action of the splitting prisms **25** and the depending louvers **30** as a control of light from the linearly extended fluorescent lamp. While a louver action is shown in FIG. 11, FIG. 11*b* indicates the combined action of the prisms and the depending louvers as they cooperate to prevent glare immediately below the refractor and at high angle longitudinal directions.

A fluorescent lamp **58** of approximately 6 feet in length may be used and located approximately 3 inches above the prismatic plate. The light rays which emanate from the lamp **58** are numbered consecutively from **1** to **9**. Each is indicated with a prime designation in the directions in which they are emitted on the outside of the refractor. For example, ray **9** is directed from a relatively remote spot of the lamp **58** and is indicated bent downwardly in the direction **9′** on the outside of the refractor. Rays **1**, **2** and **3** are emitted from the splitting prisms and high angles and they are bent so that rays **1′** and **2′** strike a prismatic louver **30** and are lowered in a direction to avoid high-angle brightness of the luminaire when viewed from distant observer locations on the street. Ray **3′** is shown as skimming just below the louver **30** and hence is not influenced thereby.

Ray **4** coming straight down from the lamp is refracted toward the right as shown by ray **4′**. Ray **5** from the right portion of the lamp is emitted at direction **5′**. Right next to it ray **6** jumps in emission to direction **6′**, being emitted at high angles to the left and brought down by the prismatic action of the louver, as shown.

Ray **7**, **8** and **9** coming from the right side of the lamp are transmitted in directions **7′**, **8′** and **9′** and ray **10** coming from a very far point from the right portion of the lamp constitutes, when emitted, the limiting ray **101**. There is a sudden jump in emitted ray direction from ray **5′** to ray **6′** due to the prismatic action of a splitting prism. It can thus be seen that no light is emitted in essentially straight down directions between days **5′** and **90′** as indicated in FIG. 11*b*.

While a splitting prism thus controls the light in substantially downward directions, it does permit emission of a considerable amount of light at high angles. Thus, in accordance with the invention, there is provided cooperating louvers **30** and **28** to eliminate light in a zone substantially up to 15° below the horizontal as indicated in the drawings (FIGS. 10, 11 and 11*b*). Rays **1′** and **6′** are brought down so that there is a zone of no emitted light from the horizontal to a position substantially 15° therebelow.

FIGS. 13*a* and 13*b* indicate the effect of the use of splitting prisms and louvers either singly or in combination, in accordance with the present invention, on the candle power distribution lengthwise of the lamp and the street. If there were no correction provided by the prismatic arrangement, the light distribution would be that of a linearly extended fluorescent lamp which is a completely diffuse distribution characterized by a circle **60** of the polar candle power distribution diagram of FIG. 13*a*.

The splitting prisms as indicated in FIGS. 11 and 11*b* do not affect the high angle light so that at high angles the distribution curve as shown at **62** is only slightly modified from that without any prismatic correction. The main action of the splitting prisms is to reduce the amounts of light sent straight down and instead to emphasize candle power at directions somewhere between 30 and 60° from nadir as is indicated on curve **62** in FIG. 13*a*.

In the FIG. 13*b* there is indicated the uncontrolled polar candle power distribution curve **64**. When the louvers **30** are added, a curve **66** is obtained which indicates that the louvers have no effect on the candle power distribution at low angles but do cut down candle power at high angles. The curve **66** indicates that the light output at high angles is reduced in favor of an increase in candle power again between approximately 30° and 60° from nadir.

When both effects of splitting prisms and louvers are considered in combination, it can be seen that the resultant curve **68** exceeds the bare lamp curve substantially in the ranges between approximately 30° to 60° at the expense of low-angle light which is reduced to supply good uniformity of illumination on the street and at the expense of high-angle light which is reduced to cut down glare at ordinary view of motorists and pedestrians. The resultant curve **68** corresponds to the distribution curve shown in FIG. 13 of the drawings.

FIG. 13 illustrates the type of photometric curve **68** to be obtained from a luminaire such as described. It will be noted that there is sharp cutoff angle at 75° from the nadir, so that light at or immediately below the horizontal is avoided, also that the dominant light output is spread away from the nadir.

Since it is obvious that the invention may be embodied in other forms and constructions within the scope of the claims, we wish it to be understood that the particular forms shown are but a few of these forms, and, various modifications and changes being possible, we do not otherwise limit ourselves in any way with respect thereto.

This application is a continuation-in-part of my copending application Serial No. 497,188, filed March 28, 1955, now abandoned.

What is claimed is:

1. An elongated refractor for controlling the vertical angles of downwardly transmitted light from an elongated horizontal light source, said refractor having an upper surface, a plurality of light splitting prisms arranged in side by side relationship on the upper surface of said refractor and extending transversely of the longitudinal axis thereof, each of said light splitting prisms having a pair of faces symmetrically disposed on either side of a vertical plane through the apex thereof, said faces of said light splitting prisms being disposed at such angles relative to the vertical and to the longitudinal axis of said refractor that all light, emitted toward said prisms in directions transverse thereto, and striking any one of said light splitting prisms at all angles between the horizontal and the vertical is transmitted between angles on either side of nadir and the horizontal, with the minimum possible light being transmitted vertically downward, and a series of spaced, downwardly extending elements of a depth to eclipse all light above substantially 15° below the horizontal, said elements extending transversely to the longitudinal axis of said refractor and including vertically spaced horizontal refracting ribs, the faces of said refracting ribs being disposed at such angles relative to the horizontal that the light which is eclipsed by said elements is depressed to substantially 15° below the horizontal.

2. A refractor as claimed in claim 1, wherein the refractor has an index of refraction of approximately 1.50 and the apex angle of the light splitting prisms is substantially 82°.

3. A refractor as claimed in claim 1, wherein the horizontal refracting ribs are of V-shaped cross section.

4. In combination with an elongated light source, a light splitting prism suspended below said light source and disposed transversely thereto, said prism being composed of a medium with a known index of refraction and comprising an emergent surface and two incident surfaces, said incident surfaces being symmetrically disposed on opposite sides of a median plane normal to said emergent surface said incident surfaces being disposed and at such angles to said median plane that the twice refracted light entering one incident surface at the maximum angle of incidence emerges from the emergent surface at the same side and with substantially the same angular value as does the emergent ray corresponding with an incident ray normal to the median plane, refractively transmitted by said incident surface, then internally reflected by the other incident surface and refractively transmitted by the emergent surface.

5. In the combination of claim 4, wherein the index of refraction of said light spreading prism is about 1.50 and the apex angle of the prism is substantially 82°.

6. An elongated refractor for controlling the vertical angles of longitudinally and downwardly transmitted light from an elongated horizontal light source, said refractor having an upper surface, a plurality of substantially identical light splitting prisms arranged in side-by-side relationship on the upper surface of said refractor and extending transversely of the longitudinal axis thereof, each of said light splitting prisms having a pair of light incident surfaces symmetrically disposed on either side of a vertical plane through the apex thereof, said light incident surfaces of said light splitting prisms being disposed at such angles relative to the vertical and to the longitudinal axis of said refractor that all light emitted toward said prisms in directions transverse thereto and striking any one of said light splitting prisms at all angles between the horizontal and the vertical is transmitted between angles on either side of nadir and the horizontal with the minimum possible light being transmitted vertically downward, the total effect of all of said prisms being to create a glare free light zone immediately below said refractor.

7. A refractor as claimed in claim 6, wherein the apex angle of the light splitting prisms is substantially between 79° and 86° for a prismatic medium with an index of refraction of 1.50.

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