

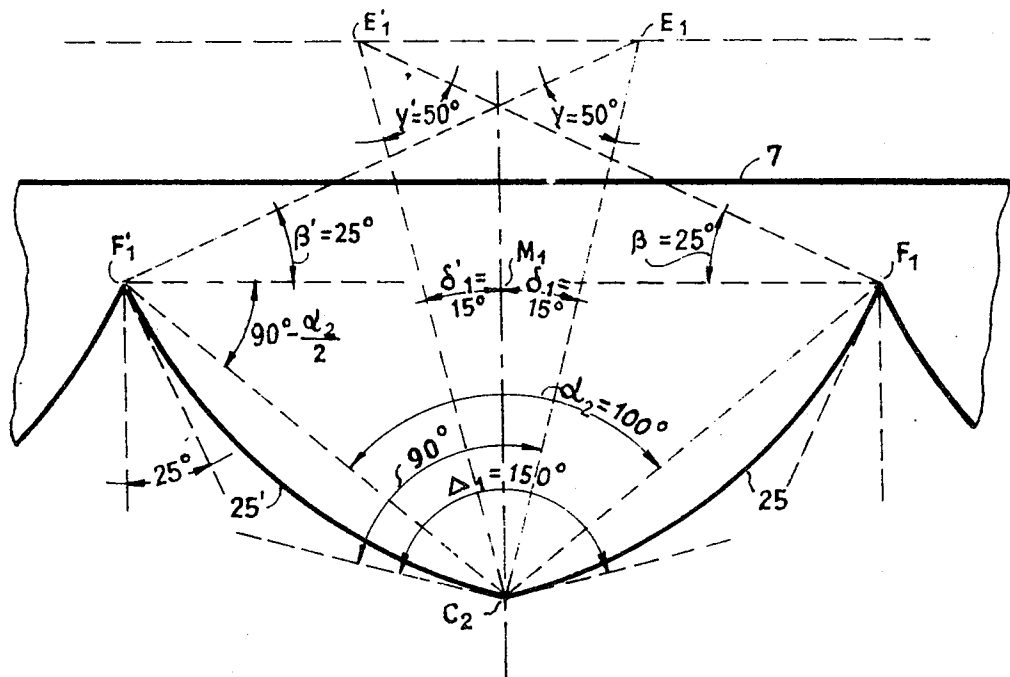
[54] ZERO LUMINANCE LIGHTING PANEL
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[51] Int. Cl.F21v 5/04
[58] Field of Search240/106, 106.1

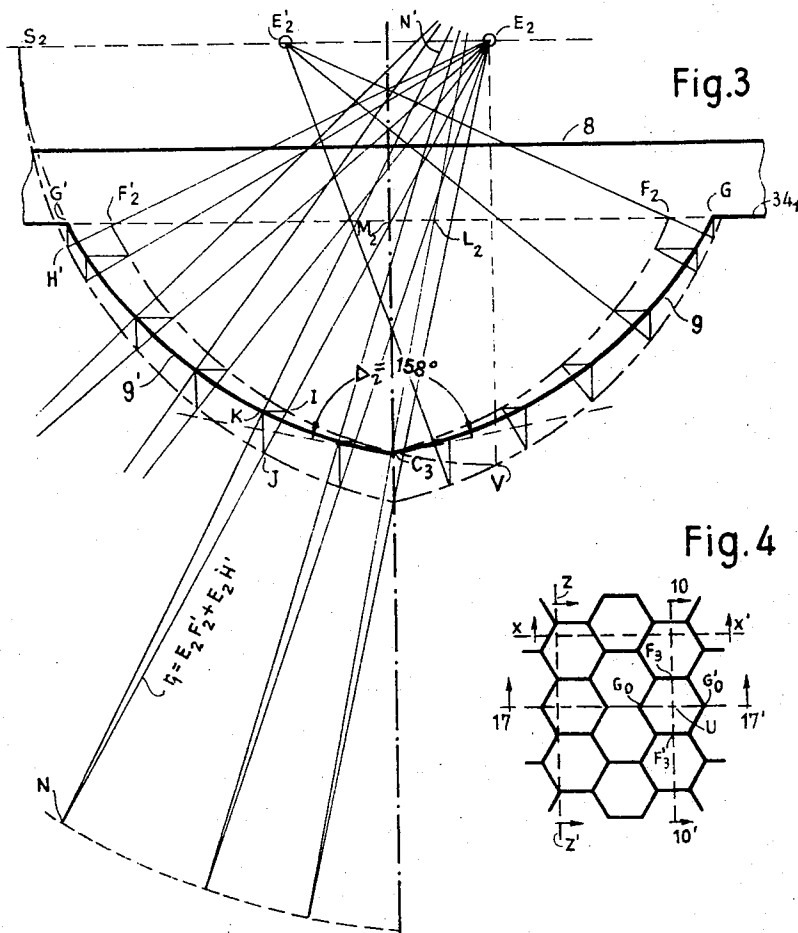
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[57] ABSTRACT
A transparent prismatic lighting panel, having on its exterior surface a multiplicity of pyramids or cones having curved lateral surfaces. The curvature being such that substantially all of the light rays refracted through these surfaces form, with the axis of the pyramid or cone, angles which do not fall between 60° and 90°. As a result of which the panel gives rise to substantially zero luminance.

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10 Claims, 8 Drawing Figures





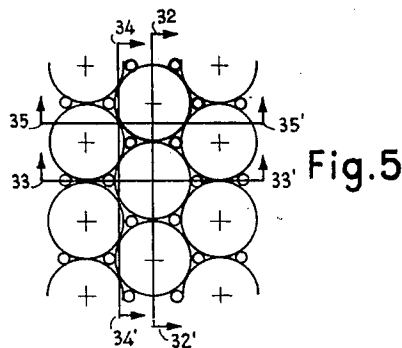


Fig. 5

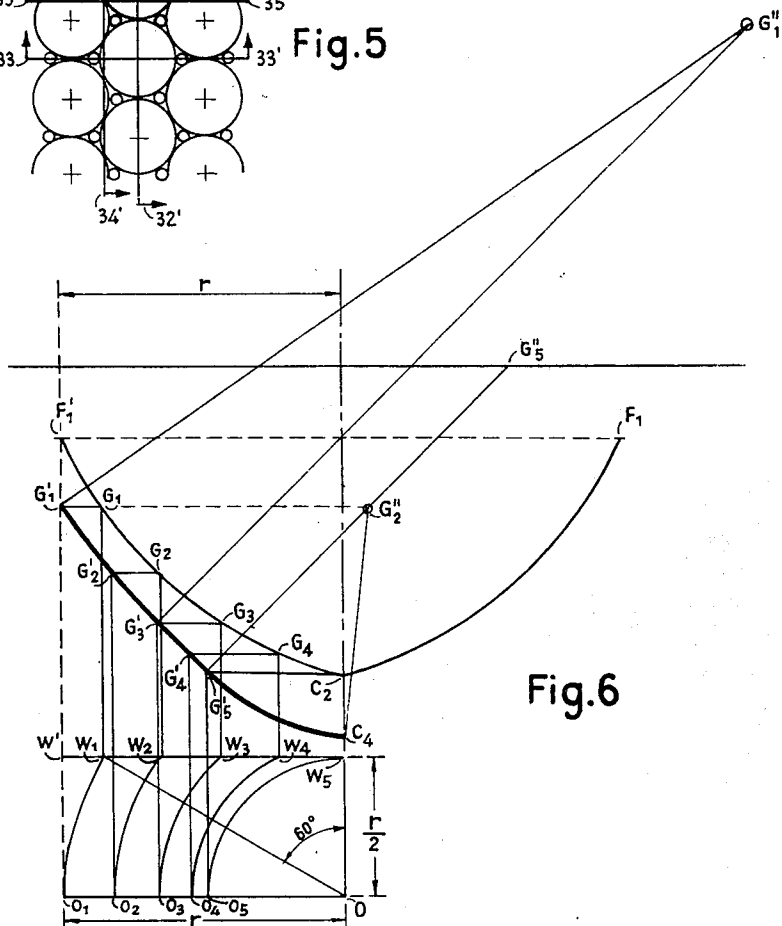


Fig. 6

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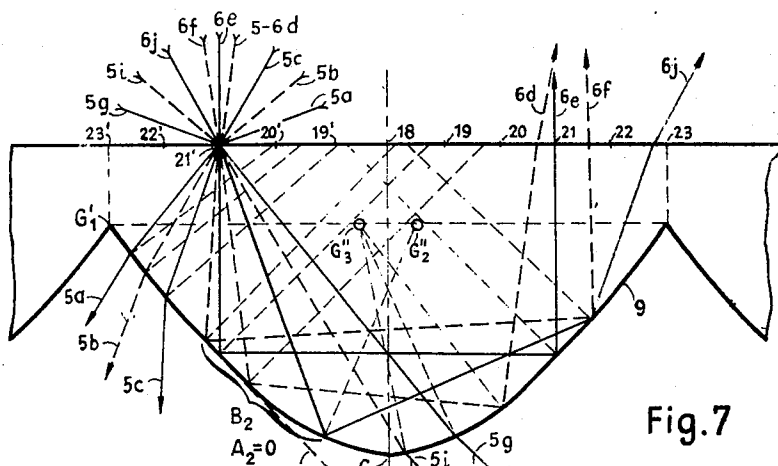


Fig. 7

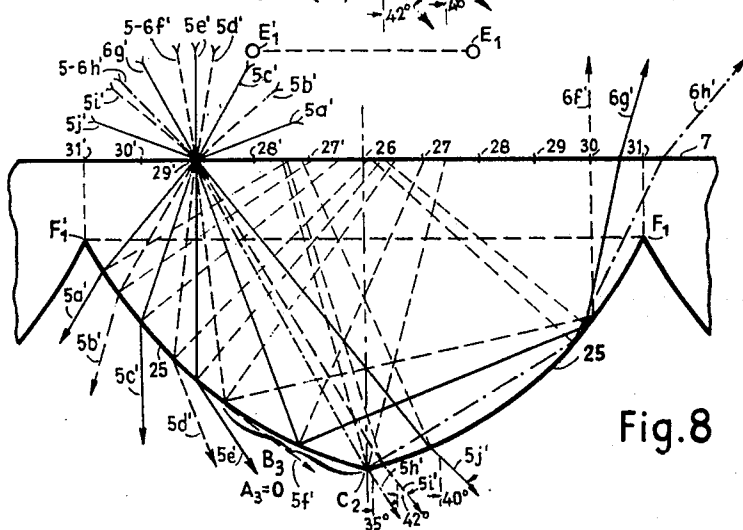


Fig. 8

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ZERO LUMINANCE LIGHTING PANEL

This invention deals with lighting panels, more particularly those having refracting prismatic elements, for use in light fittings using fluorescent lighting sources.

Two conditions which a lighting panel must fulfil are that it must have a high lighting efficiency permitting the passage of the greatest possible number of light rays and that it must have the lowest possible luminance insofar as of the number of rays passing through the panel possible number do so forming with the vertical, at angles between 60° and 90° so as to avoid a glare effect.

Of the three types of panels generally used in lighting fixtures using a fluorescent source, opal type panels in general give a low lighting output ratio and excessive glare; prismatic type panels, fitted with transparent prisms or pyramids have a good lighting output ratio but suffer from the fact that they also have a very high luminance; and lastly, louver type panels, while having no, or very little luminance, have a very low lighting efficiency.

In view of the foregoing, it is therefore an object of the present invention to overcome the deficiencies and shortcomings found in prior art panels, and to provide a new and improved lighting panel.

Another object of the invention is to provide a highly efficient optical lighting panel, that has a high output ratio in comparison with other lighting panels. Another object of the invention is to provide a transparent prismatic lighting panel of substantially zero luminance.

The achievement of these objects and the general advantages of the present invention will become apparent from the following detailed description and the accompanying drawings.

The above mentioned objects are achieved by means of a transparent plastic lighting panel provided with a plurality of refracting prismatic protrusions on its exterior surface. These protrusions are in the form of pyramids or cones and the lateral surfaces of these cones and pyramids are of such curvature that substantially none of the light rays are refracted through these pyramids and cones at angles between 60° and 90° with respect to the cone or pyramid axis. This results in a substantially zero luminance lighting panel.

With reference to the attached drawings:

FIG. 1 is a schematic illustration of a prism of a prior art lighting panel showing the trajectory of an eccentric beam of light.

FIG. 2 is a schematic representation of the profile of a curvilinear pyramid of a panel of the present invention taken along the line 10—10' of FIG. 4, showing the angles which determine said profile.

FIG. 3 is a schematic illustration of the profile of the same curvilinear pyramid of FIG. 2, considered along the line 17—17' of FIG. 4, showing the corresponding angles.

FIG. 4 is a fragmentary top plan view of a lighting panel of the invention with hexagonal curvilinear pyramids.

FIG. 5 is a fragmentary top plan view similar to that shown in FIG. 4, but showing a modification of the invention in which the panel is provided with curvilinear cones.

FIG. 6 is a diagrammatical view of the profiles of a cone of the panel along lines 32—32' and 35—35' of FIG. 5.

FIG. 7, is a schematic illustration of the profile of a curvilinear cone of the panel along line 32—32' of FIG. 5, showing the trajectory of an eccentric beam of light.

FIG. 8 is a schematic illustration of the profile of a curvilinear pyramid of the panel along line 10—10' of FIG. 4, showing the trajectory of an eccentric beam of light.

In general the invention comprises a prismatic lighting panel suitable for use in recessed, flush, pendant, or other known lighting fixtures. These panels are provided with prismatic elements designed with a particular curvature which produces a distribution of light (depending on the angle in the vertex of these prismatic elements) such; that a very low luminance (approaching zero) is achieved.

In FIG. 1 it can be seen that with prior art prisms having flat lateral surfaces three types of rays issue from the panel. First, there are the useful rays. These are the rays which form an angle of under 60° with respect to a straight line parallel to the axis of the prism. The second rays issue at angles of between 60° and 90° and therefore produce glare, and the third rays issue through the upper part of the panel resulting in loss.

Since the source of light will normally be one or more fluorescent tubes fitted in a metal chassis having a white baked enamel reflector, the panel which closes the fitting and contains the prismatic elements receives rays of light from all directions and on all of the flat surface exposed to the fluorescent tubes. So as to more easily understand the optical behavior of the light rays striking the upper part of the prismatic elements, let us take as an example a prism 1 having a vertex angle of $\alpha_1=100^\circ$. Cutting such a prism through an axial plane we have the section drawing in which we mark points 11, 12, 13, 14, 15, 16, 12', 13', 14', 15', 16', distributed regularly in the upper plane 24 represented by the line ST.

As the most significant example of a radiation diffused in the interior of the prism, the incident rays at point 15' will be considered. It should be apparent that a symmetric radiation is situated at point 15 and both behave identically.

Straight lines of particular interest are C_1D' and C_1D which form an angle of $\theta=42^\circ$ with the normals C_1R_1 , $C_1R'_1$ respectively of the sides C_1Y and C_1Y' ; $\theta=42^\circ$ being the value of the critical angle of the material used in the panels, which in this example is polymethylmethacrylate.

The straight lines C_1D and C_1D' cut the line ST, which represents the upper plane 24 of the panel, at the points D and D' situated between the points 11, 12 and 11, 12'. The radiations which issue from D and D' or any point between these points do not undergo any internal reflection as they have an angle of incidence in the face of the pyramid less than the critical angle and are thus refracted. The radiations issuing from the surface of the panel furthest from the axis of the prism produce rays of light which strike the faces of the pyramid at incidence angles greater than that of the critical angle. This means that they suffer total internal reflection instead of being refracted. Thus, in the example under consideration there is no internal reflection of the radiations which issue from points between D and D', total internal reflection taking place at 16 and 16'. Radiation issuing from point 15' has been selected

because said radiation illustrates clearly the behavior of rays 2a, 2b, 2c, 2d, 2e, 2f, 2g, which are usefully refracted with issuing angles of less than 60°, of the rays 4g, 4i, which produce glaring issuing with angles of between 60° and 90°, of the ray 4j which on entering the immediate prism and others not represented in the drawing, is refracted and reflected on incidence with these prisms, finally to pass through one of these issuing with an angle of 60°, that is, on the border between the rays which produce glare and those which don't; and finally of the rays 3e and 3h which suffer total internal reflection and pass through the upper part of the panel with the consequent loss of lighting.

A₁ marks the zone which produces glaring rays and B₁ marks the zone which produces rays that are lost. The remaining refracted rays are useful. It should be noted that the ray 2-3e which corresponds to the critical angle is subdivided into the rays 2e and 3e, that is, it corresponds to the border of the zone B₁.

Referring now to FIGS. 2, 3, and 4, the invention consists of a prismatic type transparent plastic panel in which refracting prismatic elements have the form of pyramids with square or hexagonal bases. The lateral faces of the elements have curved or more exactly cylindrical surfaces. These are curved in such a way that the profiles of the sections of these pyramids determined by axial planes normal to the lateral faces of the pyramids, are determined by two equal arcs of circumference which meet at in the vertex of the pyramid.

FIG. 2 shows the geometric construction of an axial section of a curvilinear according to the instant invention and is taken from line 10-10' of FIG. 4. The figure shows straight line 7 corresponding to the upper plane of the panel; the centers E₁ and E'₁ of the arcs of circumference 25' and the angle Δ₁ of 150° between the tangents at the vertex C₂ of the section, and the geometric relationship which ties together the angles α, β, δ, γ. The angles α and β constitute the basic elements from which the following formulas

$$\gamma = 180^\circ - 2(90^\circ - \alpha/2 + \beta) = \alpha - 2\beta,$$

$$\delta = 180^\circ - (90^\circ + \beta + \gamma) = 90^\circ - \alpha + \beta$$

obtain the values of δ and γ which fix the position of the centers of the arcs and their corresponding curvatures.

FIG. 3 represents the geometric construction of a section of the same curvilinear pyramid but taken from line 17-17' of FIG. 4. The straight line 8 of FIG. 3 represents the upper part of the panel. FIG. 4 also shows that the distances UF'₃ and UG'₀ are directly related because UF'₃ = UG'₀ X cos 30° given that the figure is a hexagon. Therefore the arcs 9 and 9' of FIG. 3 are portions of two ellipses with equal semi-axis. The lesser semi-axis E₂V has the same dimensions as the radii E₂F'₂ and E'₂F₂ of the lesser arcs of circumference of FIG. 3. These are also equal to the arcs of circumference 25 of FIG. 2. The greater semi-axis E₂S₂ of the ellipse is the result of the distances M₁F'₁ and M₁F₁ of FIG. 2 having become the distances M₂G' and M₂G of FIG. 3 according to the relationships:

$$M_2G' = M_1F'_1 / \cos 30^\circ$$

and

$$M_2G = M_1F_1 / \cos 30^\circ$$

These data are sufficient, by means of a well known geometrical construction, to draw the segments of the ellipses, that is, from point G'' the triangle F₂' G' H' is drawn and point H' is found which in turn fixes the radius E₂H' which corresponds to the dimension of the greater semi-axis of the ellipse. The triangle KJL is repeated as often as necessary for the construction of the segments of the ellipse.

With these two circumferences of radii E₂F₂' and E₂H' and with the circumference drawn from the sum of these radii, that is $r_1 = E_2F_2' + E_2H'$, are obtained all the elements for drawing, according to well-known geometric methods, the portion of the ellipses of interest. Also the normals at each point of the ellipse, as for example NN' and C₃L₂, which are necessary for finding the angles of refraction and reflection of the rays of incidence in these segments of the ellipse can be drawn.

Referring now to FIGS. 5 and 6, a modified form of the invention is described in which the prismatic refracting elements of the panel take the form having cones of circular bases and in which the generatrix is a non-straight line. The generatrix in general is a curved line of such curvature that the profiles of the sections of these cones determined by planes parallel to the axes of the cones and normal to the bases are determined by two arcs of circumference which are similar to those described in reference to FIG. 2 in the case of prismatic refracting elements in the form of curvilinear pyramids.

FIG. 5 represents said variation of the panel which is of zero luminance and in which the prisms are formed by cones instead of pyramids, the generatrix being the profile G₁'C₄ of FIG. 6. Such a panel possesses other smaller cones which serve to fill the spaces between the principal cones, as shown in FIG. 5, in such a way that there is practically no space without prisms. The shape of these smaller cones is similar to that of the main cones, the diameter at the base of said smaller cones being 0.155 of the diameter of the main cones.

FIG. 6 is a geometric representation of the generation of the curvilinear cone which is a solid of revolution, the axial section showing the curve G'₁, G'₂, G'₃, G'₄, G'₅ and C₄ as the generatrix. The lower half of FIG. 6 below the straight line W'W₅ corresponds to the view of the horizontal sections through G'₁G₁, G'₂G₂, G'₃G₃, G'₄G₄ and G'₅C₂ while the upper half above the straight line W'W₅ corresponds to the view through vertical sections by O₁O and W'W₅ of the figure.

To obtain the generatrix curve of the axial section of the curvilinear cone use is made of the curve F'₁C₂ of FIG. 2, which represents the axial section of the curvilinear pyramid, having a zero luminance value. The curve F'₁C₂ of FIG. 2 corresponds to a section of the cone at half the distance of the value r of the radius of the base of the cone.

It is sufficient by following the drawing of FIG. 6 to understand, how, starting from the curve F'₁C₂ the curve G'₁C₄ is obtained. The curve G'₁C₄ is the generatrix curve of the curvilinear cone in its axial section.

In FIG. 6 we can see that starting from the points G₁, G₂, G₃, G₄ and C₂ of the profile F'₁C₂ we obtain the

points G'_1, G'_2, G'_3, G'_4 and G'_5 of the profile G'_1C_4 thanks to the verticals $G_1W_1, G_2W_2, G_3W_3, G_4W_4, C_2W_5$, which with the arcs $W_1O_1, W_2O_2, W_3O_3, W_4O_4, W_5O_5$, mark the points O_1, O_2, O_3, O_4, O_5 . These latter points determine the verticals $O_1G'_1, O_2G'_2, O_3G'_3, O_4G'_4, O_5G'_5$, which indicate the required points $G'_1, G'_2, G'_3, G'_4, G'_5$ on the horizontal straight lines drawn from G_1, G_2, G_3, G_4, C_2 .

The generatrix curve can be assimilated into a certain curve by first drawing an arc of circumference $G'_1G'_3$ with its center at the meeting point of the straight lines $G'_1G'_1$ and $G'_3G'_1$. The curve then has a straight part G'_3, G'_4, G'_5 , tangent to the first part and ends with an arc of circumference G'_5C_4 with its center at G'_2 .

The curvilinear cone of the instant invention has a zero luminance. This is proved by the graphical calculations corresponding to sections in any axial or non-axial direction of FIG. 5. On the other hand in the case of the curvilinear pyramid, if cuts are made in FIG. 4 in sections parallel to 17—17', such as X—X', there is some small amount of luminance in the flat parts marked 34, in FIG. 3.

FIG. 7 represents a sectional view of a curvilinear cone having a profile drawn according to the lines G'_1C_4 of FIG. 6 and corresponding to a cut in the panel according to the line 32—32' of FIG. 5. Radiations corresponding to point 21' and the normals to the surface at the points of incidence of the rays are all shown. It can be seen that the rays 6d, 6e, 6f, and 6j, fall within the zone B_2 of lost rays. The useful rays 5a, 5b, 5c, 5d, 5i, and 5g are refracted with issuing angles lower than 60° . There is no zone A_2 in this embodiment as there are no glare rays refracted falling between 60° and 90° . Therefore, this section of the curvilinear cone has zero luminance; The same thing happens at any point of ray emission from the surface of the panel. Except for zone B_2 , there are only useful zones of radiation at the points situated between the axis of the prism and the limit points 23 and 23'. The same can be shown to be true when the section of the curvilinear cone is made through non-axial planes represented in FIG. 5 by the straight lines 34—34' and 35—35'.

The same reasoning and the same result can be seen in FIG. 8 corresponding to FIG. 2, previously described. This corresponds to the section according to the cut 10—10 of FIG. 4 of a curvilinear pyramid and the point of situation of the radiation is marked 29'. In this case the beams 6f', 6g' and 6h' are within zone B_3 of lost beams, while 5a', 5b', 5c', 5d', 5e', 5f', 5h', 5i', and 5j', are useful beams with an issuing angle of less than 60° . As above there are no glare beams with an issuing angle of between 60° and 90° that is to say, that zone A_3 has a nil value. It is to be noted here also that a similar situation is produced in the beams situated between the axis of the prism and the limit points 31 and 31'.

It can be said that in all the axial sections of the described curvilinear pyramid, which in FIG. 4 pass through the axis marked by point U and corresponding to the straight lines $G_0—G'_0$ and $F_3—F'_3$, as well as the non-axial sections such as Z—Z' and X—X' of FIG. 4, the absence of glare rays is almost total and a very low luminance panel has been achieved.

Regarding the output ratio of the zero luminance prismatic panel, the efficiency of the prismatic panels is far higher than that of opal or louver panels. However, the louver panels have a very low luminance, a quality not possessed by opal panels nor normal prismatic panels. The output ratio of all lighting fixtures with fluorescent light sources depends to a high degree on the efficiency of the baked enamel reflector which forms the upper part of the fixture. The output ratio of fixtures using louver panels, in the case of recessed fixtures, where there is a greater proportion of strayed rays, is below 30 percent; in fixtures using opal panels it is about 50 percent and in fixtures with prismatic panels, it is about 60 percent. The losses of the normal prismatic panel and the zero luminance prismatic panel will now be compared. Developing the graphic calculations at the several points 11, 12, 13, 14, 15, 16, 12', 13', 14', 15', 16', of FIG. 1 and looking for the Zone Flux constants according to the angle middle zone of the rays which cross inside of the panel. The average for four sections is 0.175 for the Glare Zones A and the average is 0.433 for Zones B of strayed rays. Therefore the total average for the Zone Flux Constant of non-useful rays A + B is 0.608. Developing similar graphic calculations for points 18, 19, 20, 21, 22, 23, 19', 20', 21', 22', 23', of FIG. 7 and points 26, 27, 28, 29, 30, 31, 27', 28', 29', 30', 31' of FIG. 8, I obtain an average total of 0.558 and of 0.560 for zones A + B in the case of four cuts, values which are below those of the normal prismatic panel. It is known that the Zone Flux Constants of the outside of the panel, multiplied by the corresponding candle power give us the value of the fluxes. In the case of the zero luminance panel, having less useless flux out of the total flux emitted by the panel, the result is that the panel is not only of practically zero luminance, but also has the highest output ratio.

What is claimed is:

1. A transparent prismatic lighting panel comprising in its outer surface a plurality of pointed optical prismatic refracting elements having respective axes of symmetry which pass through their vertices, the axial sections of said prismatic elements taken in planes normal to their lateral surfaces being limited by symmetrical curved lines with respect to the said axis of symmetry, the convexity of said curved lines being towards the outside of the panel, said optical prismatic refracting elements consist of pyramids the lateral faces of which are equal cylindrical surfaces and the curvature of the generatrix of said cylindrical surfaces is such that the sections of each pyramid taken according to axial planes normal to two opposite faces of the said lateral faces are limited by two arcs of circumference symmetrical with respect to said axis of symmetry of the pyramid, the center of said arcs of circumference being situated above the base of the pyramid and symmetrically on opposite sides of said axis of symmetry of the pyramid.

2. A transparent prismatic lighting panel according to claim 1 in which said pyramids have hexagonal bases.

3. A transparent prismatic lighting panel which has on its exterior surface a plurality of optical refracting pyramids, each one of which has an axis of symmetry which passes through its vertex and the lateral faces of

which are equal cylindrical surfaces and the sections of each of said pyramids taken in axial planes normal to two of said lateral faces are limited by two arcs of circumference symmetrical with reference to said axis of symmetry of the pyramid, the centers of said arcs of circumference being situated above the base of the pyramid and symmetrically on opposite sides of said axis of symmetry of the pyramid at the points determined by the formulae:

$$\gamma = 180^\circ - 2(90^\circ - \alpha/2 + \beta) = \alpha - 2\beta; \quad \text{and}$$

$$\delta = 180^\circ - (90^\circ + \beta + \gamma) = 90^\circ - \alpha + \beta$$

where:

α is the angle in the vertex of the section of the pyramid between the chords of the arcs of circumference;

β is the angle formed with the base of the pyramid by a straight line normal to a tangent of one of said arcs of circumference at the point at which the arc cuts the base of the pyramid;

γ is the angle covered by each of the said arcs of circumference; and

δ is the angle which, with the said axis of symmetry of the pyramid, forms the extreme radius of each of said arcs of circumference which passes through the vertex of the pyramid.

4. A transparent prismatic lighting panel according to claim 3 wherein the value of angle α is essentially 100° and the value of angle β is essentially 25° .

5. A transparent prismatic lighting panel according to claim 3 in which said pyramids have hexagonal bases.

6. A transparent lighting panel comprising in its outer surface a plurality of pointed optical prismatic refracting elements having respective axes of symmetry which pass through their vertices, the axial sections of said prismatic elements taken in planes normal to their lateral surfaces being limited by symmetrical curved lines with respect to the said axis of symmetry, the convexity of said curved lines being towards the outside of the panel, said optical prismatic refracting elements consisting of cones having circular bases, the generatrix of said cones being a curved line of such curvature that the sections of each of said optical cones taken through planes parallel to said axis of symmetry and normal to the base of said cone at the median point of radius are limited by arcs of circumferences symmetrical with respect to a straight line normal to said base at the median point of said radius, the centers of said arcs of circumference being situated above the base of said cone and symmetrically on opposite sides of said straight line.

7. A transparent prismatic light panel according to claim 6 comprising, in its outer surface, a plurality of optical cones similar to, but smaller than, said conical refracting cones, substantially filling the spaces between the bases of said larger optical refracting cones.

8. A transparent prismatic lighting panel comprising, in its outer surface, a plurality of circular based optical refracting cones, each cone having an axis of symmetry which passes through its vertex, the generatrix of said cone being a curved line and sections of each one of said optical cones taken through planes parallel to said axis of symmetry and normal to the base of said cone at the median point of a radius are limited by two arcs of circumference symmetrical with respect to a straight line normal to said base at the median point of said radius, the centers of said arcs of circumference being situated above the base of said cone and symmetrically situated on opposite sides of said straight line at points determined by the following formulae:

$$\gamma = 180^\circ - 2(90^\circ - \alpha/2 + \beta) = \alpha - 2\beta; \quad \text{and}$$

$$\delta = 180^\circ - (90^\circ + \beta + \gamma) = 90^\circ - \alpha + \beta$$

where:

α is the angle in the vertex of the section of the pyramid between the chords of the arcs of circumference;

β is the angle formed with the base of the pyramid by a straight line normal to a tangent of one of said arcs of circumference at the point at which the arc cuts the base of the pyramid;

γ is the angle covered by each of the said arcs of circumference; and

δ is the angle which, with the said axis of symmetry of the pyramid, forms the extreme radius of each of said arcs of circumference which passes through the vertex of the pyramid.

9. A transparent prismatic lighting panel according to claim 8 wherein the value of angle α is essentially 100° and the value of angle β is essentially 25° .

10. A transparent prismatic lighting panel according to claim 8 in which the profiles of the axial sections of each of the said cones are limited by two lines symmetrical with respect to the axis of symmetry of the cone, each of which comprises a first arc of circumference, the center of which is situated at the other side of said axis of symmetry and above the plane of the base of the cone; a segment of straight line tangential to the first arc of circumference, and a second arc of circumference the center of which is situated at the other side of the axis of symmetry and on the plane of the base of said cone.

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