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Jones

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[54] **LIGHTING PANEL**

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[52] **U.S. Cl.** **240/106**
[51] **Int. Cl.** **F21v 5/02**
[58] **Field of Search** .... 240/106 R

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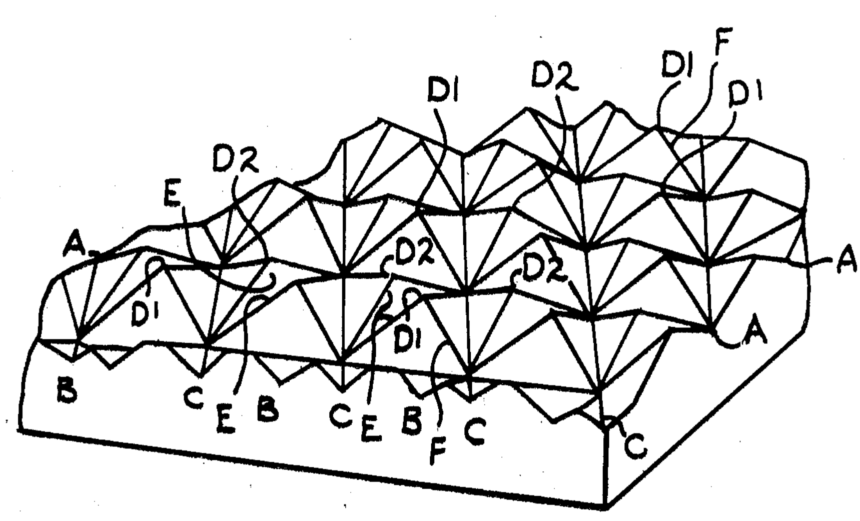
[57] **ABSTRACT**

A lighting panel for use in overhead lighting fixtures and the like which may readily be fabricated in plastic sheet by extrusion-embossing techniques and which minimizes veiling reflections. The panel contains a continuous pattern of triangular projections, each having three mutually substantially perpendicular surfaces projecting upward for disposition toward the light source. The base lines of the mutually perpendicular surfaces are co-planar and the pattern of projections is such that the base lines of all projections on a panel form continuous straight lines directed in three specific directions. This allows the fabrication of a relatively inexpensive engraved roller for embossing the pattern on a plastic sheet and results in a light panel which minimizes veiling reflections from the illuminated matter. The panel in accordance with the present invention provides a radial distribution of light with high lighting efficiency and with the maximum light in the area which is 30° to 60° from the vertical.

13 Claims, 7 Drawing Figures



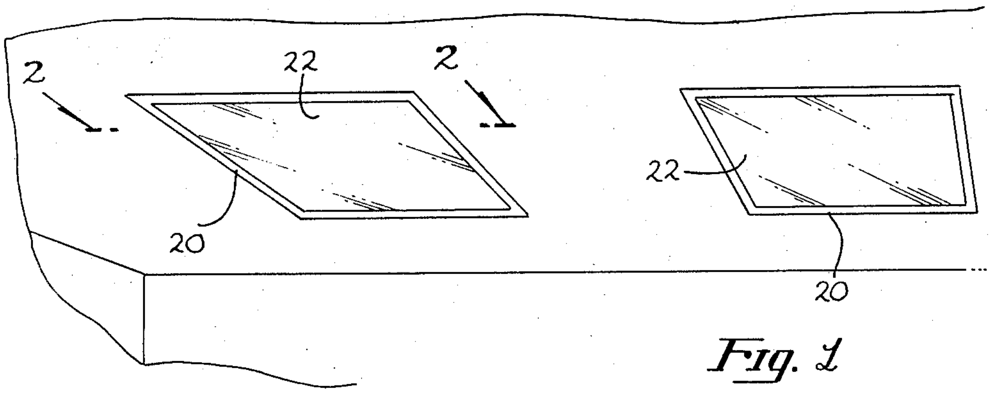


Fig. 1

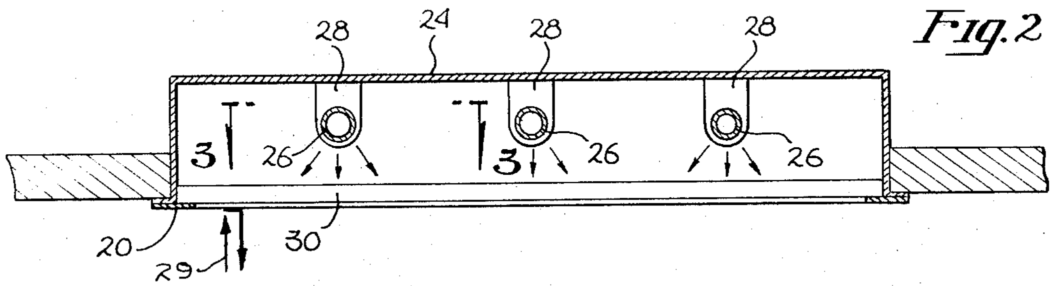


Fig. 2

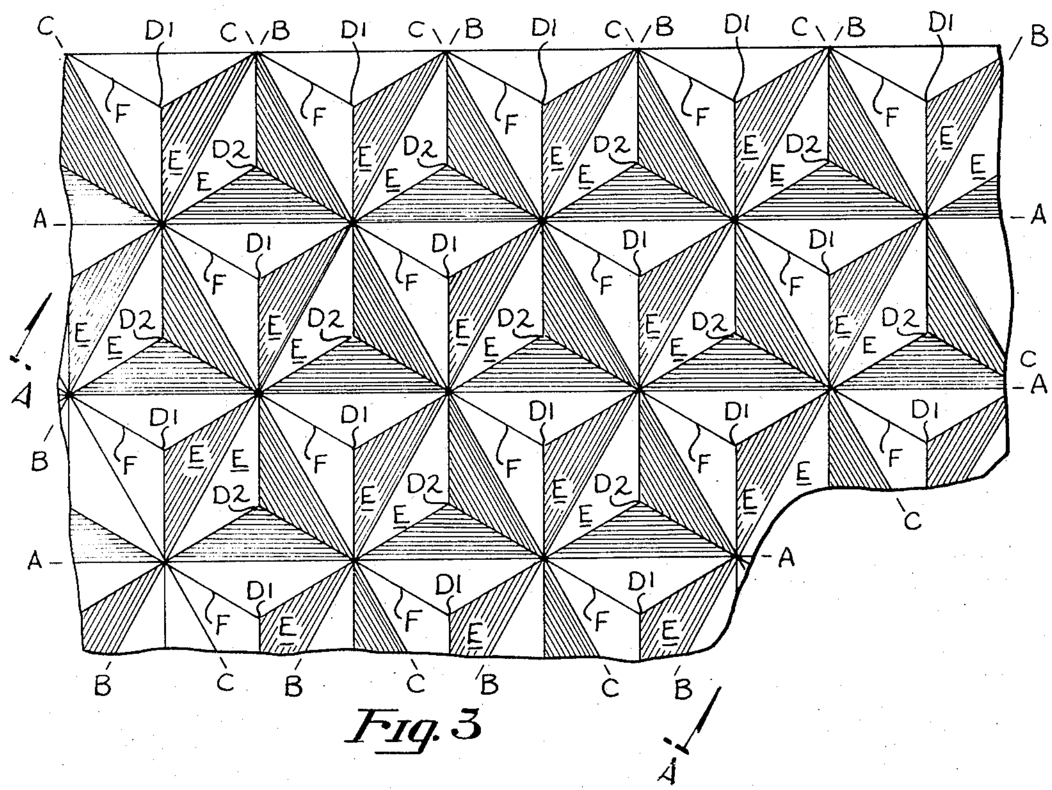
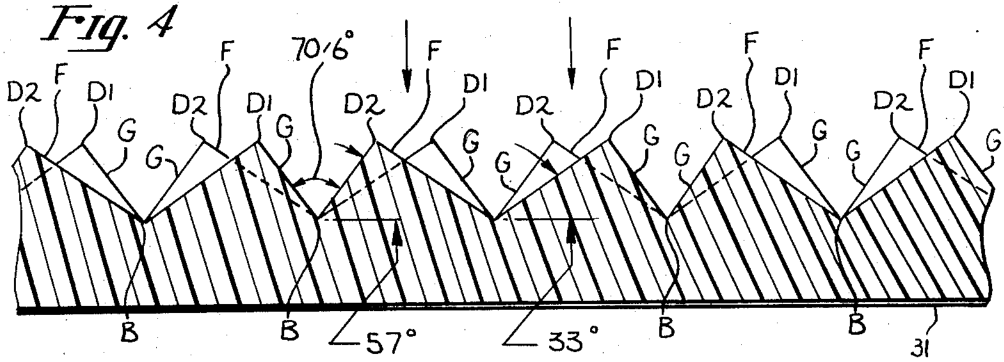


Fig. 3

Fig. 4



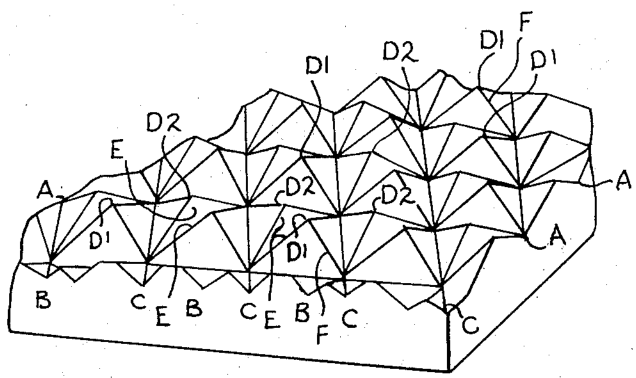


Fig. 5

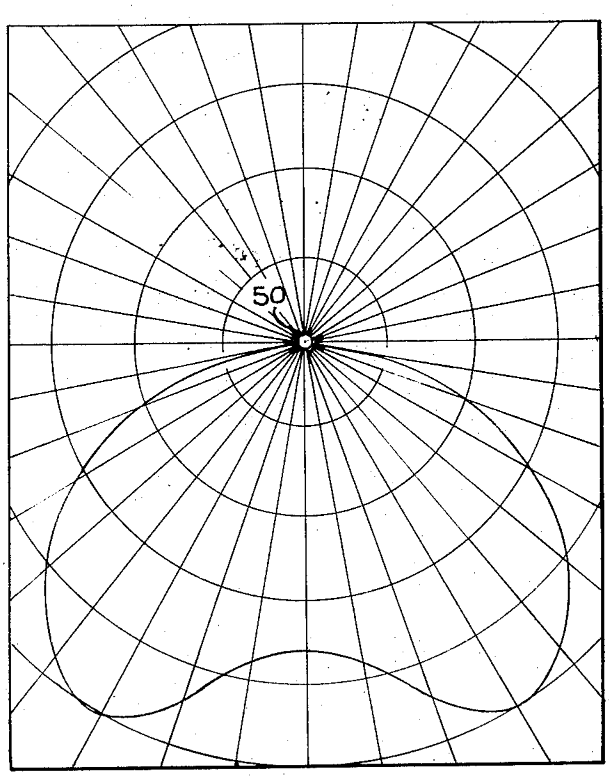
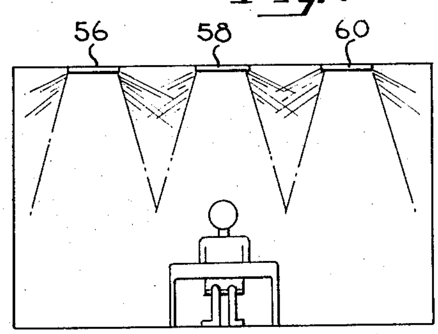


Fig. 6

Fig. 7



LIGHTING PANEL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of lighting panels.

2. Disclosure Document Program

This application for patent is based on a disclosure filed on July 1, 1971, as Disclosure Document No. 005990, under the Disclosure Document Program.

3. Prior Art

It is commonly recognized that an artificial lighting system should provide not only light of the proper intensity but also light of the proper characteristics to minimize glare and to maximize contrast, particularly in written or printed matter. Thus, modern lighting systems are generally comprised of a plurality of lighting fixtures, usually fluorescent, distributed over the ceiling of a room and having lighting panels (generally plastic panels) over the fluorescent fixtures to redirect the light in an attempt to achieve the desired result.

If printed matter is illuminated with light originating from a light source above and slightly forward of the reader, a considerable amount of the light may be directly reflected from the surface of the printed matter into the eyes of the viewer. In such a case, the light will tend to be reflected both by the dark printing itself and by the background so that the printing no longer appears black or dark, but instead approaches the lighter color of the background. Thus, the normal contrast in the printed matter is lost, and in the extreme the printed matter may be totally unreadable. In any event, these veiling reflections tend to reduce the contrast and make reading more difficult and uncomfortable. Of course, the effect is worse on glossy surfaces and with particularly intense lights, but control of the light intensity and selection of the surface characteristic for the printed matter will not totally eliminate the effect.

If printed matter is illuminated from the side, or from an area considerably forward of the reader, the direct reflections from the surface of the printed matter will not be directed upward for the eyes of the reader, but instead will be reflected at a lower angle and, therefore, will not affect the appearance of the matter being viewed. However, some of this light which is incident upon the surface of the printed matter will be redirected upward in a diffuse pattern in accordance with the color of the surface. Consequently, a white sheet of paper will clearly appear white, whereas the black print thereon will appear in its true color. Thus, there are no veiling reflections and a very high degree of contract is obtained. Consequently, lighting from the side, rear and/or considerably in front of a reader is highly desirable, whereas lighting from a point slightly forward of the reader is undesirable. Of course, the particular position for lighting which is most undesirable for illumination of a task depends upon the orientation or angular position of the task, but, in general, may be usually characterized as above and slightly forward of the reader. For minimal veiling reflections, it is highly desirable to have the light projected as a conical annulus in which the light is directed at **30°** to **60°** from the vertical in all radial directions.

Some patterns of prismatic lenses are known to the prior art which are intended to reduce veiling reflections. These patterns generally are of either of two types. The first type of pattern is a longitudinal pattern, that is, a pattern of longitudinal raised areas generally of uniform cross-section and repetitive cross the width of the panel. Such patterns can be produced on lighting panels by extrusion techniques. By properly choosing the geometry of the raised areas, redirection of the light is obtained. Since lighting panels are generally fabricated of thermo-plastic materials, such as, by way of example, acrylic, rolls for embossing such a pattern in a sheet of plastic may easily be fabricated, and inexpensive lighting panels produced therefrom. Some attempts have been made to reduce veiling reflections in such extruded panels, as for example, by combining the panels with a louver system or by painting opaque areas in the extruded panel to block the path of vertical light. However, the opaque areas reduce the amount of light passing therethrough and the panel thereby reducing the light efficiency of the panel and such panels deflect light only to either side and not in the fore and aft direction.

The second type of pattern which has been utilized in the prior art as an attempt to reduce veiling reflections is a two-dimensional pattern, that is, a pattern of depressions which varies both across the width of the panel and along the length of the panel. Such a panel has a complex prismatic pattern which in the present state of the art can be manufactured only by injection molding.

Such injection molded panels, besides their high expense, have other disadvantages in that they are in general useful as wrap around panels on surface mounted fixtures rather than recessed flush fixtures.

In the prior art, the type of panels heretofore known to the art to reduce veiling reflections transmit light primarily in two directions only, i.e., to each side of the longitudinal axis of the panel. That is, there are light panels known to the prior art which project the light sideways in a twin beam pattern, rather than downward in order to minimize veiling reflections. This is sometimes referred to as a linear batwing light distribution. Such panels, however, result in poor end-on distribution and control, i.e., the light is distributed only to the sides of the panel. Prior to the present invention, no panel, and particularly one capable of being extruded, could accomplish what could be termed a radial batwing distribution in which the light is transmitted in a conical configuration while eliminating the vertical distribution, as described more fully hereinafter.

BRIEF SUMMARY OF THE INVENTION

A lighting panel for use in overhead lighting fixtures and the like which may readily be fabricated in plastic sheet by embossing techniques and which minimizes veiling reflections. In the preferred embodiment the panel contains a continuous pattern of triangular projections, each having three mutually substantially perpendicular surfaces projecting upward for disposition toward the light source. The base lines of the mutually substantially perpendicular surfaces are co-planar and the pattern of the projections is such that the base lines of all projections on the panel form continuous straight lines directed in three specific directions. This allows the fabrication of a relatively inexpensive engraved roll for embossing the pattern on a plastic sheet and results in a panel which minimizes veiling reflections from the illuminated matter.

The embossed pattern of the present invention can be used singly or combined with embossed or non-embossed clear and opalescent panels to further decrease lamp images and reduce high-angle brightness. The lens of the present invention can be embossed on clear material or the material can be tinted to increase the visual comfort probability.

Additionally, the panel of the present invention transmits light not only to the sides of the panel but also in the fore and aft direction with respect to the longitudinal axis. The light distribution to the sides of the vertical axis is sometimes referred to as "batwing" distribution. By means of the present invention, a radial batwing light distribution is accomplished in that light distribution is in a conical shape extending from approximately 30° from the vertical to 60° from the vertical in all directions.

The use of the wholly prismatic design of the present invention eliminates the use of opaqued areas or other light blocking means. This results in higher efficiency of light utilization, thus reducing the amount of electrical power needed to achieve the visual performance conditions desired.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a section of a typical ceiling having a plurality of fluorescent lighting fixtures therein.

FIG. 2 is a cross-section taken along lines 2-2 of FIG. 1 illustrating the construction of the fluorscent fixtures.

FIG. 3 is a top view of the lighting panel of the present invention showing the pattern on the surface thereof.

FIG. 4 is a cross-section taken along lines 4—4 of FIG. 3.

FIG. 5 is a perspective view of a section of the lighting panel of the present invention illustrating the pattern of projections on the surface thereof.

FIG. 6 is a polar plot of the light intensity versus direction for the light emitted from the lighting panel of the present invention mounted in a fluorescent fixture, such as shown in FIG. 2.

FIG. 7 is a schematic representation of the lighting obtained from a plurality of fluorescent fixtures using the lighting panel of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

First referring to FIG. 1, a perspective view of two fluorescent lighting fixtures as such fixtures are characteristically mounted in a ceiling may be seen. Such lighting fixtures are characteristically arranged in a pattern throughout the ceiling area so as to illuminate the entire room in as uniform manner as possible. As viewed from within the room, the lighting fixtures comprise a front molding or frame 20 and a lighting panel 22 to which the present invention is directed.

Now referring to FIG. 2, a cross-section of one of the lighting fixtures of FIG. 1 taken along lines 2—2 of that figure may be seen. The lighting fixture is comprised of a frame 24, one or more fluorescent tubes 26 supported by suitable mounting brackets 28, an outer molding 20 and a lighting panel 30 supported by the molding 20 below the fluorescent tubes. The function of the lighting panel 30 in modern day lighting systems is to redistribute the illumination from the fluorescent tubes so as to reduce the vertical and nearly vertical components of light from the fluorescent tubes and to redirect part of this light toward the side, thus increasing the side illumination and decreasing the substantially vertical illumination passing downward from the lighting panel. The lighting panel 30 is generally a sheet of plastic with a pattern embossed on the sheet so as to create a pattern of prismatic lenses to redirect the light incident thereto from the fluorescent tubes in the desired manner. It is this form of lighting panel to which the present invention is directed and, in particular, the present invention is a lighting panel which may be quickly and easily fabricated from such materials as thermoplastic materials by conventional extrusion embossing process, utilizing rollers which may be relatively easily and inexpensively fabricated.

Now referring to FIGS. 3, 4 and 5, the pattern on the upper surface of the lighting panel of the present invention, that is, the surface facing the light source, may be seen. FIG. 3 is a view taken along lines 3—3 of FIG. 2, looking downward onto the lighting panel 30. FIG. 4 is a cross-sectional view of the lighting panel taken along lines 4—4 of FIG. 3. FIG. 5 is a perspective view of the lighting panel illustrating the form of the top surface thereof. The pattern may be most easily described by identifying the characteristic lines, surfaces and points identifying the pattern.

Referring first specifically to FIG. 3, and the orientation of the pattern is depicted therein, the various surfaces of the pattern mate so as to define a repetitive series of lines, all of which are co-planar. The first series of lines are lines A—A having a parallel horizontal disposition. A second set of lines identified as the B—B lines, co-planar with and having the same spacing as the first set of lines, cross the first set of lines at an angle of 60°. A third set of lines identified as the C—C lines are co-planar with and have the same spacing as the A—A lines and the B—B lines. Furthermore, the C—C lines cross the A—A lines at the same point as the B—B lines and are located 60° from both the A—A lines and the B—B lines. These various lines are defined by the junction of triangular shaped flat surfaces projecting upward and mating in threes to define a plurality of apexes identified by the letter D, with each of the flat surfaces mating to define an apex being substantially perpendicular to the two adjacent surfaces cooperating to define the apex. Thus, the three sides mating to define an apex D define a projecting surface having essentially the geometrical characteristics of a corner of a cube.

FIG. 4 is a cross-section of the panel looking along the B—B lines, the ends of the lines being identified by the letter B in that figure. FIG. 5 is a perspective view of a portion of the lighting panel of the present invention having identified thereon various of the points, lines and surfaces herein identified with respect to FIGS. 3 and 4. It will be noted that the apexes between any two B—B lines lie to two rows rather than a single row. Thus, the apexes identified as D1 lie to the right of the apexes identified as D2. The lines G joining the apexes and the lines B—B, as shown in FIG. 4, are the side views of the triangular surfaces having their bases on the lines B—B, whereas the lines F in FIG. 4 are the lines extending from the lines B-B to the apexes and defining the junction of the other two surfaces of each protrusion.

It should be noted that though the cross-section shown in FIG. 4 was taken about a line perpendicular to the B—B lines, the cross-section of the pattern taken along A—A lines and C—C lines is also the same. Thus, the pattern hereinabove described may be formed in a sheet of plastic by forming parallel, equally spaced V grooves of the proper angle in a first direction, in a second direction 60° to one side of the first direction, and in a third direction 60° to the opposite side of the first direction, in a pattern such that the junction of the two sides of the second and third set of V grooves cross the junction of the two sides of the first set of V grooves at the same points.

In order for the three surfaces projecting upward to an apex to be substantially perpendicular to each other, that is, to have the geometric properties of a corner of a box, each side of the V grooves should be disposed at an angle of from 50° to 60° upward from the plane of the sheet of plastic thus causing the V grooves to have an included angle of from 80° to 60°. As a result of the V grooves, the lines identified by the letter F in FIG. **4** will define the complimentary angle of from 40° to 30° upward from the plane of the sheet of plastic. In the presently preferred embodiment, each side of the V grooves is disposed at an angle of 57° upward from the plane of the sheet, thus resulting in an included angle of 66° such that the lines F in FIG. **4** are at an angle of 33° upward from the plane of the sheet of plastic. Thus, each surface E of the pattern is inclined at an angle of 33° with respect to the vertical.

The function of the pattern on the lighting panel of the present invention may be described as follows: Light directed from immediately above onto the lighting panel will strike one of the surfaces of the protrusion at an angle of 33°, since all surfaces in the pattern are inclined with respect to the vertical by this angle. Since the light is entering a medium of higher index of refraction, the light path will be curved toward a perpendicular to the surface and, thus, deflected somewhat to the side in comparison to its initial vertical path. The lower surface of the panel being flat as shown in FIGS. **4** and **5**, the light will strike the lower surface at a substantial angle and, upon passing therethrough into a medium (air) having a lower index of refraction, will be further deflected away from the vertical. By way of example, if the lighting panel is fabricated from a polystyrene sheet having an index of refraction of approximately 1.6, most of the light incident upon the surfaces as hereinabove described will be transmitted therethrough, rather than reflected, and the light emerging from the lower surface of the panel will have a total deflection from the vertical of approximately 57°. The direction of any particular light ray will depend upon which of the triangular surfaces it initially entered in the pattern on the upper surface of the panel and, in general, light rays which initially were purely vertical with respect to the panel will be deflected to the side of six directions approximately 60° apart.

From the lower (non-embossed) side of the panel, the elements act to redirect any light coming into the panel from directly below back in its original direction. By the reciprocity of light rays, this means that no light from above the panel can penetrate into the angles directly below the panel. (This redirection is generally illustrated by the light ray **29** in FIG. **2.** Total theoretical reflection for redirection will generally be achieved when somewhat different surface angles are used, depending upon the index of refraction of material).

Referring now to FIG. **2,** it will be seen that only a very limited portion of the lighting panel **30** is located immediately below any of the fluorescent tubes **26,** and further, the portion of the panel located immediately below any of the tubes will receive substantial illumination from the tubes other than from the portion of the tube directly above, that is, from portions of the tube longitudinally displaced from that section of the panel and from the reflective surface of the fixture. Consequently, a considerable amount of light will strike the top surface of the panel at substantial angles from the vertical and, therefore, the light projecting downward from the bottom surface of the panel will be distributed over all angles. In fact, some of the light striking the upper surface of the panel at certain angles will be deflected on passing through the panel, so as to be emitted from the panel in a vertical downward direction. However, the amount of light emitted from the panel in a vertical direction is limited and, in general, the intensity of the light emitted to the side and fore and aft of the panel will be substantially higher than the vertical component. By way of example, the distribution of intensity versus angle in a typical installation using the panel of the present invention is as shown in FIG. **6.** This figure is a plot, in a polar coordinate system, of the intensity of illumination versus direction, with the intensity being indicated by the distance from point **50** to a point on the curve, and the direction being indicated by the direction of a line point **50** to the corresponding point on the curve. It will be noted while there is substantial vertical illumination, the illumination to each side in any azimuthal plane is substantially greater than the vertical illumination. Furthermore, the said illumination is distributed over a substantial angle so that strong veiling reflections will, in general, not be obtained regardless of the orientation of the task. Thus, the objects of eliminating particularly intense vertical or near vertical illumination and of further eliminating particularly intense illumination in any specific direction, have been achieved with the panel of the present invention. (Orienting the panel so that the pattern is on the surface directed away from the light source will also reduce the vertical component of illumination since the projections will act as retrodirective reflectors as the vertical and near vertical components of light. However, this illumination will be lost unless the top surface of the panel and/or the fixture enclosure are adapted to reflect this light downward again at a different angle.)

Now referring to FIG. **7,** a schematic representation of a student in a classroom illuminated by a plurality of overhead fixtures utilizing the lighting panel of the present invention may be seen. The lighting distribution of FIG. **6** is approximately indicated by the length of the lines representing the light rays in FIG. **7.** It will be noted that the table **52** in front of the student **54** is more strongly illuminated by light fixtures **56** and **60** to each side of the student than by the fixture **58** immediately overhead. It should also be noted that the lighting panels have substantial areas, typically on the order of 2 feet by 4 feet, and thus even the light reaching a printed page in front of the student from a particular light panel is not light having a fixed direction, but is light distributed over a substantial angle dependent upon the size and orientation of the lighting panel with respect to the printed matter. (Typically, a significant percentage of a ceiling area is occupied by such areas.)

Other patterns for use on lighting panels which will generally achieve the optical objects of the present invention are also known. However, the pattern of the present invention is particularly advantageous since lighting panels of the present invention may be readily fabricated by an extrusion-embossing process using simple and inexpensive rolls. By way of example, the pattern shown in detail in FIGS. 3, 4 and 5 was characterized as being formable in a sheet of plastic by creating parallel, equally spaced V grooves of the proper angle in a first direction, in a second direction 60° one side of the first direction, and in a third direction 60° to the opposite side of the first direction, in a pattern such that the junction of the two sides of the second and third set of V grooves cross the junction of the two sides of the first set of V grooves at the same points. The roll for producing this pattern, of course, must have the negative of the pattern of the surface thereof.

In some instances and in the presently preferred embodiment of the present invention, an overlay sheet is affixed to the embossed surface, i.e., the upper surface of the panel to reduce any visible lamp image. In the presently preferred embodiment a high light transmission acrylic overlay of typical thickness such as an 0.040 to 0.060 inch thick sheet of opal acrylic is used. This does not effect the light distribution previously described but serves only to reduce any visible image of the lamp within the fixture.

In other instances, a second panel **31** may be affixed to the non-embossed surface, i.e., the lower surface of the panel, in order to modify the distribution or constitute a decorative element. Or, a decorative or modifying pattern may be impressed into the lower (non-embossed) surface itself. One of the reasons for an embodiment utilizing such a second panel is to redirect light rays to reduce high-angle luminance.

The advantage of the particular pattern used on the panel of the present invention is that the pattern is the net result of a plurality of generated surfaces and a suitable roll (press, mold and the like, depending upon the particular fabrication process desired) for embossing the pattern on a sheet of thermoplastic may similarly be easily generated. Also, while the particular pattern described in detail above is comprised of a pattern of projections having three mutually perpendicular surfaces, the angles generating these surfaces may be varied somewhat from the values given herein so that the surfaces defining each projection are not perpendicular. By varying the angle, the distribution of illumination may be varied. Similarly, the V grooves and thus the plurality of triangular shaped surfaces defining the pattern may be curved somewhat, that is, the V grooves may have curved legs, perhaps near their junction to also vary the distribution of illumination created by the panel. These and other variations of the present invention panel may readily be designed and constructed by one skilled in the art from the disclosure provided herein without departing from the spirit and scope of the present invention.

I claim:

1. A lighting panel having on one surface thereof a pattern of protrusions each defined by three generally flat triangular surfaces, each of said triangular surfaces having first and second sides and a base, and mating the other two of said three triangular surfaces defining each of said protrusions on said first and second sides thereof, each of said bases of said three triangular surfaces defining each of said protrusions being substantially coincident with the base of one of said triangular surfaces defining an adjacent protrusion, all of said bases being substantially coplanar, each of said three triangular surfaces being disposed at approximately 50° to 60° with respect to the plane of said bases.

2. The lighting panel of claim **1** wherein said three triangular surfaces defining each of said protrusions being mutually substantially perpendicular surfaces.

3. The lighting panel of claim **2** wherein there is affixed to the surface opposite said one surface a second panel designed to further reduce veiling reflections.

4. The lighting panel of claim **1** wherein there is affixed to said one surface a high transmission overlay means for damping lamp images.

5. The lighting panel of claim **1** wherein there is impressed into the surface opposite said one surface a pattern designed to further reduce veiling reflections.

6. A lighting panel having on one surface thereof a pattern of protrusions defined by a first set of parallel, equidistantly spaced V grooves directed downward into said panel; a second set of parallel V grooves directed downward into said panel; said second set of V grooves having the same spacing as said first set and crossing said first set at an angle of approximately 60°; and a third set of parallel V grooves directed downward into said panel; said third set of V grooves having the same spacing as said first set and crossing said first and second sets at an angle of approximately 60°; said first, second and third sets of V grooves being disposed so that the lines defined by the junction of the two sides of each of said V grooves are substantially coplanar, each of said two sides of each of said V grooves being disposed at approximately 50° to 60° with respect to the plane of said lines defined by the junction of the two sides of each of said V grooves.

7. The lighting panel of claim **6** wherein each of said two sides of each of said V grooves are disposed at approximately 57° with respect to the plane of said lines defined by the junction of the two sides of each of said V grooves.

8. The lighting panel of claim **6** wherein there is affixed to the side opposite said one side of the panel an acrylic sheet of high light transmitting diffusing material for damping lamp images visible through said panel.

9. In a lighting fixture of the type including a housing and a light source within the housing, a lighting panel having first and second surfaces, and having on said first surface thereof a pattern of protrusions each defined by three generally triangular surfaces; each of said triangular surfaces having first and second sides and a base and mating the other two of said three triangular surfaces defining each of said protrusions on said first and second sides thereof; each of said bases of said three triangular surfaces defining each of said protrusions being substantially coincident with the base of one of said triangular surfaces defining an adjacent protrusion, all of said bases being substantially coplanar; said triangular surfaces being inclined with respect to the plane of said bases by a predetermined angle so that light coming directly toward said second surface is redirected back toward its original direction by said pattern.

10. An improved lighting panel comprising a sheet having first and second surfaces, and having on said first first surface thereof a pattern of protrusions, each of said protrusions having a plurality of surfaces extending toward an apex, each of said protrusion surfaces being inclined at a predetermined angle with respect to a first line perpendicular to said second panel surface, said predetermined angle being an angle smaller than the limiting angle at which total reflection of light impinging on a first of said protrusion surfaces from within said panel and directed along said first line would occur, whereby total reflection of said light toward a second of said protrusion surfaces would occur, said predetermined angle being an angle larger than the limiting angle at which said light reflected by said first of said protrusion surfaces would be totally reflected by said second of said protrusion surfaces, whereby light impinging on said panel substantially perpendicular to said second panel surface will be reflected by said pattern back toward the direction said light originated as a result of the reflection of said light from at least a first and a second surface of said protrusions.

11. The lighting panel of claim **10** wherein each of said protrusions is defined by a plurality of generally flat surfaces so that a cross-section of each of said protrusions is a polygon.

12. The lighting panel of claim **11** wherein said cross-section is an equilateral triangle.

13. A lighting panel having on one surface thereof a pattern defined by a plurality of groups of three generally triangular surfaces, each of said triangular surfaces having first and second sides and a base, and mating the other two of said three triangular surfaces on said first and second sides thereof, each of said bases of said three triangular surfaces in a group being substantially coincident with the base of one of said triangular surfaces in an adjacent group, all of said bases being substantially coplanar, each of said three triangular surfaces being disposed at approximately 50° to 60° with respect to the plane of said bases.

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