Feb. 7, 1961 D. R. PHILLIPS ET AL 2,971,083

LOW BRIGHTNESS LOUVER

Filed Nov. 14, 1958 2 Sheets-Sheet 1

Fig. 1.

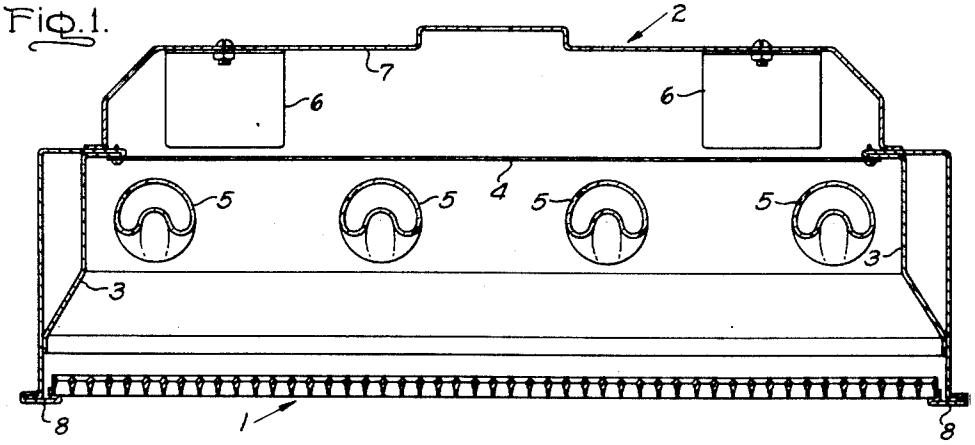


Fig. 2.

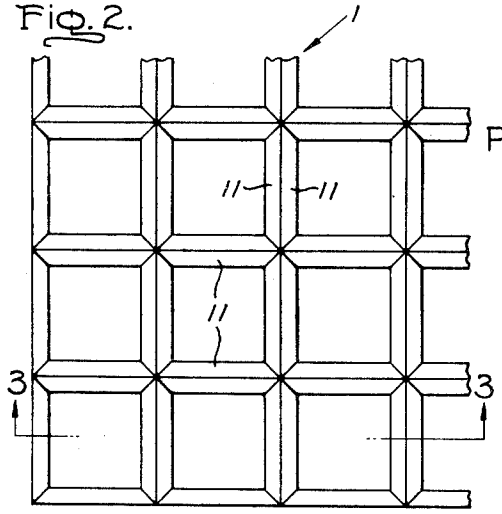


Fig. 3.

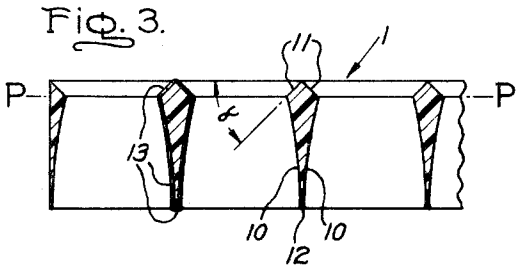
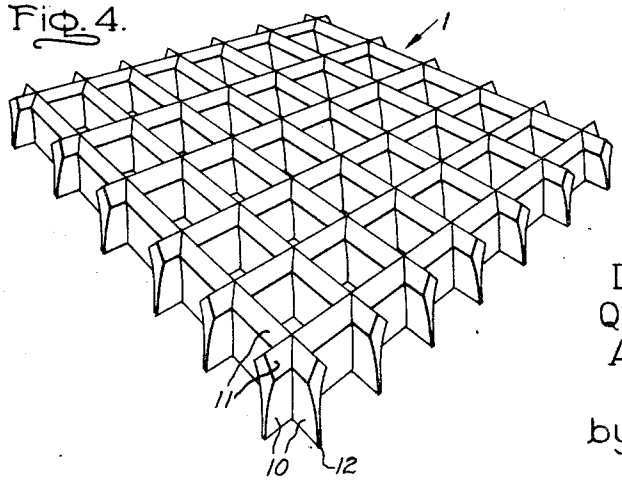


Fig. 4.



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Fig. 5.

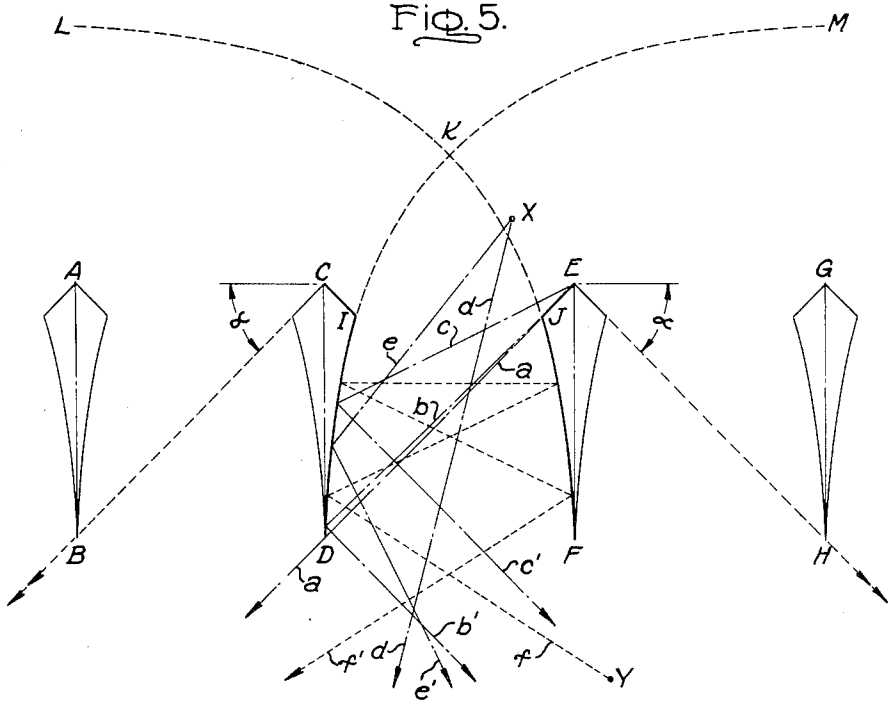


Fig. 6.

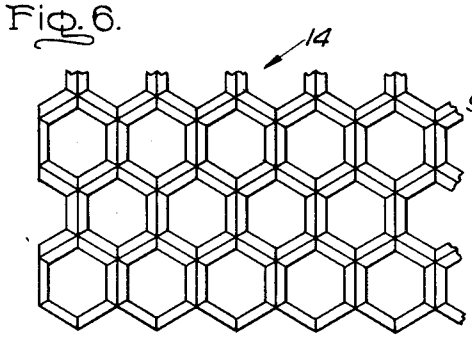
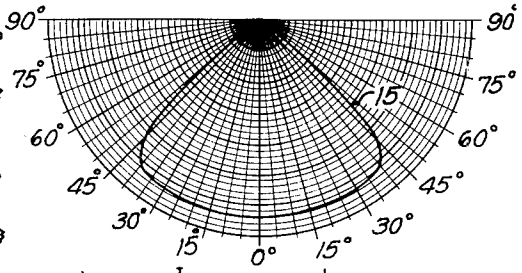


Fig. 7.

POLAR PLOT OF RELATIVE CANDLEPOWER



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LOW BRIGHTNESS LOUVER

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6 Claims. (Cl. 240—78)

This invention relates to panel louvers or diffusion grids for use in connection with lighting fixtures and light sources. It is more particularly concerned with a panel louver which has a low brightness when viewed at angles below a predetermined cutoff angle and gives a low brightness ceiling concurrently with a controlled high level of illumination.

With the introduction of higher brightness fluorescent lamps and the gradual recognition of the utility and advantages of higher levels of illumination, a need has arisen for better control of the brightness of lighting fixtures. A common practice up to the present has been to apply a diffusion panel such as a grid or so-called egg crate louver under the opening of a lighting fixture. The panel generally consists of a lattice of cells, usually rectangular but sometimes hexagonal, and open at the top and bottom. When the cells of the panel are cubic, direct rays from the lamps are cut off for viewing angles above the horizontal less than 45°. This is desirable of course for improving visual comfort in the lighted area. The cell sizes or dimensions used in such louvers may be anywhere from a few inches down to approximately ¼", the smaller sizes being generally preferred for luminous ceiling installations wherein the louvers extend continuously in a false ceiling throughout the lighted area. Both opaque and translucent materials have been used for these louvers and it has been recognized that in order for the desired reduction of glare to be accomplished, the material of the louver should be translucent or a diffuse reflector. Although such light control means have been adequate to provide an acceptable visual comfort index at the lighting levels commonly used up to the present, they are insufficient for high lighting levels, for instance lighting levels of several hundreds or one thousand foot-candles and up.

One technique which has been proposed for reducing ceiling brightness at very high lighting levels is a louver wherein the vertical walls of the cells are light absorbing, for instance coated with a black matte paint. This does accomplish the desired object of a low brightness ceiling inasmuch as for viewing angles less than the cutoff angle there is substantially no light escaping from the louver either by internal reflection within the cells or by transmission through the cell walls. However such control is effected at the efficiency since a high percentage of light is absorbed in the louver. For this reason this method of light control is generally unacceptable.

The principal object of the invention is to provide an improved high-efficiency louver which will effectively control the intensity and direction of light transmitted from a source.

A more specific object of the invention is to provide a high-efficiency louver whose outstanding characteristics are high and substantially uniform transmission of light at viewing angles above a predetermined cutoff angle and very low transmission of light at viewing angles below the cutoff angle.

Yet another object of the invention is to provide an

improved louver having the foregoing advantageous characteristics and which can be readily and economically manufactured using conventional techniques for injection molding of plastics.

In accordance with the invention, a louver achieving the foregoing objects is of the cellular type and consists of material treated to have a high reflectivity. The desired light control is achieved by means of a unique wedge-shaped cross section in the vertical side walls of the cells which imparts precise optical characteristics. In general, the optical relationship is such that any rays glancing by the apex or upper edge of one wall of a cell at an angle less than the cutoff angle are reflected by the opposite wall of the cell in a direction substantially parallel to the cutoff angle. In the ideal case the contours of a cell wall on opposite sides consist of portions of parabolas having their axes inclined in opposite directions at the cutoff angle and their focal points located at the apex or upper edge of the next adjacent cell wall on either side.

Further objects and advantages of the invention will become apparent from the following detailed description of embodiments thereof read in conjunction with the accompanying drawings. The features of the invention believed to be novel will be more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a cross sectional view through a four-lamp high light output fixture provided with a low brightness louver embodying the invention.

Fig. 2 is a plan view of a portion of a cubic cell low-brightness louver embodying the invention and drawn to an enlarged scale.

Fig. 3 is a cross sectional view of the louver of Fig. 2.

Fig. 4 is a perspective seen from above of a fragment of a cubic cell louver embodying the invention.

Fig. 5 is a diagram illustrating optical and geometrical relationships in a louver according to the invention.

Fig. 6 is a plan view of a portion of a hexagonal cell louver embodying the invention.

Fig. 7 is a typical polar diagram of the light distribution achieved with a louver embodying the invention.

Referring to Fig. 1, there is shown a cubic cell low brightness louver **1** mounted under the opening of a high light output fixture **2**. The fixture typically comprises a generally rectangular light box defined by side walls **3** and a top wall **4** coated with a light-reflecting paint. Within the light box are mounted in parallel spaced relation four elongated fluorescent lamps **5** here shown as being of the high output grooved type known commercially as Power Groove. A pair of ballast transformers **6** for energizing the lamps are mounted in an auxiliary chamber defined by a panel **7** fastened to the upper side of the light box. The louver **1** is supported by T-shaped brackets **8** fastened to the sides of the light box. Typically the fixture may be approximately 8' x 2' and the louver may be made up if desired of two panels 48" x 24" in nominal dimensions.

The structure of the louver proper is shown in Figs. 2 to 4. Figs. 2 and 3 show in plan view from above and in side cross section respectively, a cubic cell louver **1** whose general appearance is illustrated pictorially in Fig. 4. The walls of the cells are wedge-shaped in cross section, the longer side portions **10** being preferably portions of parabolic curves as will be more specifically described hereafter. The parabolic side portions are cut off at their upper extremity by straight surfaces **11** inclined at an angle α to the plane of the louver; the angle α is the cutoff angle of the louver and for the illustrated cubic cell louver is 45°. The thickness of the base **12** or bottom edge of the wall is not important as regards the optics of the louver

and is determined principally on the basis of providing sufficient mechanical strength and rigidity to the louver.

In order to achieve the stated object of a louver which can be readily and economically manufactured using conventional techniques for injection molding of plastics, all surfaces must taper outwardly relative to the plane at which the two halves of the mold will meet and there must not be any inversions of inclination within either half. The illustrated louver meets these requirements inasmuch as it can be injection molded in a pair of separable molds which meet at the plane *p—p* corresponding to the lines of intersection of the parabolic surfaces **10, 10** with the inclined surfaces **11, 11** in Fig. 3.

Contrary to the prevailing practice up to the present, the louver of the present invention rather than being made of translucent or diffuse reflecting material, is provided with a finish which has substantial specular or mirror-like reflection at least over the parabolic surfaces **10, 10**. From the theoretical point of view assuming perfect compliance with the optical and geometrical considerations to be explained hereafter, a polished or fully specularly reflecting surface over the curved surfaces **10, 10** assures optimum control of light and minimum louver brightness for viewing angles less than the cutoff angle. In practice, however, in order to disguise imperfections in the optics of the louver due to manufacturing tolerances, some minor degree of diffuse reflectance may be desirable. Some diffuse reflectance is also beneficial in order to make soil marks and fingerprints less noticeable.

For greater utilization efficiency, the upper inclined surfaces **11, 11** are also preferably coated with a light-reflecting coating, though it is immaterial in this case whether the reflectance be specular or diffuse. For the sake of best appearance, the bottom edges **12** of the louver are likewise reflectively coated. As a practical matter, it appears preferable to coat the entire louver with a layer **13** of specularly reflecting material such as aluminum, as shown in Fig. 3 wherein the thickness of the layer has been exaggerated for purposes of illustration. The layer **13** may then be etched slightly to provide a minor degree of diffuse reflectance. Since the entire surface of the louver is coated, the color or translucency of the plastic material of which the louver is made becomes immaterial and lower grade gray or dark plastics including scrap materials may be used, thus providing a substantial cost advantage.

The optical and geometrical relationships in a louver according to the invention may be explained by reference to Fig. 5. Four baffle elements or wall sections AB, CD, EF and GH are shown arranged for a cutoff angle α of 45°. The same principles are applicable irrespectively of the cutoff angle which can be increased by moving the elements closer together. Referring particularly to element CD, curved portion DI is part of a parabolic curve DKM whose focus E is the apex of the adjacent baffle element EF, and whose axis is the line EH inclined at the cutoff angle α away from the element. The point I is determined by the intersection with the parabola of a straight line drawn from the apex C of the element at the cutoff angle. In like manner, curved portion FJ of baffle element EF is a portion of parabola FKL whose focus is the apex C of adjacent baffle element CD, and whose axis is the line CB inclined at the cutoff angle α away from the element. Line EJ is likewise inclined at the cutoff angle to the plane of the louver. All the baffle elements of the louver are constructed in corresponding fashion, opposite sides of any one element being portions of parabolas having their foci at the apices of the adjacent baffle elements and their axes inclined at the cutoff angle in opposite directions.

The optical characteristics of a louver having the foregoing geometrical relationships will become apparent upon considering the behavior of various rays originating above the louver and represented in Fig. 5 by dot dash lines. Considering a ray *a* glancing by the apex E of element EF at the cutoff angle α that ray will just graze the base point D of baffle element CD and continue uninterrupted at the cutoff angle. However a ray *b* originating as if from the same point E but at an angle slightly less than the cutoff angle will be reflected by parabolic surface DI in a direction parallel to the axis EH of the parabola; in other words the reflected ray *b'* will be inclined at the cutoff angle to the right. Similarly any ray (not shown in the drawing) glancing by the apex C of baffle element CD at an angle less than the cutoff angle will be reflected by parabolic surface FJ in a direction parallel to the cutoff angle to the left. The foregoing follows of course from the fact that points E and C are the foci of parabolas DKM and FKL respectively. However rays can also originate from any point X located behind the foci E and C. Such rays may either proceed directly through the opening between the baffle elements as in the case of ray *d*, in which case the ray will pass through at an angle greater of course than the cutoff angle. Other rays such as ray *e* may strike one or the other of the parabolic surfaces FJ and DI; since the point X is located behind the focus E of parabola DKM, the reflected ray *e'* will be divergent relative ot the axis of the parabola; in other words, ray *e'* will be directed downward at an angle greater than the cutoff angle. It is therefore apparent that no light rays can pass through the louver at an angle less than the cutoff angle α to the plane of the louver, that is at an angle less than 45° to the horizontal for the illustrated case.

A very interesting feature which is at the same time an advantageous characteristic of the louver is that for any angle less than the cutoff angle, the lower surface behaves like a totally reflecting surface, that is it behaves like a plane mirror. Thus a ray *f* shown in dotted lines originating from the point Y below the louver at an angle less than the cutoff angle is subjected to multiple reflections between the parabolic surfaces DI and FJ and emerges as reflected ray *f'* downwardly inclined at the same angle. On account of this characteristic, an observer in a room equipped with a false ceiling made up of the louver panels of the present invention and observing the ceiling at an angle less than the cutoff angle, will see light originating from the walls or the floor of the room. As a result, the ceiling takes on the general color and brightness of the walls and floor of the room and its appearance is independent of the amount, quality or color of the light streaming through from above except of course inasmuch as such light conrtibutes generally to the room illumination. If desired, a transparent colored lacquer or coating may be applied over the reflecting surfaces of the louver and the louver or ceiling then appears substantially colored when viewed at angles less than the cutoff angle.

Where the inclined surfaces of the upper side of the louver are silvered or light-reflecting, it is possible for light rays reflected from these surfaces, and then further refleeted from the parabolic surfaces, to diverge slightly beyond the cutoff angle. This may be corrected by making the uppermost points of the parabolic curves of any one louver element the foci of the parabolic curves next adjacent. For instance, in Fig. 5, point J would become the focus of parabolic curve DIM and point I the focus of parabolic curve FJL, the axes of the parabolas being as before inclined at the cutoff angle. This entails a slightly thicker cross section at the widest part of the louver elements and results in a sharper cutoff at the selected cutoff angle.

Although the contour demanded for the baffle element is in the ideal a parabolic curve, substantial departure from the ideal may be made without excessive degradation of performance. The parabolic curve is preferred because it permits a sharp cutoff angle inasmuch as rays originating in any direction from the focus are reflected parallel to the axis, the axis being inclined of course at

the critical cutoff angle. However any curve which will reflect rays from a focal point in a direction substantially parallel to a predetermined axis may also be used. Thus the curve DI may be part of a circular or elliptical curve so long as its focus is located approximately at the point E and rays glancing by the point E will be reflected thereby approximately at the cutoff angle.

As previously stated, for maximum louver efficiency and in order to achieve the lowest possible ceiling brightness, the parabolic surfaces of the baffle elements in the louver are specularly reflecting surfaces, that is polished mirror-like surfaces. However for practical applications some degree of diffuse reflectance is generally desirable in order to disguise blemishes and imperfections. It must be understood however that the brightness of the ceiling for angles less than the cutoff angle will increase with the degree of diffuse reflectance. This is the very opposite of the situation with prior art louvers and is due to the fact that the optical relationships discussed above which govern the operation of a louver according to the invention in the ideal case, are then no longer fully effective.

Although in the typical application example illustrated in Fig. 1 the louver is provided with cubic cells approximately one-half inch on a side, the invention is not limited thereto and may be used with other sizes of cell. The invention may also be used with other than cubic or rectangular cells, for instance with a hexagonal cell or lattice structure **14** as illustrated in Fig. 6. A hexagonal cell lattice may be desirable for certain application from the aesthetic point of view. Also the cutoff angle with a hexagonal lattice is more constant for various viewing angles than for a cubic lattice. When the cutoff angle of a cubic lattice is stated to be 45°, that cutoff angle is applicable only when the louver is viewed in directions normal to the directions of the baffle elements. At intermediate viewing angles, the cutoff angle is reduced and when the louver is viewed along the diagonal to the cubic cells, the cutoff angle is reduced from 45° to approximately 35°. This effect is much less pronounced with a hexagonal cell lattice.

Another important and advantageous characteristic of the louver in accordance with our invention is the substantial uniformity of candle power within the illuminated zone, that is from one cutoff angle through the nadir to the other cutoff angle, where the brightness of the light source above the louver is substantially uniform. This is illustrated in Fig. 7 wherein curve **15** illustrates in polar coordinates the relative candle power at various angles measured under the fixture of Fig. 1 in a plane transverse to the axes of the lamps. The relative constancy of candle power within the 45° cutoff angles and the sharp cutoff beyond will be noted.

While certain specific embodiments of the invention have been illustrated and described in detail, these are intended as exemplary and not in order to limit the invention thereto. The scope of the invention is to be determined by the appended claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A low brightness louver comprising a grid of cells open to light at the top and bottom, said cells having walls whereof each side surface extends upwardly as a portion of an optical curve having its focus approximately at the apex of the next adjacent cell wall on the same side and its axis inclined downwardly substantially at the cutoff angle to the plane of the louver in a direction away from said side, said side surfaces having a substantial degree of specular reflection.

2. A low brightness louver comprising a grid of cells open to light at the top and bottom, said cells having walls whereof each side surface extends upwardly as a portion of an optical curve having its focus approximately at the apex of the next adjacent cell wall on the same side and its axis inclined downwardly substantially at the cutoff angle to the plane of the louver in a direction away from said side, said optical curve having the property of reflecting at angles not less than the cutoff angle rays originating from and behind the focus, said side surfaces having a substantial degree of specular reflection.

3. A low brightness louver comprising a grid of cells open to light at the top and bottom, said cells having walls whereof each side surface extends upwardly as a portion of a substantially parabolic curve having its focus approximately at the apex of the next adjacent cell wall on the same side and its axis inclined downwardly substantially at the cutoff angle to the plane of the louver in a direction away from said side, said side surfaces having a substantial degree of specular reflection.

4. A low brightness louver comprising a grid of cells open to light at the top and bottom, said cells having walls whereof each side surface extends upwardly as a portion of an optical curve having its focus approximately at the apex of the next adjacent cell wall on the same side and its axis inclined downwardly substantially at the cutoff angle to the plane of the louver in a direction away from said side, the upper surfaces of said walls being in planes inclined downwardly from the apex substantially at the cutoff angle and extending to a line of intersection with the curved portions of said walls, said walls having a substantial degree of specular reflection.

5. A low brightness louver comprising an integral molded lattice of plastic material defining between the walls thereof a multiplicity of cells open at the top and bottom, the walls of said cells being generally wedge-shaped in cross section and the major portion of the wall contour on either side consisting of an optical curve having its focus approximately at the apex of the next adjacent cell wall and its axis directed downwardly substantially at the cutoff angle to the plane of the louver, the walls of said cells being provided with a reflective coating having a substantial degree of specular reflection.

6. A low brightness louver comprising an integral molded lattice of plastic material defining between the walls thereof a multiplicity of cells open at the top and bottom, the walls of said cells being elements generally wedge-shaped in cross section and comprising for the major portion of the contour on either side an optical curve extending upwardly from the base of the element and having its focus at the apex of the next adjacent cell wall and its axis directed downwardly away from the element at the cutoff angle to the plane of the louver, and for a minor portion of the contour a surface extending downwardly from the apex of the element at the cutoff angle to a line of intersection with the curved major portion, said line of intersection being in a plane on either side of which the elements have no inversions of inclination, the walls of said cells being provided with a reflective coating having a substantial degree of specular reflection.

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