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[45] Jan. 9, 1973

[54] **METHOD OF MAKING A FACETED REFLECTOR FOR A LIGHTING UNIT**

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[73] Assignee: **General Motors Corporation**, Detroit, Mich.

[22] Filed: **Sept. 23, 1970**

[21] Appl. No.: **74,562**

[52] **U.S. Cl.** **240/41.36,** 350/299

[51] **Int. Cl.** **F21v 7/09**

[58] **Field of Search** .... 240/8.2, 41.36, 103 R; 350/292, 296, 299

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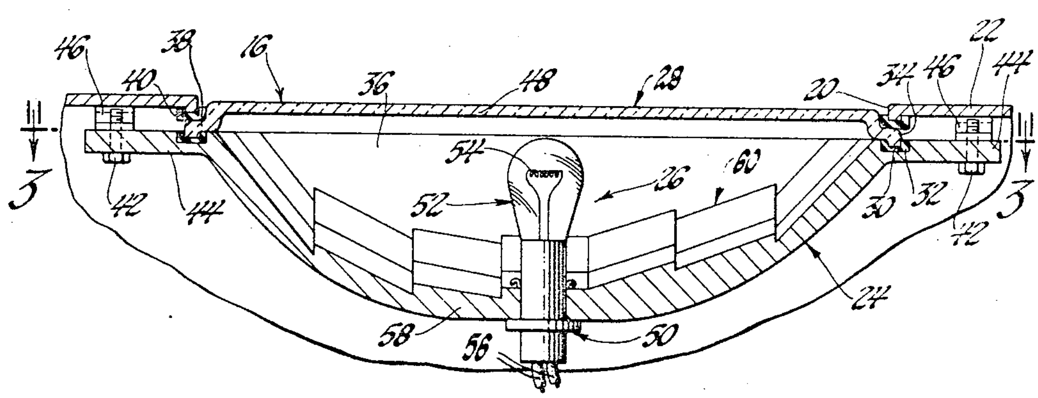
Assistant Examiner—Fred L. Braun

Attorney—J. L. Carpenter, E. J. Biskup and Peter D. Sachtjen

[57] **ABSTRACT**

A method of making a reflector for predictably projecting a light beam from a light source by individually orienting a plurality of discrete reflecting facets with respect to the source such that the superposition of the reflected images synthesizes a predetermined lighting distribution. By selecting the number, size, curvature, and location according to the techniques disclosed herein, the prescription for the reflector produces the desired illumination distribution within prescribed limits. By positioning contiguous facets such that uncontrolled reflectors are shaded from the light source, glare from the lighting unit is substantially eliminated.

3 Claims, 20 Drawing Figures



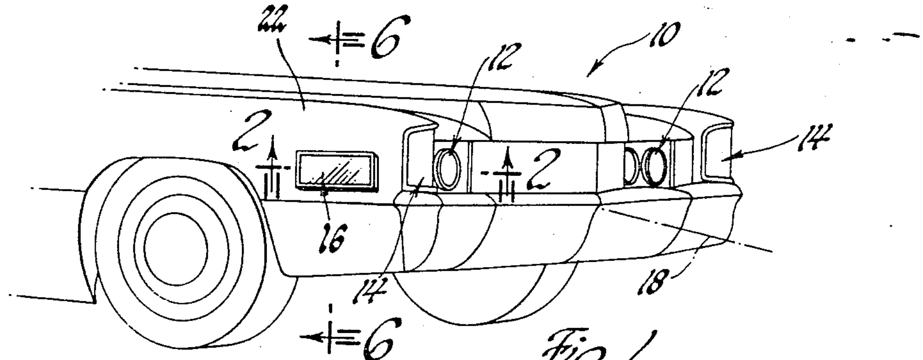


Fig. 1

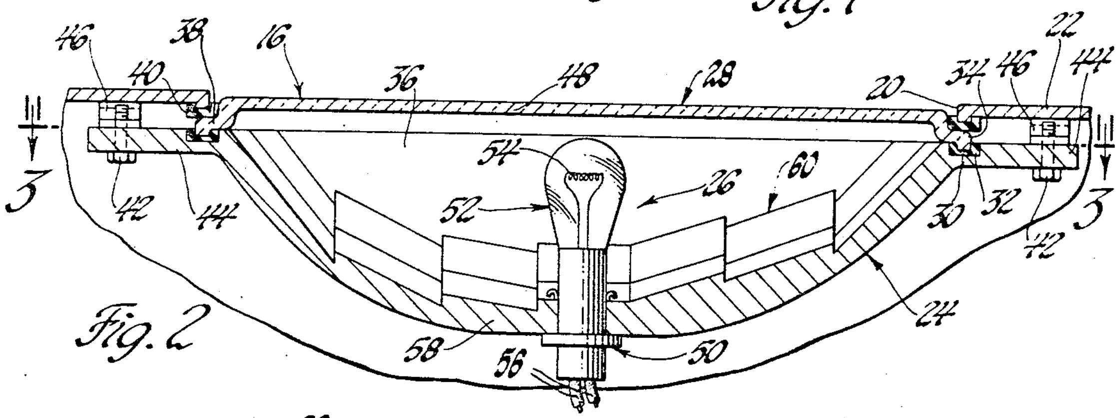


Fig. 2

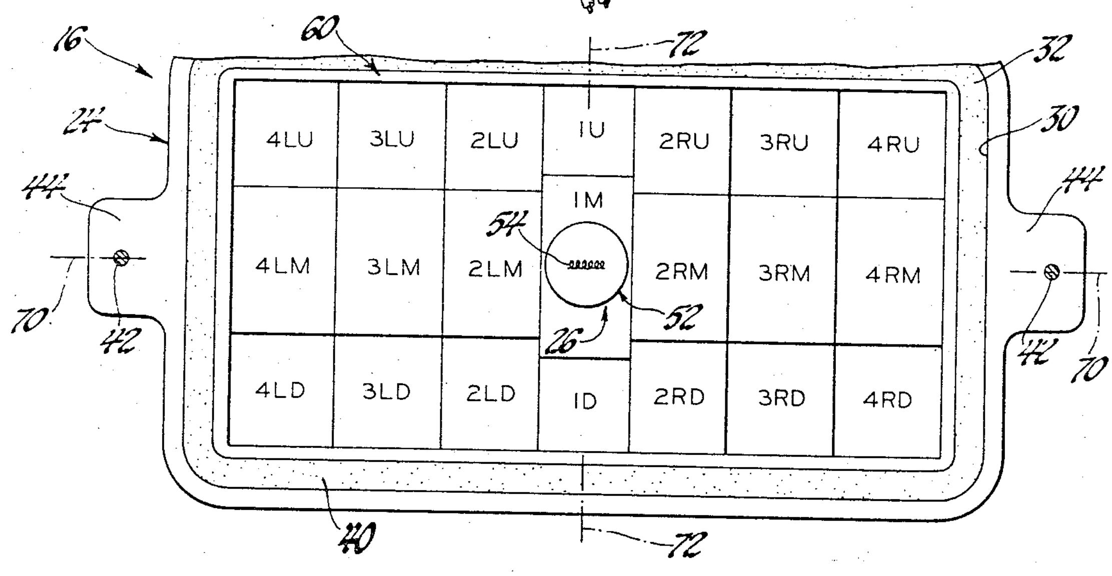


Fig. 3

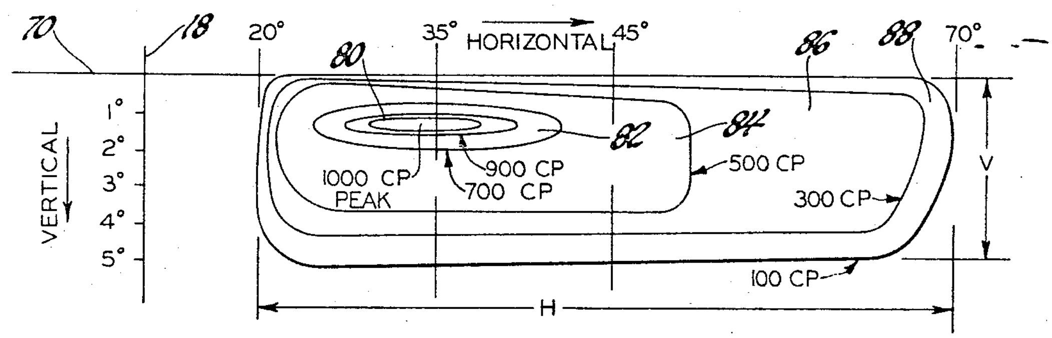


Fig. 4

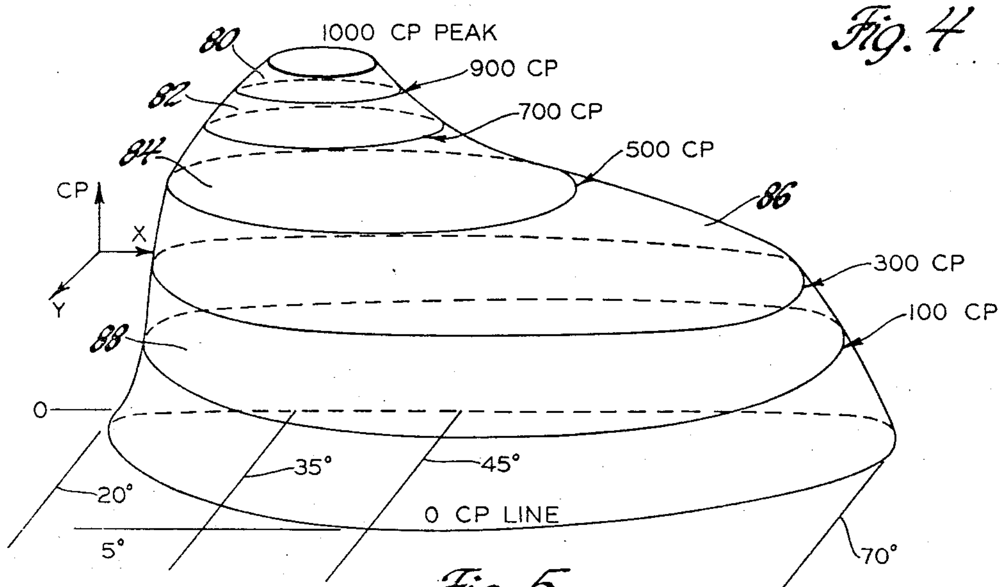


Fig. 5

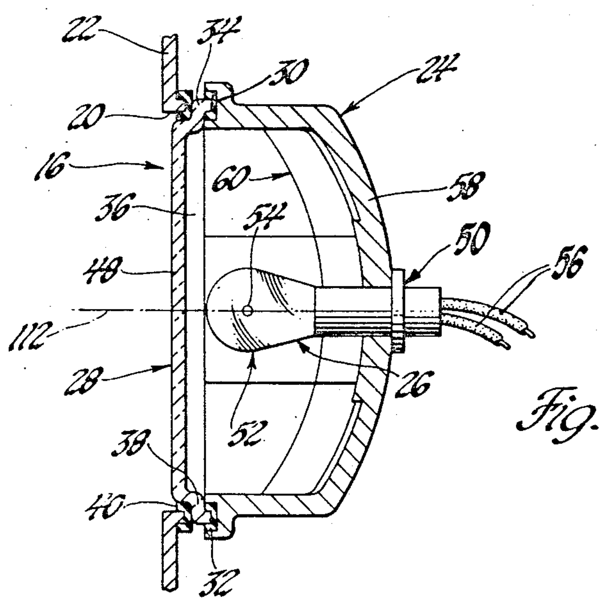


Fig. 6

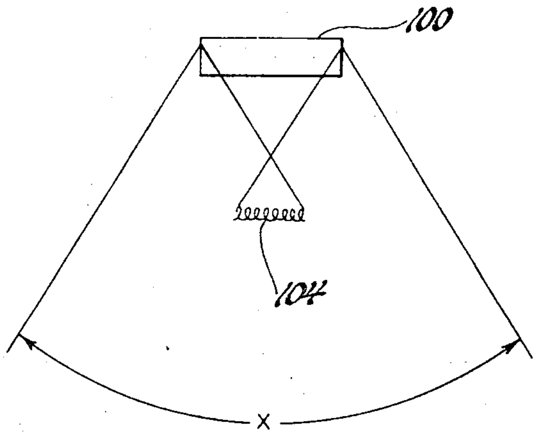


Fig. 7

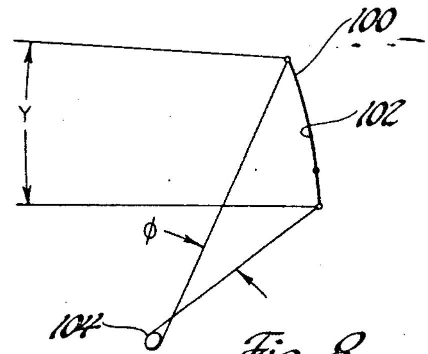


Fig. 8

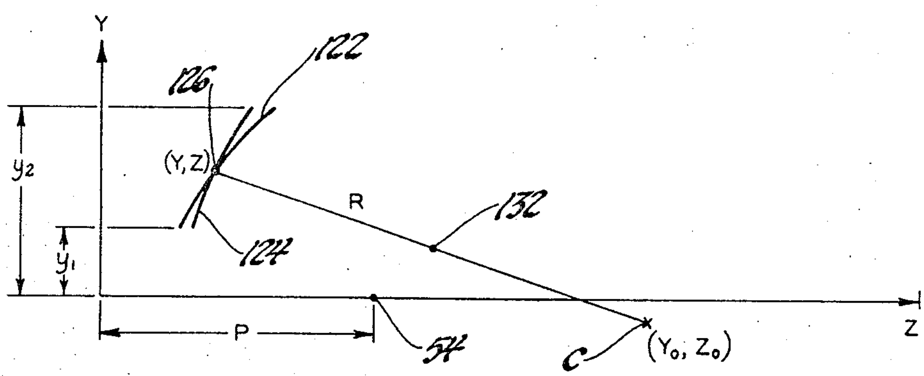


Fig. 9

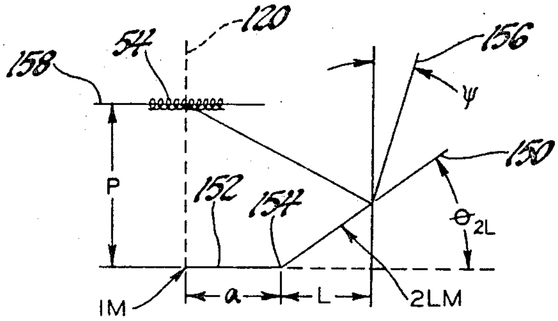


Fig. 10

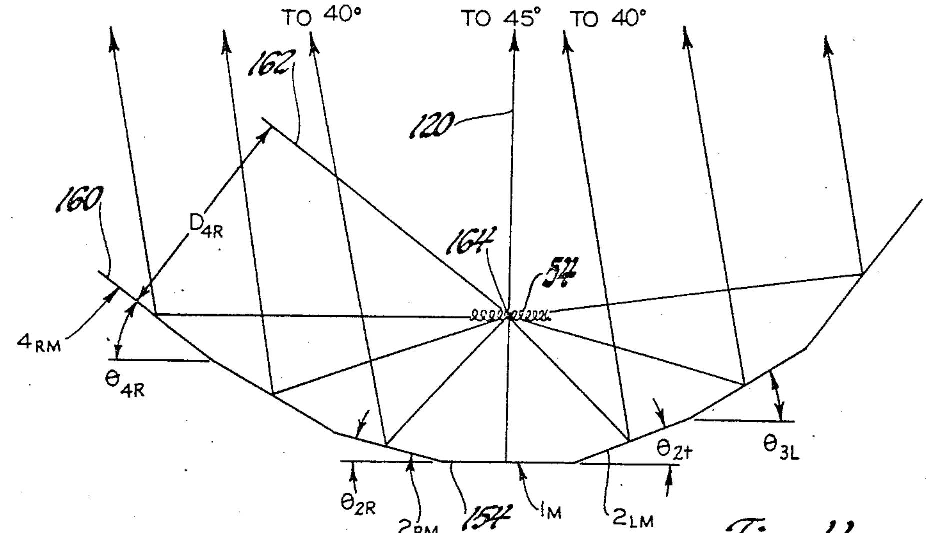


Fig. 11

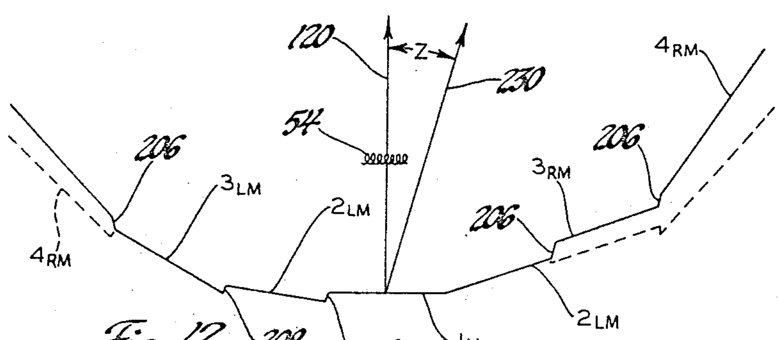


Fig. 12

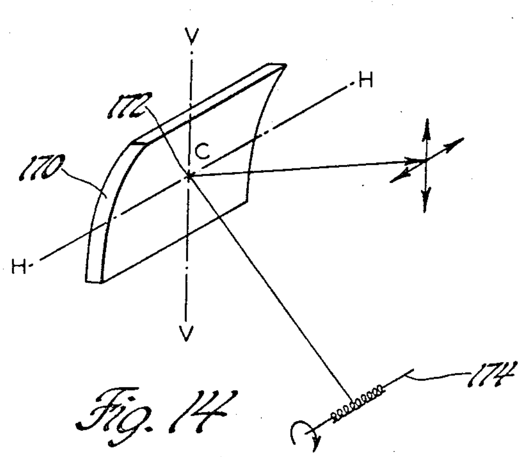


Fig. 14

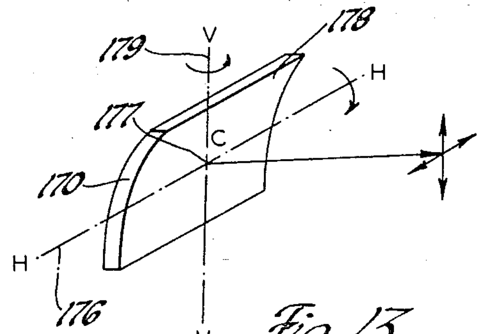


Fig. 13

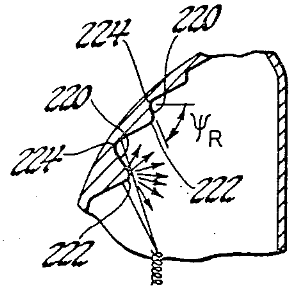


Fig. 15

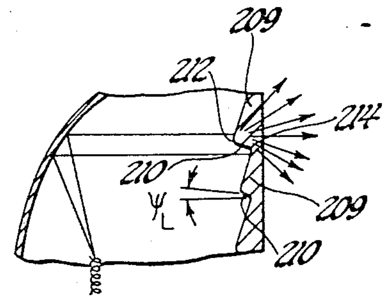


Fig. 16

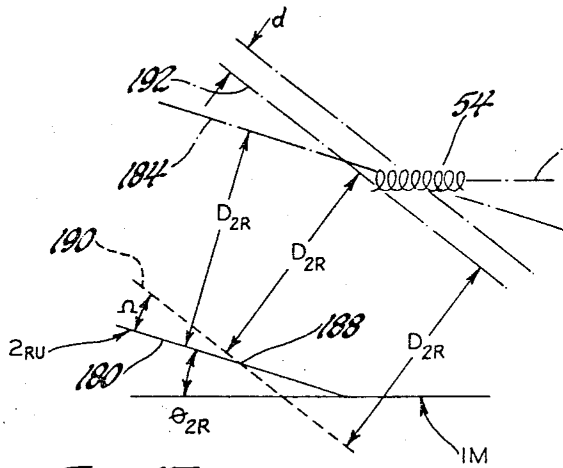


Fig. 17

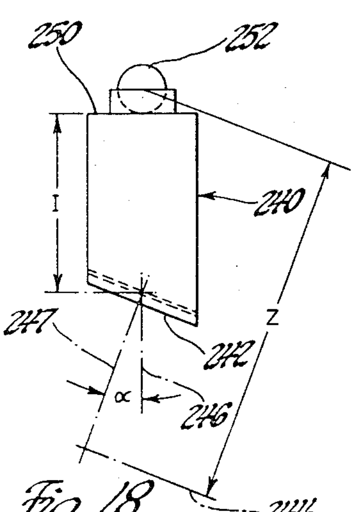


Fig. 18

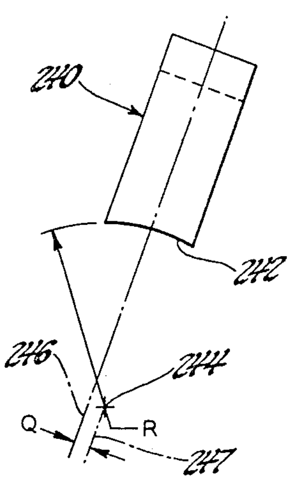


Fig. 19

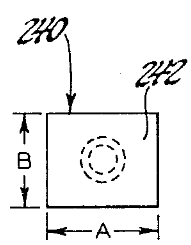


Fig. 20

METHOD OF MAKING A FACETED REFLECTOR FOR A LIGHTING UNIT

This invention relates to a method of making reflectors, and in particular, to a method for making the reflectors of lighting units such as motor vehicle lamp assemblies.

Motor vehicle lighting units of the types used as headlamps, taillamps, cornering lamps, and backup lamps normally include a reflector and a lens defining a sealed lamp envelope in which a coiled filament light source is positioned. The reflector is provided with a suitably curved surface for collecting illumination from the light source and redirecting the same outwardly onto the lens. A light focusing optical system in the form of dioptic and catadioptic rings, flutes, and prisms is normally provided on the lens for horizontally and vertically distributing the illumination outwardly from the lamp.

One of the primary factors affecting the quality of the projected beam in these lighting units is the ability of the reflector to intercept and direct toward the lens the light which is emitted from the source. This capability of intercepting source illumination, commonly designated the reflector light collection efficiency, is defined as the fraction of total emitted light that is intercepted by the reflector. The collection efficiency for a given reflector is dependent on many structural characteristics of the lamp such as reflector curvature, frontal area, and depth as well as the location of the filament with respect to the reflector. As a general statement, the efficiency is proportional to the total solid angle subtended by the reflector surface as referenced to the light source. Moreover, for a given reflector volume the efficiency is dependent on the reflector shape or curvature which also influences the quality of the projected beam. Thus, spherical surfaces, while having an excellent light collecting efficiency, provide little control over the reflected beam. Parabolic surfaces provide slightly greater beam control but generally have a lower light collecting efficiency than the spherical surfaces. Paraboloidal surfaces, on the other hand, yield high collecting efficiencies and directional beam control and, for this reason, have found the greatest acceptance as reflecting surfaces for projected beam lamps.

The optical performance for a paraboloidal reflector is, to a large extent, determined by the position of the filament and the overall size and focal length of the reflector. The efficiency as calculated by conventional means, however, is merely an approximation inasmuch as the filament normally has a finite length and cannot be accurately located at the reflector focal point. For this reason, the efficiency of a typical commercial lighting unit may be considerably below the calculated value. Additionally, the optical performance of a paraboloidal surface for a given focal length and reflector depth is greatly influenced by frontal configuration. By way of example, a right circular section will produce the maximum collection efficiency with alterations of the configuration, particularly from intentionally noncircular frontal profiles, markedly reducing the reflector efficiency. While the resultant loss can be partially recovered by increasing the operating temperature and hence the illumination from the filament, these required compensating manipulations present a definite hindrance to the development of noncircular high performance lamps.

The overall quality of the projected beam from the lamp assembly is further affected by the optical characteristics of the lens used to impart directional control to the reflected beam. More specifically, the lens is typically comprised of numerous optical bodies which refract the incident light to produce an undesirable scattering or glare. Generally, this type of glare is associated with the juncture between the adjacent optical bodies in the lamp lens. The two edges produced during the lens manufacture have radii which uncontrollably scatter illumination throughout the lens thereby producing glare and, additionally, reducing the output efficiency of the lamp assembly.

Accordingly, an object of the present invention is to provide a method for making a reflector which projects a predetermined lighting pattern by individually orienting a plurality of discrete reflecting surfaces with respect to a light source.

Another object of the present invention is to provide a method of making a reflector having a variable frontal configuration and depth without an accompanying impairment of optical performance.

A further object of the present invention is to provide a method for making a reflector having optics entirely on its reflecting surface for predictably distributing a light beam in a desired illumination pattern by segmenting the reflector into a plurality of discrete facets, and individually orienting the facet to project undistorted images toward select portions of the pattern.

Yet another object of the present invention is to provide a method for making a reflector of a lighting unit wherein glare is significantly reduced by positioning the junctures of contiguous facets so as to shadow uncontrolled reflecting surfaces from the light source.

Still another object of the present invention is to produce an improved method of making a projected beam lighting unit having better pattern controls and sharper cut-offs by incorporating beam control entirely on a first optical surface.

Generally, the above objects are accomplished by providing a reflector of predetermined frontal area and depth with a plurality of discrete reflecting facets. Each facet is individually oriented with respect to the light source so as to project an undistorted reflection of the latter in a prescribed direction. The superposition of the individual reflections is then utilized to produce a given illumination pattern. By combining a sufficient number of reflector facets of the proper size, shape, and orientation, a composite intensity contour can be synthesized within prescribed limits. Such a reflector can incorporate a number of geometrical surfaces. For example, paraboloidal sections, circular cylinders, or parabolic cylinders, or a combination thereof may be individually or collectively used to best synthesize the desired pattern. After selection of the facet curvature necessary to fulfill the desired optical prescription, the facets are arrayed with respect to adjacent facets and the light source so as to expose only one light diffusing structural radius to emitted light thereby reducing glare due to uncontrolled reflection.

The aforementioned features and advantages of the present invention will be apparent to one skilled in the art upon reading the following detailed description, reference being made to the accompanying drawings in which:

FIG. 1 is a front perspective view of a motor vehicle having a lighting system including a cornering lamp made in accordance with the present invention;

FIG. 2 is an enlarged view taken along line 2—2 of FIG. 1;

FIG. 3 is a view taken along line 3—3 of FIG. 2;

FIG. 4 is a two dimensional intensity contour of the illumination pattern for the cornering lamp;

FIG. 5 is a three dimensional intensity contour of the illumination pattern shown in FIG. 4;

FIG. 6 is a view taken along line 6—6 of FIG. 1;

FIG. 7 is a schematic view illustrating horizontal image spread of a facet reflecting surface;

FIG. 8 is a schematic view illustrating vertical image spread of a facet reflecting surface;

FIG. 9 is a schematic view illustrating the circular approximation of a parabolic surface;

FIG. 10 is a schematic view illustrating selective angular positioning of the facet reflecting surfaces;

FIG. 11 is a horizontal schematic view illustrating initial angular positioning of the facets;

FIG. 12 is a view similar to FIG. 11 illustrating shadowing of uncontrolled reflecting surfaces;

FIG. 13 is a schematic view illustrating one method of facet rotation;

FIG. 14 is a view similar to FIG. 13 illustrating an alternated method of facet rotation;

FIG. 15 is a view illustrating the glare from a faceted reflector;

FIG. 16 is a view illustrating the glare from a lens;

FIG. 17 is a view illustrating the effect of the facet angle on the focal length position;

FIG. 18 is the top view of a facet die segment;

FIG. 19 is the side view of the die segment of FIG. 18; and

FIG. 20 is the front view of the die segment of FIG. 18.

Referring to FIG. 1, there is shown a motor vehicle 10 having a lighting system including headlamps 12, combination turn signal and parking lamps 14, and cornering lamps 16. All of the lamps are symmetrically disposed on opposite sides of a longitudinal vehicle axis 18. Each of the aforementioned lamps is designed to project the illumination outwardly of the vehicle into a predetermined illumination pattern as prescribed by applicable standards. Thus, the headlamps 12 are used as a major lighting device to provide general illumination ahead of the vehicle during driving conditions of reduced visibility. The turn signal lamps 14 flash in unison with corresponding rear lamps to indicate the intention of the vehicle to change direction toward the side on which the signal lamp is flashing. The parking lamps 14 on both sides of the vehicle are simultaneously steadily energized to indicate the overall width and length of the motor vehicle. The cornering lamps 16 are selectively steadily burning lamps used in conjunction with the turn signal system to supplement the headlamps 12 by providing additional illumination in the direction of a contemplated turn.

Referring to FIGS. 2, 3, and 6, the cornering lamps 16 are mounted in an opening 20 formed in the side of the vehicle at the lower forward portion of the vehicle front fender 22. Each lamp 16 generally comprises a reflector 24, a light source 26 carried by the reflector 24, and a lens 28, the outer periphery of which is bounded by the edge of the opening 20. The reflector 24 includes a peripheral groove 30 which retains a resilient gasket 32. The lens 28 includes a rearwardly projecting marginal lip 34 that engages the gasket 32 to form a sealed envelope 36 defined by the interior surfaces of the lens 28 and the reflector 24.

The lens 28 includes a marginal flange 38 on which a second resilient gasket 40 is positioned. The cornering lamp 16 is positioned at the opening 20 with an inwardly turned edge of the latter resiliently engaging the gasket 40. The cornering lamp 16 is then fixedly secured in this position by fasteners 42 which clamp outwardly projecting mounting ears 44 at the sides of the reflector 24 to spaced brackets 46 fixed to the interior surface of the front fender 22.

The lens 28 is formed of a light transmissive material such as plastic and has a clear front window 48. When used with the subject faceted reflector, the lens 28 may be optically passive and require none of corrective optical means conventionally used on lamp lenses. However, the window 48 may include optical flutes or prisms for additionally distributing the illumination controlled by the reflector 24, if the same are deemed desirable.

The light source 26 is horizontally and vertically centered with respect to the reflector 24 and generally includes a socket 50 and a lamp 52 having a helically coiled filament 54. The socket 50 includes a pair of leads 56 which are electrically connected to a power supply (not shown) such as the vehicle battery for energizing the filament 54. While the light source 26 may take various forms depending on the type of lighting unit in which it is incorporated, appropriate means should be provided for accurately locating the filament 54 in the lamp envelope 36.

The reflector 24 includes a dish-shaped base section 58 having a first optical surface in the form of a front faceted surface, generally indicated by reference numeral 60, which is suitably coated or otherwise prepared to intercept and reflect light emitted from the filament 54. More specifically, the faceted surface 60 may be aluminized, silvered, or metallically coated as by chrome deposition to provide the aforementioned reflecting capabilities.

The faceted surface 60 is defined by a plurality of individually oriented discrete facets which will be, for purposes of description, hereinafter designated by subscripts depending on their position with respect to the filament 54. Thus, as shown in FIG. 3, the faceted surface 60 is horizontally divided into three rows, a middle row bearing the subscript M, an upper row bearing the subscript U, and a lower row bearing subscript D. The faceted surface 60 is vertically divided into seven columns, the middle column being designated 1 with adjacent rows on the left being successively designated as 2L, 3L, and 4L and adjacent rows on the right being successively designated as 2R, 3R, and 4R. By way of example, the middle row successively contains the following facets: 4LM, 3LM, 2LM, 1M, 2RM, 3RM, and 4RM. Each of the aforementioned facets is positioned within the envelope 36 with respect to the filament 54 such that their cumulative effect is to horizontally and vertically distribute emitted light from the source 26 in a predetermined illumination pattern.

More specifically, all facets are deliberately positioned behind the light source **26** so as to reflect an image of the filament **54**. In this manner, the illumination pattern produced by the complete reflector is the sum or superposition of all the individual images. The particular contribution of the individual facet is determined by its projected pattern which has characteristics dependent on its shape and location with respect to the light source **26**. By combining facets in a sufficient number of the proper size, shape, and orientation, the contemplated illumination pattern can be accurately synthesized.

Experience, in this respect, has indicated that the intensity pattern for a cornering lamp should provide a wide illumination pattern in a horizontal plane and a relatively narrow or concentrated pattern in a vertical plane. Accordingly, to most conveniently accomplish this result, the major axis **70** of the lamp **16** is horizontally disposed at a suitable angle to the longitudinal vehicle axis **18** and the minor axis **72** is vertical and mutually perpendicular to the major axis **70** and vehicle axis **18**.

The intensity or isocandle contour for the cornering lamp **16** positioned on the right side of the vehicle is shown in FIGS. **4** and **5** wherein a high or peak intensity zone **80** is established slightly below the major axis **70** of the lamp and angularly displaced with respect to the longitudinal vehicle axis **18**. The high intensity zone **80** is circumscribed by zones of decreasing intensity, designated successively **82**, **84**, **86**, and **88**. For purposes of future reference, the 900 candlepower (cp) peak intensity zone **80** is positioned at 35° from the longitudinal vehicle axis **18** and 1.5° below the lamp major axis **70**. The lamp **16**, as referenced to the vehicle longitudinal axis **18**, has a reflector axis **120** angularly displaced 45° outwardly and 2.5° downwardly. The center of the overall intensity pattern is determined by the 0 to 100 cp slice pattern which has a relatively narrow vertical spread V and relatively large horizontal spread H. More particularly, in the preferred embodiment, the horizontal spread H is approximately 50° and subtends the sector from 20° to 70°. The vertical spread V is approximately 5° and extends downwardly 5° from the horizontal lamp major axis **70**.

The cornering lamp **16**, as previously mentioned, includes a plurality of individually oriented facets which accurately synthesize the above-described illumination pattern within prescribed limits. The exact size, curvature, and orientation of the individual facets is determined by a number of design requirements, foremost of which are the resultant light pattern; the peripheral configuration of the reflector; the depth into which the reflector must fit; the filament configuration; the position of the filament with respect to the reflector; and the temperature profile on the filament.

With the wide horizontal and narrow vertical spreads required in cornering lamps, a filament positioned with its longitudinal axis in a horizontal plane in combination with reflector facets which are parabolic or circular cylinders having axes parallel to the horizontal plane has been found to provide the most satisfactory results.

The peripheral configuration and depth of the reflector is normally determined in advance by styling and other design configurations. As such, the basic size of

the lamp reflector will be subjectively influenced by aesthetics, the required intensity profile, and the practical limits of reflector efficiency and focal length. Inasmuch as lamps with a collection efficiency of less than 30 percent provide unacceptably low performance, this figure will specify a reflector height once the width and focal length of the reflector are given. The width is usually prescribed by the styling esthetics insofar as the same is compatible with the practical performance limits.

Regardless of the many considerations noted above, the hereinafter described method of synthesizing a desired illumination pattern restricts the actual reflector size only to the extent that the required precision of the final pattern necessarily controls the number of facets and their accompanying reflector area. The reflector form also, to a large extent, determines the location of the filament and generally establishes the size of the central facet which constitutes the basic building block in determining the boundaries of the desired illumination pattern. The focal length of this central facet will hereinafter be regarded as the focal length of the reflector.

Other criteria for effecting initial design of the reflector are the filament candlepower required to supply the energy for the illumination pattern and the practicability of placing the filament at the focal point of the reflecting surface. Generally, this last criterion establishes a minimum focal length of about 1 inch for motor vehicle lamps. Insofar as the filament energy output is concerned, the operating temperature and lifetime requirements of tungsten filaments require a cylindrical helically wound configuration which satisfies the specified candlepower requirements.

Once the focal length is set, the depth is determined from the buildup of the facets. In this respect, the depth can be approximated by computing the depth for a paraboloid of a given frontal area having the same focal length as the faceted reflector. Alternately, the depth can be specified within the limits and the facets designed to fit within the thus prescribed frontal area and depth. This last method of building up the pattern is the most confining, of course, and may produce the least desirable fit of the desired pattern.

The exact number of facets chosen for a given reflector depends upon the permissible size of the reflector, the shape of the desired intensity pattern, and the precision to which the pattern must be fitted. The size of the facets, in turn, is determined by the size of the desired intensity pattern. The shape and orientation of the facets are primarily controlled by the relative position of the various intensity zones within the overall illumination pattern.

Regarding the optical characteristics of the facets, as shown in FIGS. **7** and **8**, a representative facet **100** having a parabolic cylindrical reflecting surface **102** will distribute light from a filament **104** through a horizontal image spread X. The magnitude of the spread X will be conventionally optically determined by the width of the facet **100**, the distance between the filament **104** and the reflecting surface **102**, as well as the overall length and configuration of the filament **104**. The reflecting surface **102** will produce vertical image spread Y, the value of which is determined by the subtended angle Φ of the surface **102** with respect to filament 104, the distance between the reflecting surface 102 and the filament 104, the curvature of the reflecting surface 102, and the diameter of the filament 104. The same relationships generally hold true for the other contemplated reflecting surfaces such as paraboloidal, spherical, cylindrical, or elliptical.

With the above guidelines, the optical prescription for the lamp 16 proceeds by dividing the idealized illumination pattern in constant intensity regions, as shown in FIGS. 4 and 5, and thereafter matching the shape and intensity of the images from the several facets with specific regions of the pattern following two criteria insofar as the shape of each individual facet pattern is concerned. First, the total spread of the image with an individual facet should not exceed either horizontal spread H or the vertical spread V of the desired resultant pattern. Second, the illumination from each facet must be directed toward an appropriate position in the resultant pattern.

In particular, the prescription for the subject cornering lamp pattern is established by initially prescribing the central column of facets 1M, 1U, and 1D. Inasmuch as this central column is virtually unrestrained insofar as width and orientati on are concerned and need only satisfy the first-mentioned criteria, their facets are, for convenience, provided with cylindrical reflecting surfaces having axes parallel to the axis of the filament 54. The central facet 1M represents the basic facet in the synthesis of the reflector and is selected to produce an image as wide and as high as the lowest considered intensity zone. In the present instance, this zone is the 100 cp. slice of the resultant beam and is approximately 50° by 5°. The sizing and placement of this facet is most easily fulfilled by using a circular cylinder having its focal length coaxial with the filament 54. As shown in FIG. 11, the perpendicular bisector of the center or primary facet 1M is colinear with the actual lamp axis 120. This orientation directs the illumination toward the geometrical center of the intensity pattern, 45° horizontal and 2.5° down vertical (FIG. 5).

With the width and height of the basic facet thus determined, the sizes of the upper and lower facets, 1U and 1D, are established. For convenience of manufacture, the width of these facets is selected to be the same as the width of the basic facet 1M. However, the height of these facets will generally be less than the height of the center facet. Accordingly, the facets will produce an image as wide as the 100 cp. pattern but with a considerably narrower vertical band.

Because of the ability of the parabola to project a confined bearing the facets 1U and 1D are most suitably parabolic cylinders having the filament 54 at their respective focal lengths. However, in order to simplify construction, inasmuch as a parabolic cylindrical surface is considerably more difficult to manufacture than the circular cylindrical surface, the present invention uses a circular approximation of these surfaces. By way of example, the radius of an approximating circular surface can be represented in the following manner taken with reference to FIG. 9 wherein a parabolic surface 122 having a focal length P is approximated by a circular surface 124 having a radius R and a center C at (Yo, Zo) according to the formulas:

$$Yo = -YZ/P$$
$$Zo = 3Z + 2P$$
$$R = [(Y - Yo)^2 + (Z - Zo)^2](1/2)$$

The shape of the circle thus generated matches the parabola at the point (Y,Z) 126 which is taken at the vertical midpoint, $(Y_1 + Y_2)/2$ of the surface. Of course, the degree of approximation diminishes as the distance from point 126 increases. Therefore, the focal point 132 and center of curvature of the circular cylinders are not necessarily in the plane of the filament 54 which is still located at the focal length P of the original parabolic surface 122.

The remaining vertical height of the reflector in the center column is evenly divided between the upper and lower facets 1U and 1D. The images of these facets are directed toward the most intense vertical region, 2.5° down, of the pattern with the center of the facet image centered on the axis 120. The center column of facets thus establishes the lowest intensity region of the desired pattern and partially contributes to the remaining regions. Thereafter, buildup of the reflector proceeds outwardly from the vertical edges of the center column facets.

The length and the height of each facet in the M or middle horizontal row is governed by the length and height of that intensity slice of the total pattern which the facet image is attempting to match. For example, the constant intensity slice 300 cp., FIG. 4, has a horizontal spread of about 40° and a vertical spread of approximately 4° with a peak intensity region which centers at 40° horizontal. Thus, as shown in FIG. 11, the facets are directed toward 40° horizontal with sufficient width for a 40° horizontal spread.

For the initial synthesis, the vertical edges of adjacent facets should be continuous in order to most efficiently utilize the predetermined reflector volume to best initially synthesize the desired pattern. The remaining middle facets are directed toward the peak intensity region of the total pattern 35° horizontal (FIG. 11). Representatively, as shown in FIG. 10, these two requirements orient the 2LM facet or surface 150 at an angle θ_{2L} with respect to the basic facet 1M or line 152 with the facets being commonly joined at vertical edge 154. Insofar as the middle row of facets is concerned, the angle is referred to the plane of the basic facet 1M at the horizontal center line of the lamp. The angle θ_x for each facet is determined by solution of the following equation:

$$\tan(2\theta_x + \psi) = (a + L)/(P - L\tan\theta_x)$$

where

- ψ is the angle between the reflected light ray 156 and the reflector axis 120;
- a is the distance from the reflector axis 120 to the edge 154;
- P is the distance along the axis 120 from the filament 54 to the edge 154; and
- L is the distance between the center of the facet 2LM and the edge 154.

For each of these facets, the radius of curvature, r_{cf}, is equal to twice the distance between the line 152 which comprises the cylindrical surface in the horizontal plane and a second line 158 through the center of the filament 54 parallel to and in the same plane as the first line, or $r_{cf} = 2P$ for facet 1M.

Referring to FIG. 11, the 4RM facet includes a line 160 comprising the cylindrical surface of the facet in the central horizontal plane. A second line 162 passes through the center 164 of the filament 54 and is parallel to and lies in the same plane as line **160**. This spacing establishes a "D-value" or distance D_{4R} between the lines **160** and **162** which is one-half the radius of curvature, r_{cf}, of the facet 4RM. The D-values for the remaining facets in the middle row M are established in a similar manner. For the upper rows U and lower rows D, the facets are circular cylinders which approximate parabolic cylinders in the above-described manner. The focal length P of the initially parabolic cylinder is the D-value of the middle facet in the corresponding column. However, as previously mentioned, when the parabolic cylinder is established, the focal point and the center of curvature of the resulting circular cylinders are not necessarily in the horizontal plane.

The upper or lower facets in a given column are, to a large extent, dependent on the size and position of the middle facet. More specifically, inasmuch as both the middle row of facets and the total lamp height are symmetrical about the horizontal lamp axis, the height of the upper facets, for instance, is the distance between the upper edge of facet **2RM** and the upper vertical edge of the reflector. The width and angle θ_x with respect to the axis of the filament **54** is the same as for the middle facet to minimize boundary gaps. This process is applicable to all the rows and columns of facets to complete initial synthesization of the desired pattern. The pattern thus prescribed, in many instances, provides an acceptable optical performance for the reflector. However, further precision and refinement of the basic reflector surface can be achieved by selectively reorienting the separate facets.

While many repositioning techniques can be used to improve the optical performance of the reflector, the two methods described below significantly improve the illumination pattern while minimizing the required facet movement. In one method, as shown in FIG. **14**, a representative facet **170** as referenced at the geometrical center of the reflecting surface **172** is universally rotated about the focal axis **174**. Alternately, the facet **170** is rotated about a horizontal axis **176** passing through the center **177** of its reflecting surface **178** to produce a vertical shift of the image and about a vertical axis **179** passing through the center **177** to produce horizontal shift of the image. Inasmuch as the latter method generally requires a lesser repositioning of the individual facets to achieve a given improvement in the overall illumination pattern, this method will be hereinafter described.

The aforementioned rotation of the element **170** about its geometrical center causes the focal length of the surface to retreat from a line through the center of the filament **54** thereby distorting the reflected image of the latter. With each incremental shift, the image projected by the reflecting surface will become increasingly distorted. Thus, at some predetermined point, which we have determined to be about 4 percent of the focal length, an unacceptably distorted image will be produced. Therefore, if the shift of the image is greater than this value, a revised facet angle θ and a new radius of curvature r_{cf} for the facet must be established so that the reflected image is once again within prescribed limits of distortion and directed toward the intended position in the illumination pattern.

For example, as shown in FIG. **17**, a facet **180** has an original facet angle θ_{2R} with respect to the axis **182** of the filament **54** and a D-value, D_{2R}, as established between a line **184** through the center of the filament **54** and a parallel line along the reflecting facet **180**. As the surface **180** is rotated about its center **188** through an angle Ω, to a rotated position **190**, the line **192** parallel to the surface **190** placed at the original D-value is shifted an incremental distance d from the center of the filament **54**. To compensate for this displacement, the radius of curvature of the facet is appropriately changed to establish a revised facet D-value, D'_{2R}. By way of example, if the original radius and the facet angle θ for the 2RM facet are 3.065 in. and 54°40°, and the image is to be shifted 10° toward the car axis in the horizontal plane, the facet is rotated 5° about the center of its surface to effect this required shift. However, this movement causes a 0.100 in. inward shift of the facet focal length thereby producing a distorted image. This movement exceeds the aforementioned 4 percent for an undistorted image inasmuch as:

$$\text{shift/focal length} = 0.100/1.5 = 6.7 \text{ percent}$$

This 10° image shift can be accomplished while maintaining the filament on focus by recomputing the facet prescription to a radius of 3.268 and a facet angle of 61°32′.

By either of the above rotational methods, the marginal edges retreat or advance with respect to the edges of adjacent facets. Referring to FIG. **12**, the boundary discontinuities between adjacent facets shown in solid lines produces uncontrolled reflecting surfaces **206** and shadowed reflecting surfaces **208**. The surfaces **206** are exposed to the filament **54** and because they have indiscriminate shapes and positions, scatter the intercepted light thereby causing glare. On the other hand, the surfaces **208** are not exposed to the light and, accordingly, do not present a glare problem.

For the molded lamp components, a minimum draft angle must be provided at the juncture between the facets in order to permit the release of the article from the mold. A conventional lens, as shown in FIG. **16**, having optical flutes **209** or the like formed on an interior surface produces uncontrolled surfaces **210** between exposed edges **212** and **214** produced by the draft angle ψ_L. At each of these edges, the light will be uncontrollably reflected and refracted. However, for the facet reflector shown in FIG. **15**, the required draft angle ψ_R produces releasable, conical surfaces **220** and permits location of adjacent facets such that only one edge **222** is exposed to the light from the filament. The other radius **224** is hidden from the filament and, therefore, does not contribute to glare.

Referring to FIG. **12**, for an arbitrary diepull angle Z between reflector and the lamp axis **120** and the pull line **230**, the uncontrolled surfaces **206** are not deliberately positioned with respect to the filament and thus randomly distribute or scatter illumination. The glare caused by such surfaces is obviated in the present invention by shifting the outward facets rearwardly along the line parallel to the pull line **230** until the juncture surface is hidden or shaded from the filament. The facet angle θ is then recalculated to redirect an undistorted image toward the intended position in the intensity pattern.

When the above operations have been completed, the same is translated into numerical form for construction of a die from which the desired reflectors can be manufactured by conventional forming processes. Each facet, as shown in FIGS. **18** through **20**, will be produced by a die segment **240** having a reflecting surface **242** with a profile width A and a profile height B. The reflecting surface **242** will have a radius R with origin axis **244** displaced a distance Q from the center axis **246** of the segment **240**. The surface normal **247** between the reflecting surface **242** and the axis **244** is inclined at an angle α. The center of the reflecting surface **242** will be displaced a distance I from rear face **250** of the segment **240**. The axis **244** is then displaced a distance Z in the horizontal plane as measured from a reference pin **252** aligned with the axis **246** and having a 0.250 in. diameter. As designated in the aforementioned manner, a lamp assembly having a frontal profile of 2.50 in. × 5.00 in. and a central facet focal length of 1 inch was successively manufactured to produce a resultant light pattern as shown in FIGS. **4** and **5** using the following dimensions.

Facet	A	B	Sin α	Z	R	Q	
1M	0.625	1.250	0.0218	3.250	2.000	0.21	Right
1U	1.625	0.625	−0.1062	3.903	2.694	1.138	Left
1D	0.625	0.625	0.1062	3.901	2.694	1.144	Right
2LM	0.688	1.000	−0.2712	3.413	2.097	0.019	Right
2LU	0.688	0.750	−0.3720	3.903	2.666	1.040	Left
2LD	0.688	0.750	0.3788	3.920	2.666	0.988	Right
2RM	0.688	1.000	0.2506	3.378	2.090	0.015	Left
2RU	0.688	0.750	0.2197	3.942	2.633	1.020	Right
2RD	0.688	0.750	−0.2346	3.939	2.663	1.015	Left
3LM	0.750	1.000	−0.6155	3.839	2.440	0.019	Right
3LU	0.750	0.750	−0.6473	4.260	2.925	0.983	Left
3LD	0.750	0.750	0.6481	4.269	2.925	0.954	Right
3RM	0.750	1.000	0.36574	3.748	2.296	0.034	Right
3RU	0.750	0.750	0.3746	4.362	2.901	1.048	Right
3RD	0.750	0.750	−0.3926	4.359	2.901	1.020	Left
4LM	0.750	1.000	−0.8161	4.556	3.065	0.047	Right
4LU	0.750	0.750	−0.8189	4.919	3.447	0.983	Left
4LD	0.750	0.750	−0.8179	4.946	2.447	0.900	Right
4RM	0.750	1.000	0.5033	4.374	2.706	0.019	Left
4RU	0.750	0.750	0.5253	4.785	3.130	0.923	Right
4RD	0.750	0.750	−0.5249	4.769	3.130	0.973	Left

The instruction left or right in the last column of the table refers to the direction of the center of the radius **244** from the facet centerline **246** (distance Q) as viewed in FIG. 19.

Although only one form of this invention has been shown and described, other forms will be readily apparent to those skilled in the art. Therefore, it is not intended to limit the scope of this invention by the embodiment selected for the purpose of this disclosure but only by the claims which follow.

What is claimed is:

1. A method of making a faceted reflector for projecting a predetermined illumination pattern from a light source, comprising the steps of; dividing said reflector into a plurality of discrete facets; establishing initial light focusing reflecting surfaces for said facets; positioning each reflecting surface in light focusing relationship with respect to the light source whereby the facet projects an undistorted image of the light source and directing said undistorted image toward select portions of said illumination pattern such that the superposition of said undistorted images synthesizes the illumination pattern; and recurving a portion of the initial light focusing reflecting surfaces to the form of right circular cylinders approximating said initial light focusing reflecting surfaces.

2. A method of making a reflector having optics entirely on its reflecting surface and vertically distributing a light beam from a light source in a desired illumination pattern, comprising the steps of:

a. prescribing a frontal profile for the reflector of a generally desired height and width;
b. establishing a focal length for said reflector to provide a generally desired depth;
c. dividing said profile into discrete facets;
d. establishing a light focusing reflecting surface for each facet having a curvature focused with respect to the source;
e. dividing an idealized illumination pattern into varying intensity regions;
f. establishing a reflecting area for a basic reflecting surface sufficient to produce an image covering the lowest considered intensity region;
g. establishing areas for the remaining reflecting surfaces to produce images having image spreads and intensities contributing to the attainment of said desired illumination pattern in said varying intensity regions;
h. individually orienting each reflecting surface with respect to the light source so as to project an undistorted image of the latter toward said select portions of said varying intensity regions whereby the projected image from each facet individually contributes to the attainment for the resultant lighting pattern;
i. revising the orientation of individual facets by select rotative movement with respect to the light source so as to increase the degree of compliance with the desired illumination pattern;
j. repositioning and recurving the individual facets subject to said revising to compensate for image distortion occasioned by said revising;
k. and further repositioning the facets and reestablishing the curvatures with respect to contiguous facets and the light source so as to limit exposure of glare producing uncontrolled reflecting surfaces to the light source thereby reducing glare due to scattered illumination.

3. A method of making a faceted reflector for distributing illumination from a light source in a desired horizontal and vertical illumination pattern having varying intensity regions, comprising the steps of:

a. prescribing a frontal profile of a given height and width for the reflector, said profile having sufficient area for project illumination of requisite intensity throughout the contemplated pattern;
b. establishing a basic facet having a curvature in focused relationship with the source and a width and a height sufficient to provide a horizontal and vertical distribution of illumination throughout the lowest considered intensity region;
c. establishing the curvatures, widths, and heights for the remaining facets to horizontally and vertically distribute illumination in select portions of said varying intensity regions in accordance with the desired resultant distribution;
d. positioning each facet with respect to the light source so as to project an undistorted image of the light source towards select portions of said pattern;
e. altering the individual facet positions by select rotative movement about the center of the facet

with respect to the light source so as to increase the degree of compliance with the desired lighting pattern;

f. repositioning and recurving the individual facets affected by said altering to return the projected images to undistorted reflections;

g. further repositioning the facets and reestablishing curvatures with respect to contiguous facets and the light source so as to limit exposure to the light source of the glare producing uncontrolled surfaces connecting the facets thereby reducing glare due to scattered illumination; and

h. further recurving said facets to the form of right circular cylinders which approximate the original light focusing curvatures.

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