# United States Patent [19]

**Heenan et al.**

[11] **3,818,218**

[45] **June 18, 1974**


[54] **LANTERN**


[75] Inventors: **Sidney A. Heenan,** Park Ridge, Ill.; **Joseph A. Ciccolella,** Summit, N.J.; **Norbert Majewski,** Elk Groove Village; **Anthony J. Montalbano,** Des Plaines, both of Ill.

[73] Assignee: **Amerace Esna Corporation,** Union, N.J.



[22] Filed: **Oct. 25, 1972**

[21] Appl. No.: **300,757**

**Related U.S. Application Data**

[62] Division of Ser. No. 185,245, Sept. 30, 1971.

[52] **U.S. Cl.**..... **240/41.3,** 240/41.35 R, 240/41.36, 240/41.38 R, 240/93, 240/103 R, 240/106 R, 350/102, 350/103, 350/106

[51] **Int. Cl.**..... **F21v 13/04,** F21v 7/00

[58] **Field of Search**..... 240/41.3, 41.36, 41.38, 240/44.2, 44.26, 93, 103, 106, 106.1, 1.2; 350/102, 103, 106, 97



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*Primary Examiner*—Richard M. Sheer

*Attorney, Agent, or Firm*—Prangley, Dithmar, Vogel, Sandler & Stotland



[57] **ABSTRACT**

A lantern includes a device for condensing light rays in at least one direction and a part-spherical, cube-corner reflector having radially directed cube axes. Light rays from a light source disposed at the focal point of the condensing device and approximately at the center of curvature of the reflector impinge on the reflector and are returned back to the source. The device condenses in at least one direction both the light emanating directly from the source and the light retrodirectively returned to the source.


**27 Claims, 58 Drawing Figures**

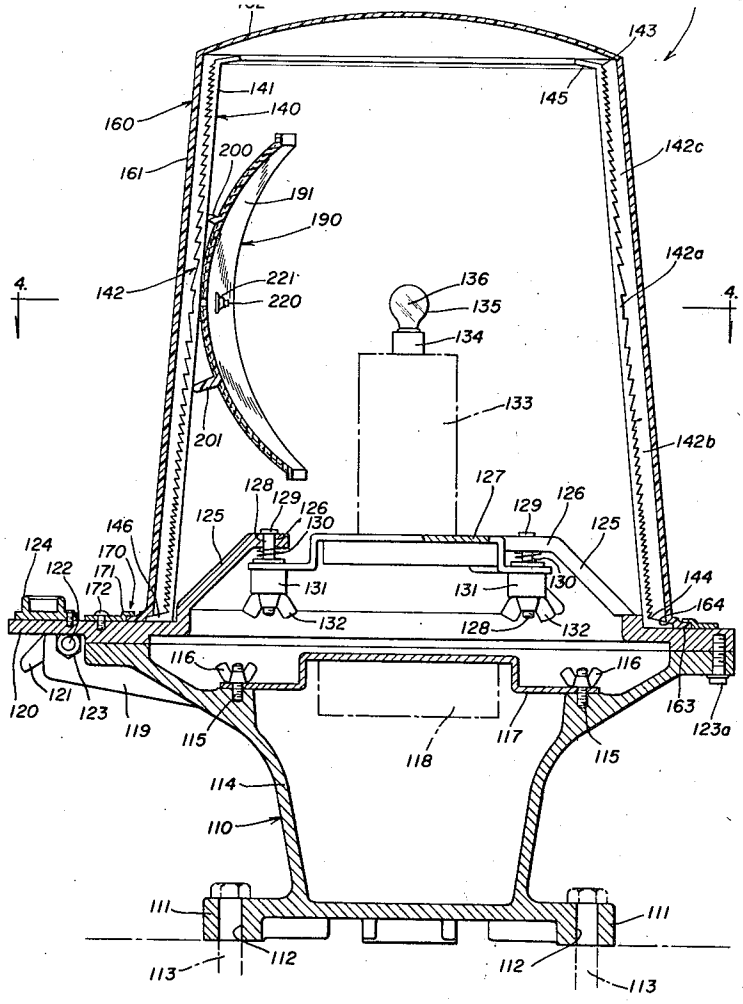


FIG. 1

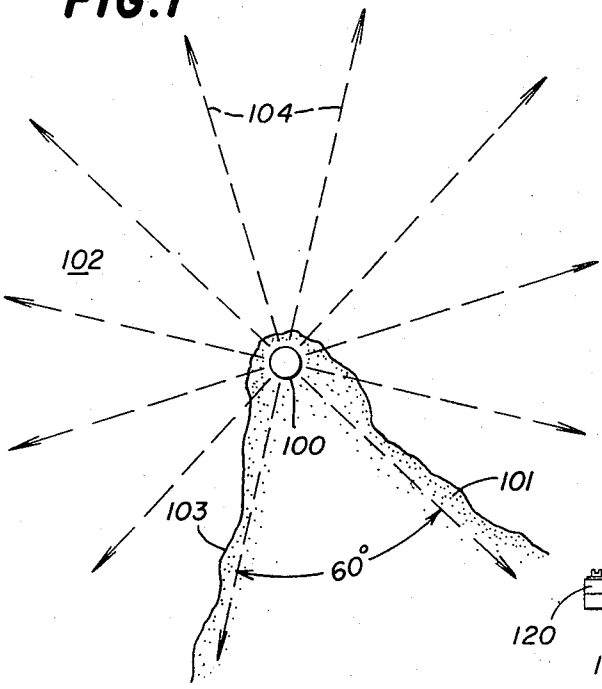



FIG. 2

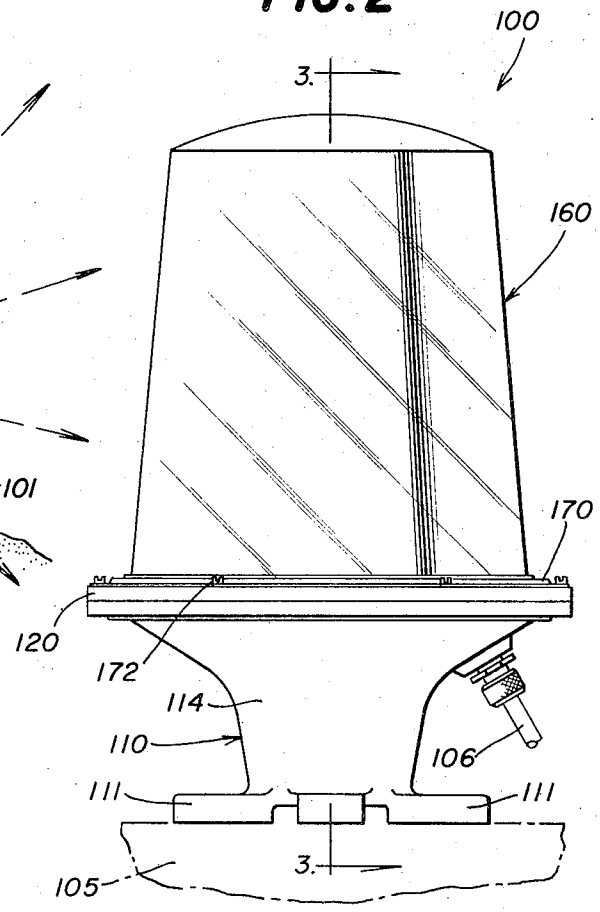



FIG. 22A

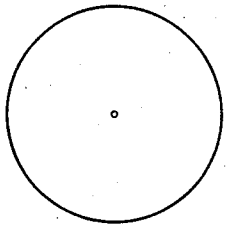


FIG. 22B

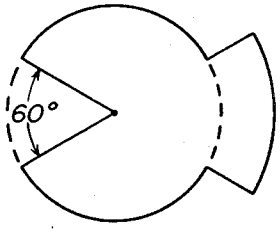



FIG. 22C

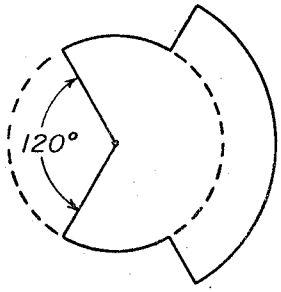



FIG. 22D

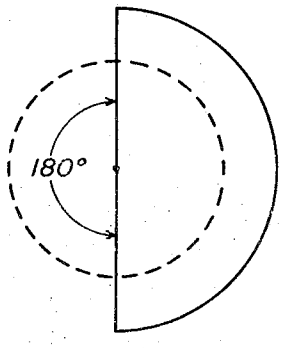


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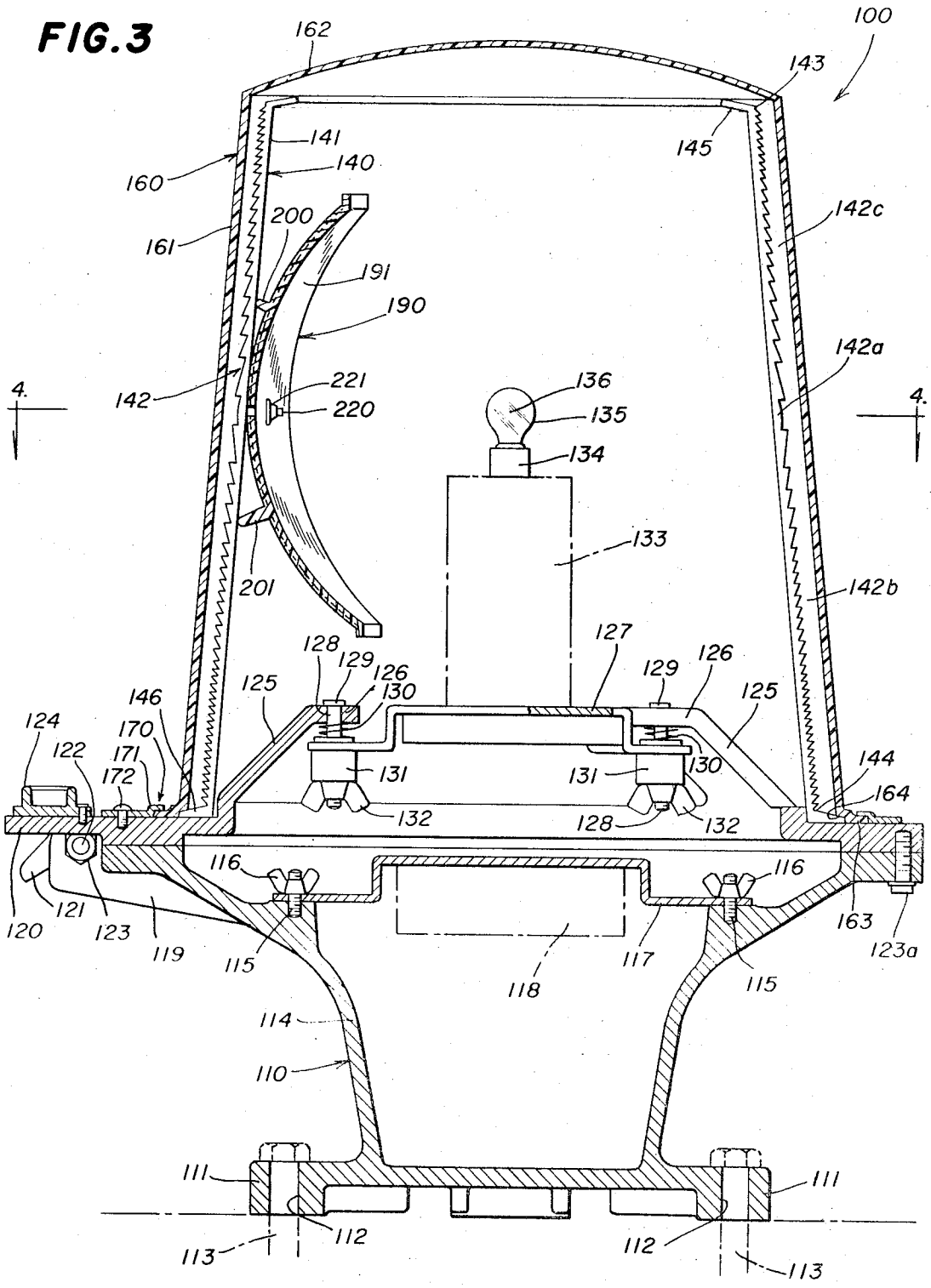

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FIG. 4

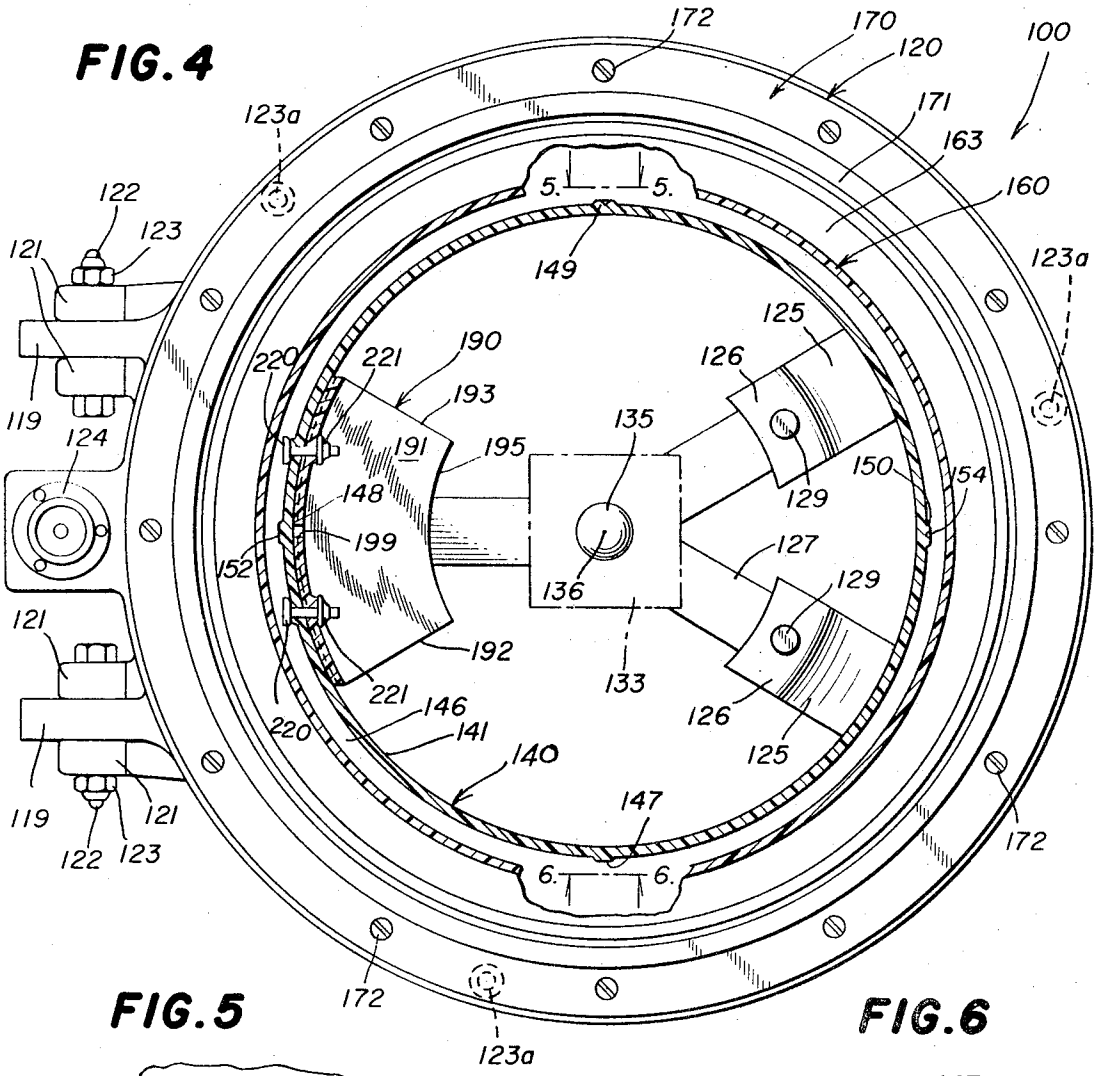



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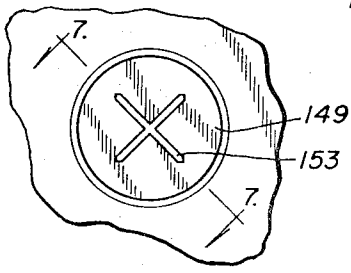



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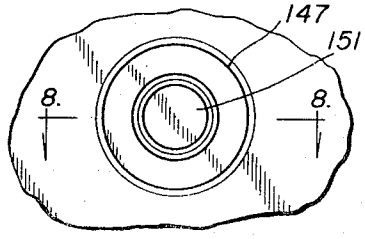



FIG. 7

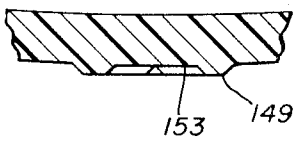



FIG. 8

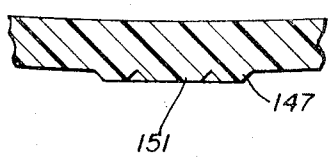


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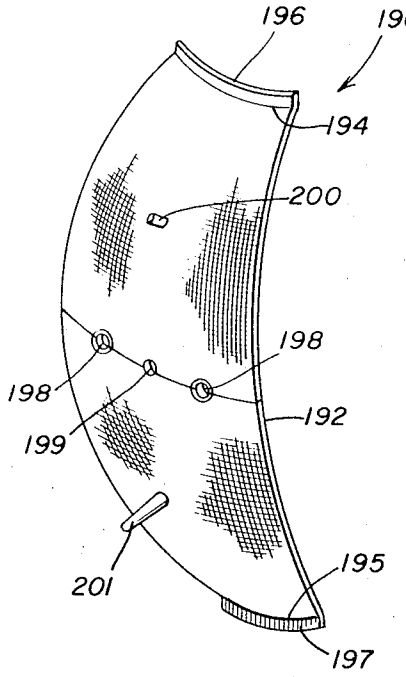



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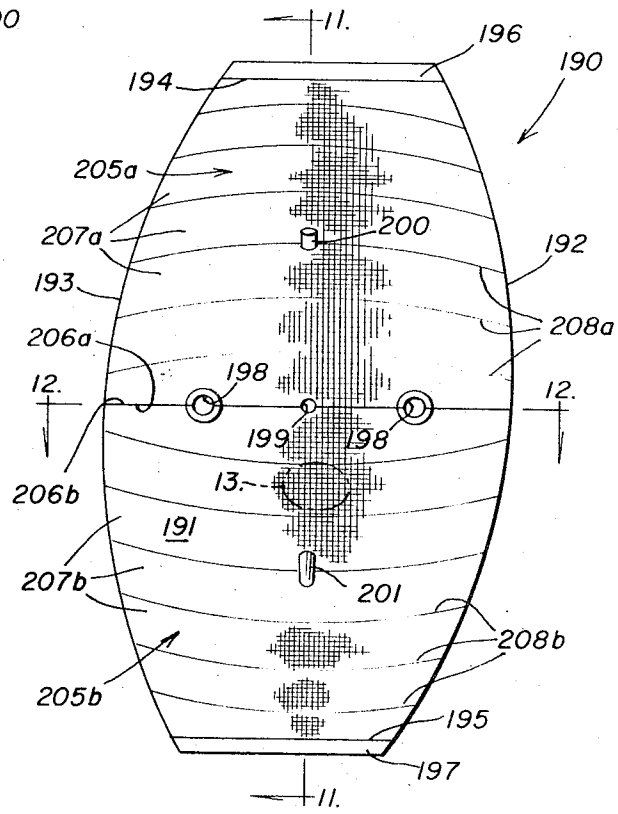



FIG. 11

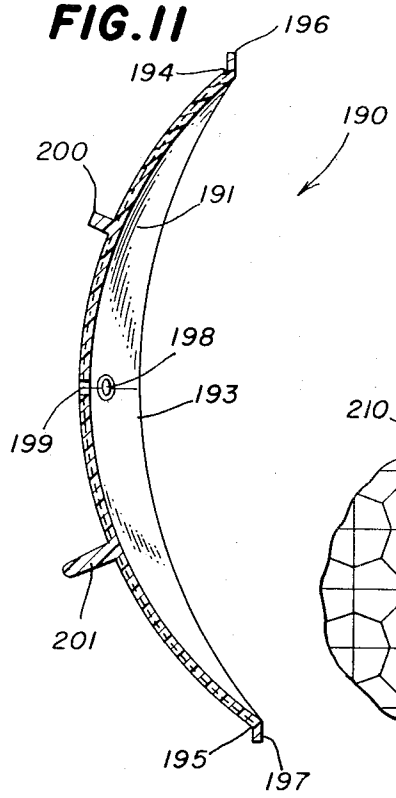



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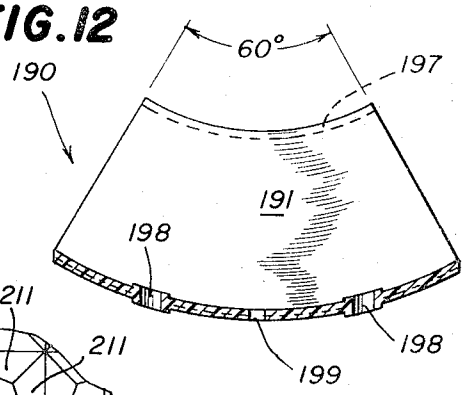



FIG. 13

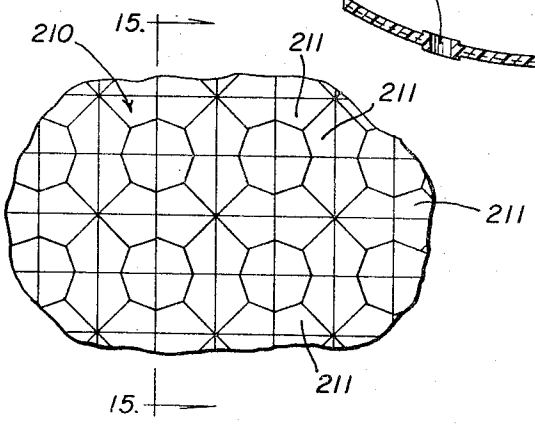


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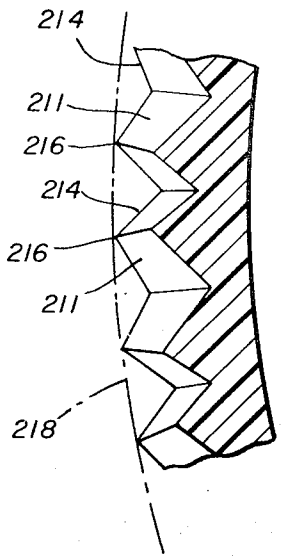



FIG. 14

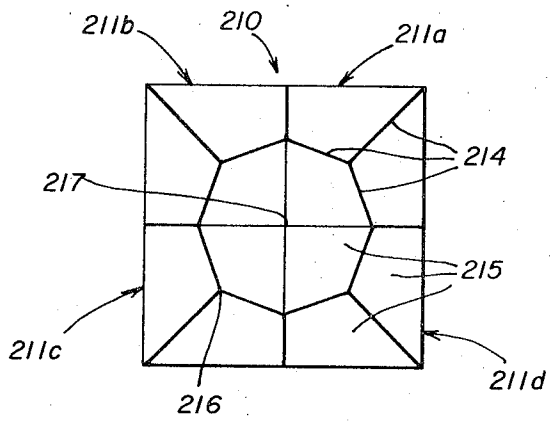



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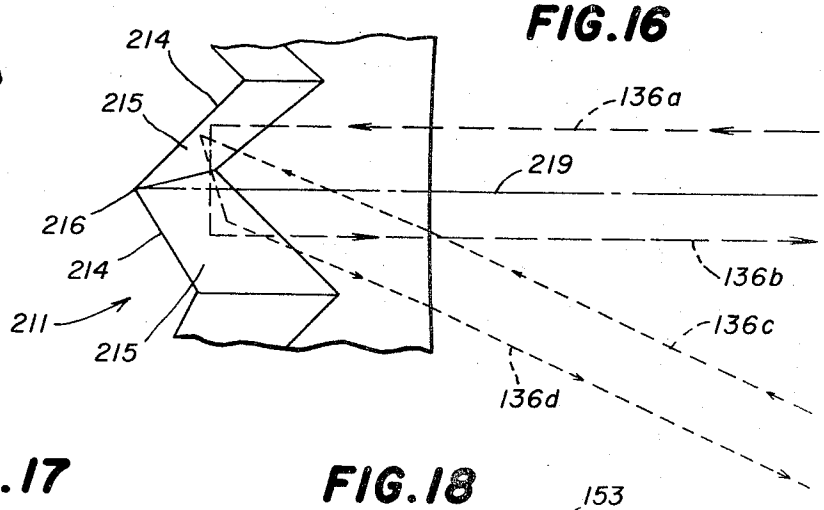



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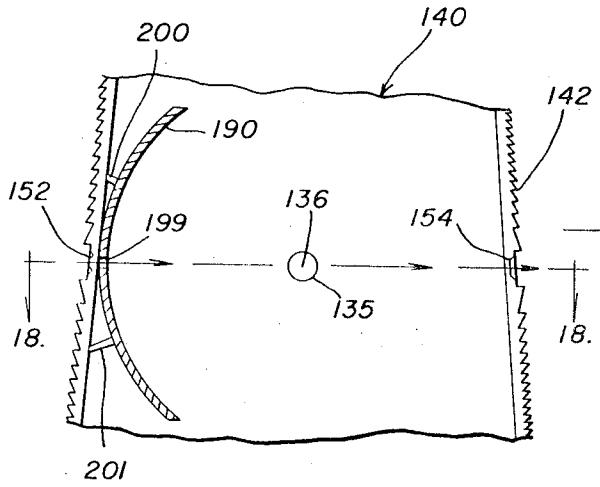



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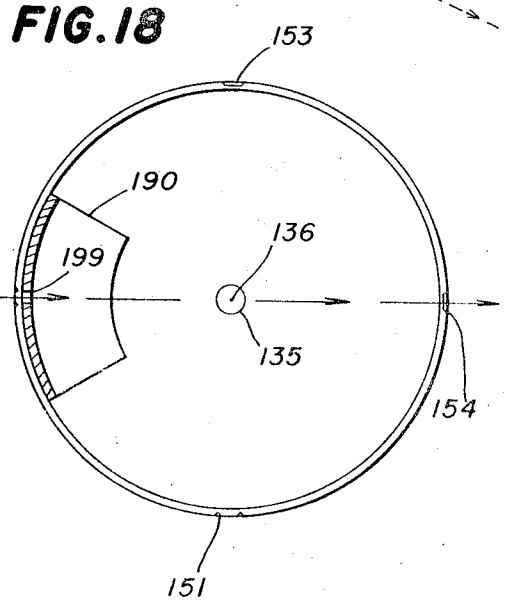


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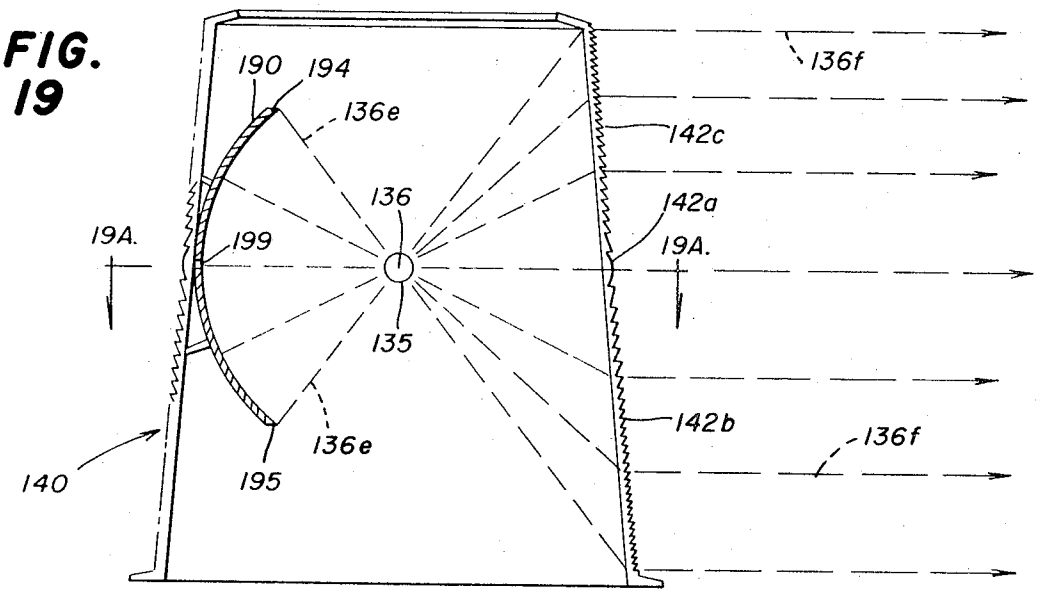



FIG. 19A

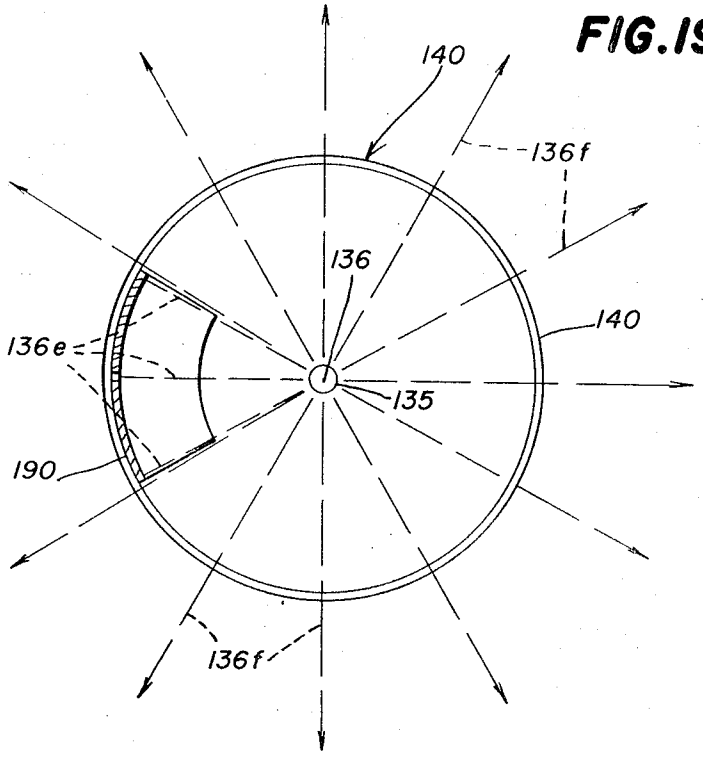


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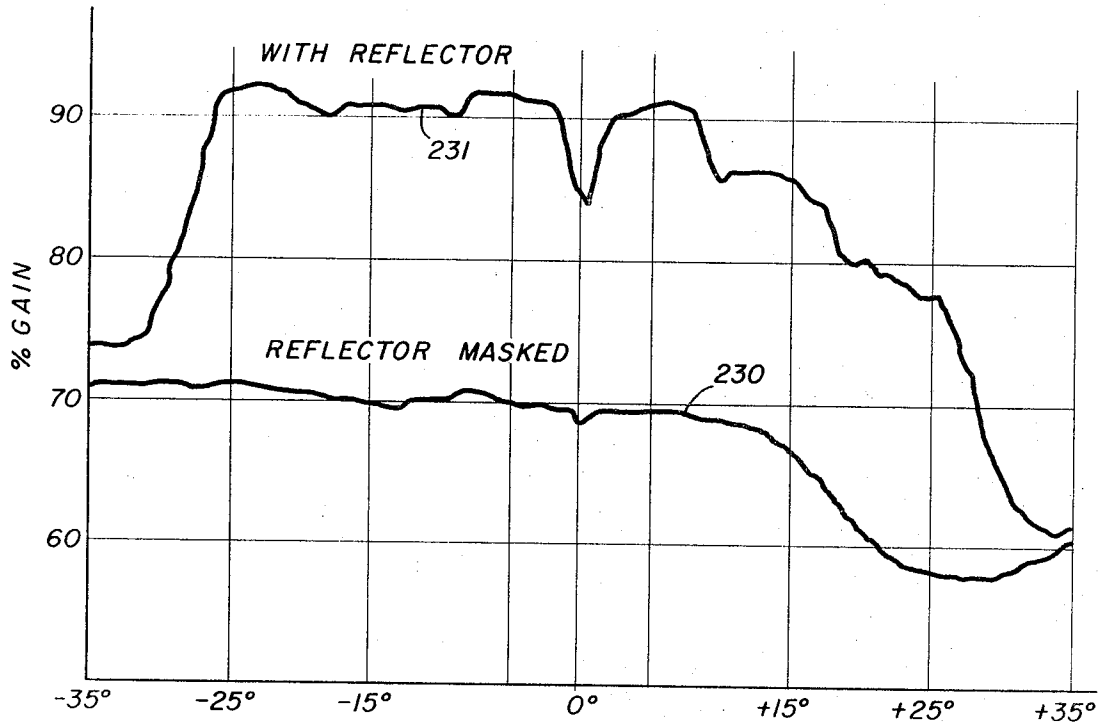

WITH REFLECTOR
231
REFLECTOR MASKED
230
% GAIN
90
80
70
60
-35°
-25°
-15°
0°
+15°
+25°
+35°

FIG. 21

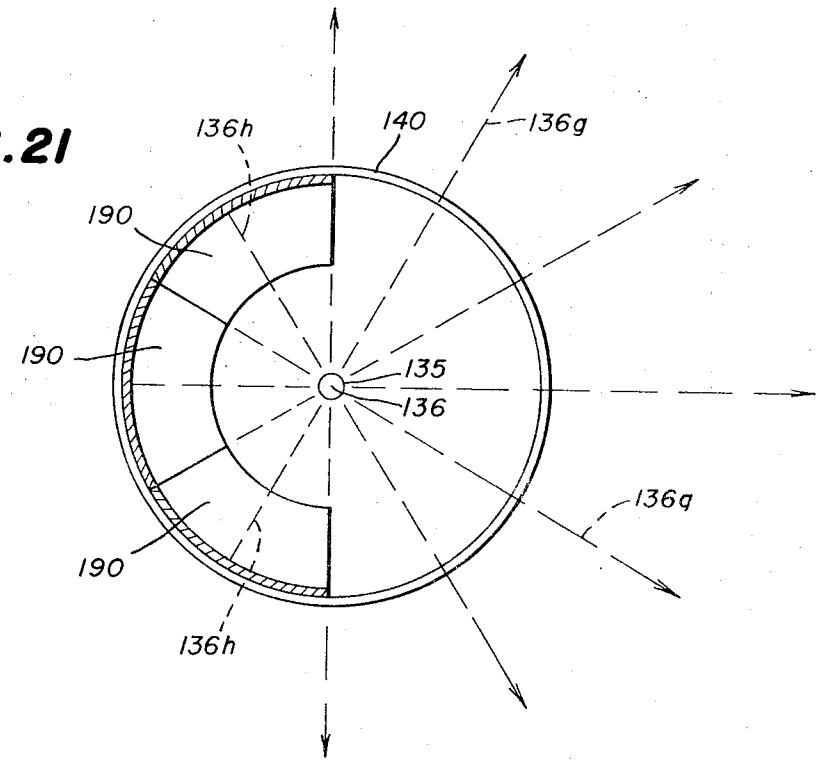

136h
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FIG.23

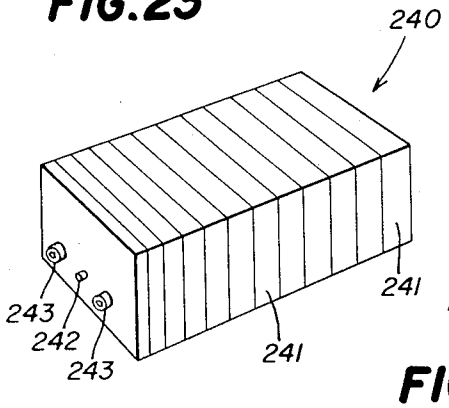



FIG.24

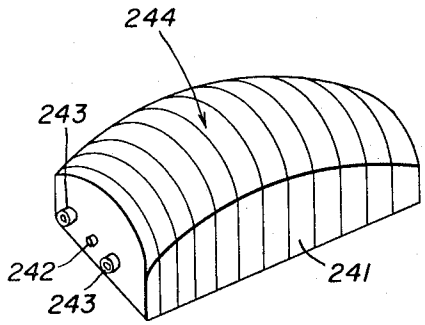



FIG.25

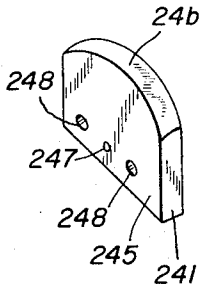



FIG. 27

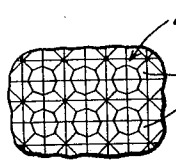



FIG.26

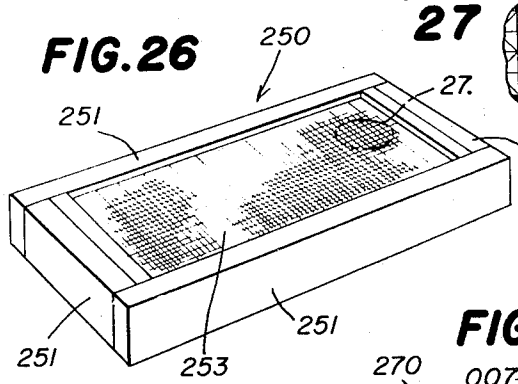



FIG.29

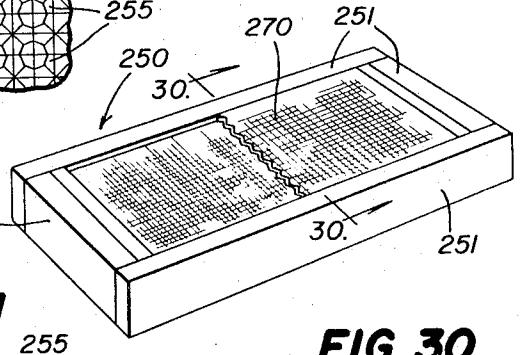



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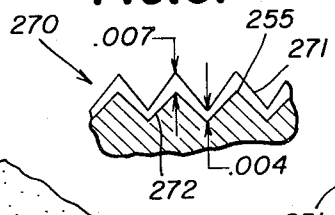



FIG.30

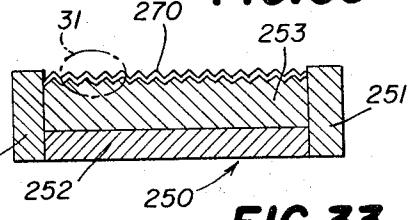



FIG.32

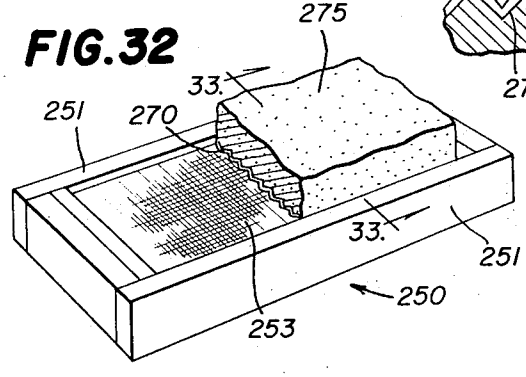



FIG.33

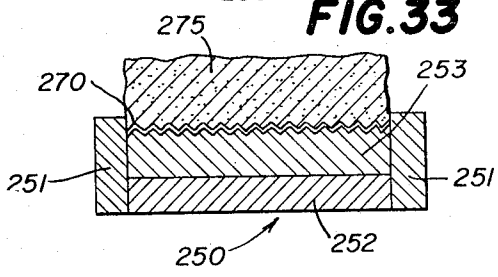



FIG.28

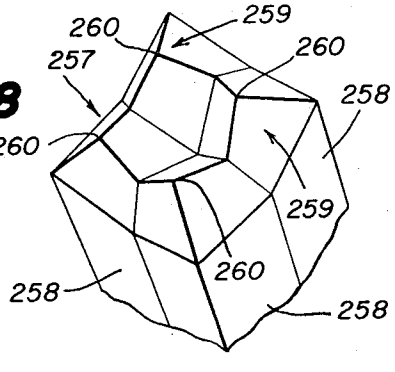



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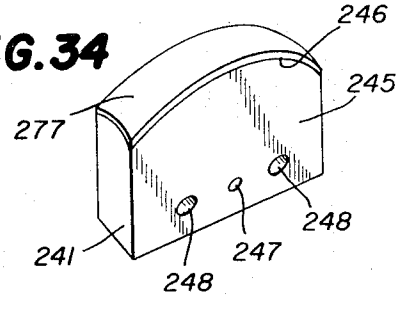


FIG. 35

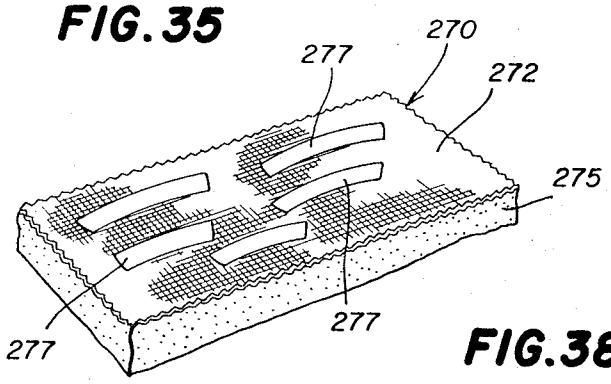



FIG. 36

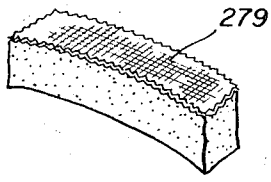



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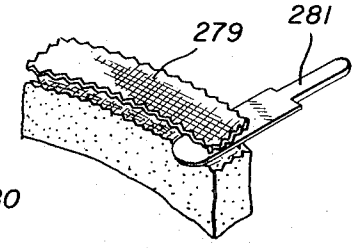



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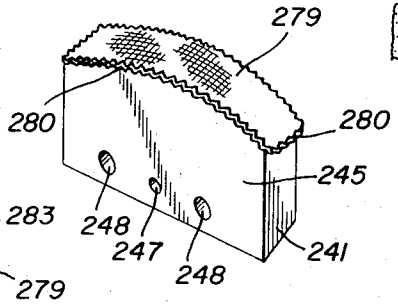



FIG. 39

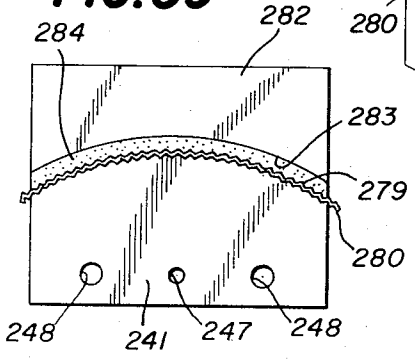



FIG. 40

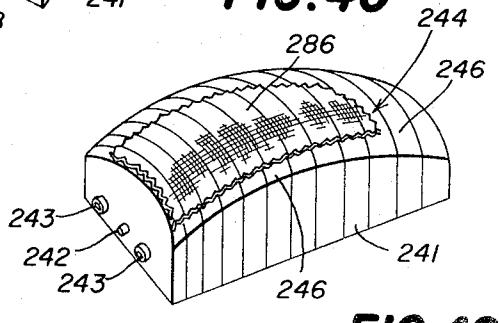



FIG. 41

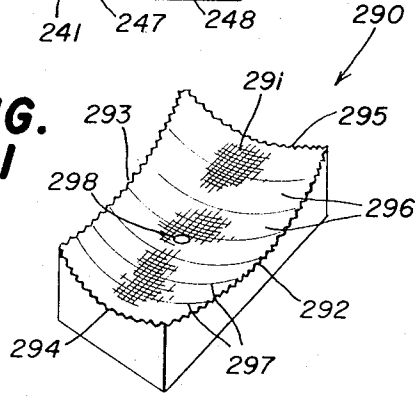



FIG. 42

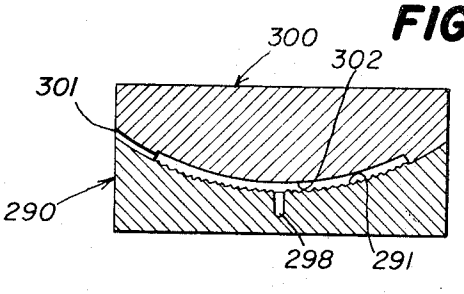



FIG. 43

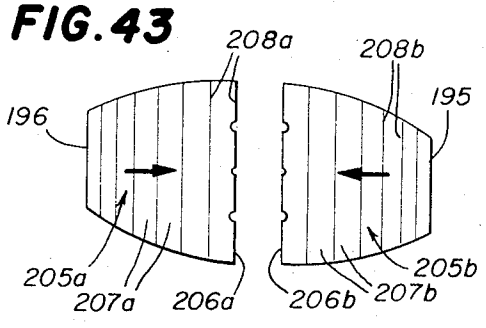



FIG. 44

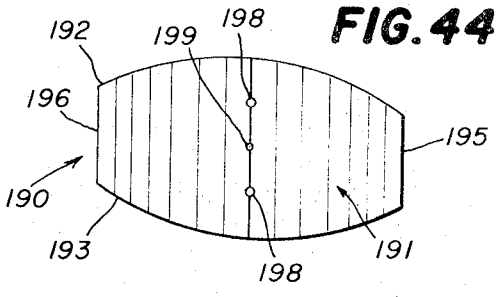


FIG. 45

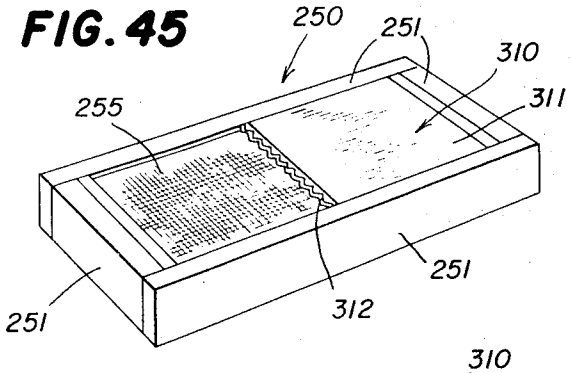



FIG. 46

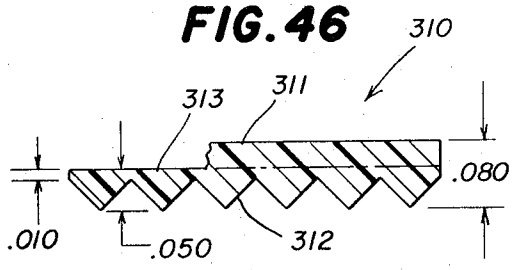



FIG. 47

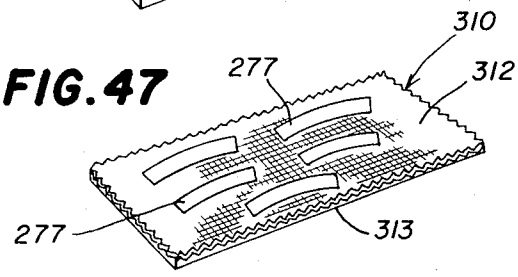



FIG. 48

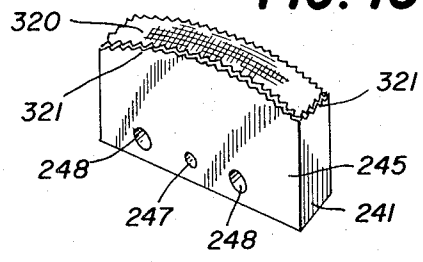



FIG. 49

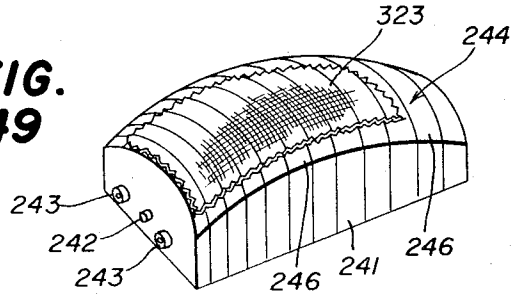



FIG. 50

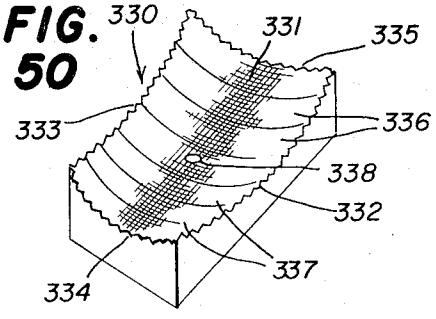



FIG. 51

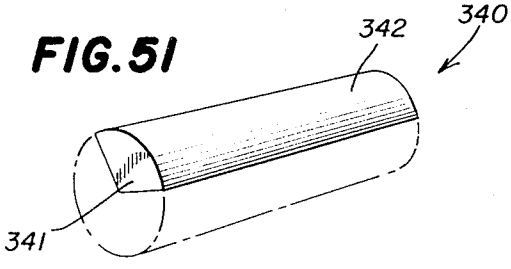



FIG. 52

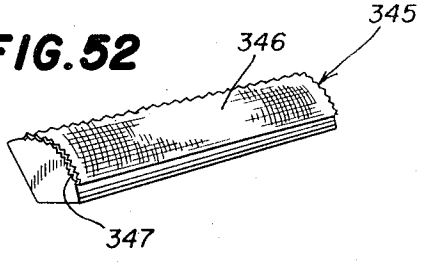



FIG. 53

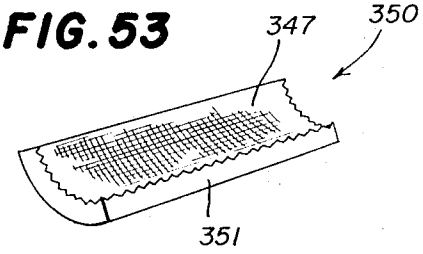
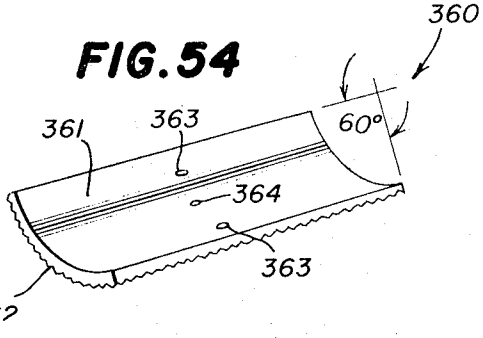



FIG. 54



# LANTERN

This is a division, of application Ser. No. 185,245, filed Sept. 30, 1971.

It is an important object of the present invention to provide a lantern capable of emitting light in a specified direction.

Another object is to provide a lantern in which light directed to a region which does not require light, is intercepted by a cube-corner reflector and retrodirectively returned to the light source, thereby intensifying the light from the light source directed to the region that does require light.

Still another object is to provide a lantern having a collimator and a reflector to redirect to the source otherwise useless light, the reflector having a multiplicity of cube-corners therein, so that accurate placement of the light source with respect to the reflector is not required.

Another object is to provide a marine lantern used near a shoreline which emits a fan pattern of light parallel to the water but is dark on at least a portion of the shoreside so as not to disturb nearby residents.

A further object is to provide a marine lantern which utilizes a lower wattage bulb thereby decreasing power consumption and increasing battery life.

A still further object is to increase the intensity of a beacon emitted by a marine lantern at least in a specified angular range, without increasing the bulb wattage.

Also, there is provided a lantern comprising a base, a reflector on the base and having therein a multiplicity of cube-corner reflector elements, the apexes of the reflector elements defining an imaginary surface which is part-spherical, a socket on the base for carrying a source of light and being arranged to cause the source to be substantially at the center of curvature of the imaginary surface, whereby light from the source that impinges on the reflector will be returned by the reflector back to the source.

Preferably, the lantern also comprises means for condensing in at least one direction the light emanating from the source.

With the foregoing and other objects in view which will appear as the description proceeds, the invention consists of certain novel steps and certain features of construction, and a combination of parts hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the steps and in the form, proportion, size, and minor details of the structure may be made without departing from the spirit or sacrificing any of the advantages of the invention.

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawings preferred embodiments thereof, from an inspection of which, when considered in connection with the following description, the invention, its mode of construction, assembly and operation, and many of its advantages should be readily understood and appreciated.

FIG. 1 is a schematic view of a shore line, with a marine lantern mounted adjacent thereto, which marine lantern incorporates therein the various features of the present invention;

FIG. 2 is an elevational view of the marine lantern illustrated in FIG. 1, on an enlarged scale;



FIG. 3 is a view in vertical section of the marine lantern in FIG. 2, on an enlarged scale, taken along the line 3—3;

FIG. 4 is a view in horizontal section of the marine lantern in FIG. 3, taken along the line 4—4 thereof;

FIG. 5 is a fragmentary view, on an enlarged scale, taken along the line 5—5 of FIG. 4, and illustrating one of the sighting markers;

FIG. 6 is a fragmentary view, on an enlarged scale taken along the line 6—6 of FIG. 4, and illustrating one of the sighting windows;

FIG. 7 is a sectional view, taken through the sighting marker of FIG. 5, along the line 7—7 thereof;

FIG. 8 is a sectional view, taken through the sighting window of FIG. 6, along the line 8—8 thereof;

FIG. 9 is a perspective view of the cube-corner reflector used in the lantern of FIGS. 1–8;

FIG. 10 is a rear elevational view of the reflector;

FIG. 11 is a view in vertical section of the reflector, taken along the line 11—11 of FIG. 10;

FIG. 12 is a view in horizontal cross section, taken along the line 12—12 of FIG. 10.

FIG. 13 is a fragmentary view, on an enlarged scale, of the portion of FIG. 10 within the circle labled 13, and showing a plurality of cube-corner reflecting units;

FIG. 14 illustrates one of the reflecting units of FIG. 13 on an enlarged scale;

FIG. 15 is a view in vertical section on an enlarged scale, taken along the line 15—15 of FIG. 13;

FIG. 16 is a representation of the manner in which a single cube-corner element retrodirectively returns light;

FIG. 17 is a schematic sectional view showing the fresnel lens and the reflector and illustrating how the light source is positioned with respect thereto;

FIG. 18 is a horizontal section, taken along the line 18—18 of FIG. 17;

FIG. 19 is a schematic view of the collimating lens and cube-corner reflector, illustrating the manner in which these two elements redirect light from the source thereof;

FIG. 19A is a horizontal section taken along the line 19A—19A of FIG. 19;

FIG. 20 illustrates a graph comparing the light intensity at various angular positions with and without the cube-corner reflector;

FIG. 21 is a view showing use of three reflectors mounted on the fresnel lens;

FIG. 22A schematically depicts the candlepower distribution of a marine lantern without the reflector incorporating the features of the instant invention;

FIG. 22B schematically depicts a candlepower distribution of a marine lantern utilizing one reflector which incorporates the features of the present invention;

FIG. 22C schematically depicts a candlepower distribution of a marine lantern utilizing two reflectors each of which incorporates the features of the present invention;

FIG. 22D schematically depicts a candlepower distribution of a marine lantern utilizing three reflectors each of which incorporates the features of the present invention;

FIG. 23 illustrates a block of material cut into segments;

FIG. 24 illustrates a segmented block with a part spherical surface formed thereon;

FIG. 25 illustrates one of the segments of FIG. 24;

FIG. 26 illustrates a die having a multiplicity of cube-corner cavities;

FIG. 27 illustrates, on an enlarged scale, the portion of FIG. 26 within the circle labeled 27, illustrating some of the cavities;

FIG. 28 illustrates a bundle of four pins each having a square outline and a cube-corner element on the end;

FIG. 29 illustrates the die having a thin electroforming thereon, the electroforming having been cut away for purposes of illustration;

FIG. 30 is a sectional view, on an enlarged scale, taken along the line 30—30 of FIG. 29;

FIG. 31 is a view, on an enlarged scale, of the portion of FIG. 30 within the circle labeled 31;

FIG. 32 is a view of the electroform on the die and an epoxy backing on the electroform;

FIG. 33 is a view in vertical section, on an enlarged scale, taken along the line 33—33 of FIG. 32;

FIG. 34 illustrates one of the segments shown in FIG. 24, with a piece of tape having been applied to the part-spherical surface thereof;

FIG. 35 illustrates the backed up electroform member with a number of pieces of tape thereon;

FIG. 36 illustrates a piece of the backed up electroformed member after it has been cut out along the tape margin;

FIG. 37 illustrates the manner in which the electroformed member is removed from the epoxy backing;

FIG. 38 illustrates the electroformed member being bent to conform to the curved surface of one segment;

FIG. 39 illustrates a pressure block being used to secure the electroformed member to the segment;

FIG. 40 illustrates the segments secured together, respectively having the associated electroformed members secured thereto;

FIG. 41 illustrates a mold made by electroforming against the outer surface of the article shown in FIG. 40;

FIG. 42 illustrates a die assembly utilizing the mold of FIG. 41 to produce molded parts;

FIG. 43 illustrates two reflector sections molded in the mold of FIG. 42;

FIG. 44 illustrates the two sections secured together to provide a unitary reflector;

FIG. 45 illustrates the first step in an alternative process of making a curved cube-corner reflector, and depicts a cube-corner mold having thereon a portion of a plastic part molded thereon;

FIG. 46 illustrates that a portion of the smooth rear surface of the reflector has been removed;

FIG. 47 illustrates a number of pieces of tape on the molded reflector;

FIG. 48 illustrates a cutout from the reflector 47 being bent to the shape of the curved surface of one of the segments;

FIG. 49 illustrates the segments secured together respectively having the associated molded members secured thereto;

FIG. 50 illustrates a mold made by electroforming against the outer surface of the article shown in FIG. 49;

FIG. 51 illustrates a step in a process by which a part-cylindrical reflector may be made, and depicts a portion of a cylinder;

FIG. 52 illustrates a thin electroformed member bent to conform to the shape of the outer surface of the cylinder of FIG. 51;

FIG. 53 illustrates a mold made by electroforming against the outer surface of the article shown in FIG. 52; and

FIG. 54 illustrates a part-cylindrical reflector molded against the mold shown in FIG. 53.

Turning now to the drawings, and more particularly to FIG. 1 thereof, the details of the instant invention will be described. There is shown in FIG. 1 a marine lantern 100 which is positioned on the shore 101 adjacent a body of water 102, the shore line 103 between the shore and the water being irregular as indicated. The purpose of the marine lantern 100 in this particular installation is to establish a reference point on the shore. Thus, light that is directed over the shore 101 would be useless in accomplishing this objective. The marine lantern 100 includes means, to be described in detail hereinafter, which reduce the amount of light directed onto the shore 101 and maximize the amount of light 104 directed over the water 102.

Turning now to FIGS. 2 to 4, the details of construction of the marine lantern 100 will be described. The marine lantern 100 is mounted on a foundation 105 which is in place on the shore 101. A power cable 106 provides power to the light source located within the lantern 100.

The marine lantern 100 comprises a base 110, which base 110 includes a set of four outwardly directed feet 111 spaced 90° from each other. In the outer end of each foot 111 is an opening 112 through which is passed a bolt 113 into the foundation 105 so as to secure the marine lantern 100 thereto. The base 110 further includes a wall 114 which flares upwardly and outwardly. Near the upper end of the flared wall 114 at diametrically opposite points thereon is a pair of upwardly directed studs 115 and associated wing nuts 116. The studs 115 and the wing nuts 116 secure a bracket 117 in the base 110, which bracket 117 may carry a flasher assembly 118. The flasher assembly 118 is shown in phantom, since this is a well-known mechanism and may or may not be utilized, depending upon whether it is desired to provide a flashing light or a continuous light. Projecting outwardly from the top of the wall 114 are two sets of spaced-apart ears 119.

The marine lantern 100 further comprises a frame member 120 which is generally round in outline, a pair of laterally spaced-apart ears 121 being directed outwardly and respectively into the spaces between the two sets of ears 119. A bolt 122 and a nut 123 pivotally mount each ear 119 and the associated pair of ears 121, whereby to pivotally mount the frame member 120 onto the base 110. The frame member 120 can be pivoted counterclockwise, as shown in FIG. 3, to expose the interior of the base 110 to gain access to the flasher assembly 118. There is also provided three screws 123*a* which respectively threadably engage the outermost portion of the flared wall 114 and the frame member 120, thereby to secure the frame member 120 to the base 110. In order to pivot the frame member 120, the screws 123*a* would have to be removed. The frame member 120 also carries a level 124 which permits the installer of the marine lantern 100 to adjust the mounting therefor, so that the lantern 100 is perfectly level.

The frame member **120** includes three arms **125**, each directed upwardly and inwardly and terminating in a substantially horizontal portion **126**. In order to mount a bracket **127**, there is provided three threaded bolts **128** respectively passing downwardly through the horizontal portions **126**. Each bolt **128** has a head **129** and passes through a compression spring **130**, through an associated opening in the bracket **127**, through a bushing **131**, and threadably engaging a wing nut **132**. The bracket **127** is adapted to carry a bulb-changer mechanism **133**. The bulb-changer mechanism **133** is shown in phantom, since it may be of standard construction and does not form part of the instant invention. The bulb-changer mechanism **133** operates sequentially to replace a burnt-out bulb with a fresh bulb. One of the sockets **134** is shown carrying a bulb **135**, which bulb **135** has a filament **136**. The wing nuts are used to accurately position the filament **136** in a manner to be explained hereinafter. For the present, it should be noted that tightening the wing nuts **132** brings the filament **136** upwardly, and loosening them causes the filament **136** to move downwardly by virtue of the force exerted by the springs **130**. Of course, by selectively adjusting the wing nuts **132**, the filament **136** can be tilted, in addition to being moved upwardly and downwardly. Also, there is provided a slightly larger opening in each horizontal portion **126**, to enable lateral movement of the filament **136**.

The marine lantern **100** further comprises a fresnel lens **140** in the shape of the frustum of a cone, which, in the embodiment shown, has a very slight deviation from a perfect cylinder. The purpose of inclining the wall defining the lens **140** is to provide the proper draft angle to enable the part to be withdrawable from the mold therefor. The interior surface **141** of the lens **140** is also frustoconical in shape and is substantially smooth. Formed on the outer surface of the lens **140** is a plurality of dioptric rings **142** extending from an upper end **143** to a lower end **144**, which dioptric rings are of basically known construction, whereby the details of construction thereof will not be described. There is provided a central dioptric ring **142*a***, a number of lower dioptric rings **142*b*** between the central dioptric ring **142*a*** and the lower end **144**, and a lesser number of upper dioptric rings **142*c*** between the central dioptric ring **142*a*** and the upper end **143**. The focal point of the dioptric rings **142** is located in a plane passing through the center of the central dioptric ring **142*a***, at the point of intersection with the conical axis of the lens **140**. The upper end **143** terminates in a lip **145** that is directed inwardly and slightly upwardly, and the lower end **144** terminates in a flange **146** directed outwardly. As is best seen in FIGS. **3** to **8**, there is provided in the central dioptric ring **142*a*** four bosses **147**, **148**, **149** and **150** respectively spaced at 90° intervals. Thus, the boss **147** is diametrically opposite the boss **149** and the boss **148** is diametrically opposite the boss **150**, all located in the central dioptric element **142*a***. Formed in the boss **147** is a window **151**, in the boss **148** a window **152**, in the boss **149** an X-shaped mark **153**, and in the boss **150** an X-shaped mark **154**. The outer surface of the windows **151** and **152** are curved to match the curvature of the interior surface **141** so that light therethrough is substantially undeviated. The windows **151** and **152** and the X-shaped marks **153** and **154** are used accurately to position the filament **136** of the bulb **135**, as will be explained hereinafter.

The marine lantern **100** further comprises a cover **160** which is constructed of transparent material and includes a frustoconical side wall **161** having substantially smooth inner and outer surfaces. The top of the sidewall **161** merges into a convex top wall **162**, and the bottom of the sidewall **161** merges into a flange **163** that is outwardly directed. Formed in the inside of the flange **163** is an annular recess defining a shoulder **164**.

The cover **160** is slightly wider than the lens **140**, but has the same general slope to the sidewalls, whereby, when the cover **160** is in place, there is a space between the dioptric elements **142** and the cover **160**. The shoulder **164** on the flange **163** rests against the upper surface of the flange **146** on the lens **140**. There is provided an annular clamping ring **170** having an offset portion **171** bearing against the upper surface of the flange **163** and is secured to the frame member **120** by means of a plurality of screws **172**.

The lantern **100** further comprises a reflector **190**. Turning now to FIGS. **9** to **12**, the details of the reflector **190** will be described. The reflector **190** has a front surface **191** which is substantially smooth and is part spherical in form with a given center of curvature. The reflector **190** has a pair of side edges **192** and **193** respectively lying in planes containing the center of curvature of the front surface **191**. The reflector **190** further has a pair of end edges **194** and **195** respectively lying in chordal planes which are disposed parallel to each other and do not pass through the center of the curvature of the front surface **191**. For reasons to be explained hereinafter, the planes which contain the side edges **192** and **193** are not perpendicular to the planes which contain the end edges **194** and **195**, and, accordingly, the reflector **190** is slightly skewed. If desired, narrow flanges **196** and **197** may be formed respectively on the end edges **194** and **195** to facilitate stripping the reflector **190** from the mold. Formed in the reflector **190** is a pair of laterally spaced-apart mounting holes **198** midway between the end edges **194** and **195**. Disposed midway between the mounting holes **198** is a sighting hole **199**. There is also provided a pair of fingers **200** and **201** directed rearwardly and located on a line passing through the sighting hole **199** and perpendicular to the line joining the mounting holes **198**, the fingers **200** and **201** being equidistant from the sighting hole **199**. For reasons to be explained subsequently, the finger **200** is about one-half the length of the finger **201**.

The reflector **190** is divided into a pair of symmetric sections **205*a*** and **205*b*** which are substantially identical. The ensuing remarks will be directed to the section **205*a*** but it is to be understood the remarks are equally pertinent in respect to the section **205*b***. The section **205*a*** has side edges which respectively lie in planes containing the center of curvature of the section's front surface and has a longer end edge **206*a*** which also lies in a plane containing the center of curvature of the front surface **191**, the plane containing the edge **206*a*** and the plane containing the end edge **194** being substantially parallel. The section **205*a*** is divided into a plurality of zones **207*a*** separated by boundary lines **208*a***. The planes containing the boundary lines **208*a*** are disposed parallel to one another and do not pass through the center of curvature of the front surface **191**. The end edges **206*a*** and **206*b*** are welded together to provide the unitary reflector **190** depicted. The side

edges of the section **205***a* merge and are continuations of the corresponding side edges of the section **205***b*, thereby to provide the side edges **192** and **193**.

In the form shown, the angular extent of the reflector **190** measured between the side edges **192** and **193** is about 60°, and the angular extent of the reflector **190** between the end edges **194** and **195** is about 110°. Since the side edges **192** and **193** of the reflector **190** lie in planes containing the center of curvature of front surface **191**, two or more such reflectors may be butted together, side by side, so as to increase the angular extent from side edge to side edge. Further details on this embellishment will be described hereinafter.

Formed in the rear surface of the reflector **190** is a plurality of juxtaposed reflector units **210**, the details of which are most clearly shown in FIGS. **13**, **14**, and **15**, each reflecting unit **210** being composed of four retrodirective reflector elements **211** (*a*, *b*, *c*, and *d*). Each reflector element **211** is square in outline and is identical to every other element **211**. Each element **211** has three faces **215** inclined from a common apex **216**. Two faces **215** intersect along an edge **214** extending from the apex **216** to one corner of the square boundary forming the outline of the element **211**. The other intersections between adjacent faces **215** extend from the apex **216** to a point at the side of the square boundary of the element **211**. The faces **215** extend substantially at right angles to each other to form a portion of a cube, and, hence, the reflector elements will hereinafter be referred to as cube-corner elements. It is to be understood, however, that a cube-corner element is not limited to one having faces of equal area but solely indicates that three faces are perpendicular to one another.

The point **217** constitutes the center of the reflecting unit **210**. The element **211***a* is rotated 90° with respect to the element **211***b*, the element **211***b* is rotated 90° with respect to the element **211***c*, the element **211***c* is rotated 90° with respect to element **211***c*, and the element **211***d* is rotated 90° with respect to the element **211***a*. Each reflecting unit **211** provides four interior cube corners, the adjacent elements of which are oriented 90° relative to each other. Each reflector element, such as, for example, the reflector element **211**, has a cube axis **219** (see also FIG. **16**), which cube axis is an imaginary line drawn through the apex **216** with respect to which the three faces **215** are symmetrically arranged and with respect to which the three edges **214** are symmetrically arranged. Thus, each face **215** forms an angle of 35° 16′ with the cube axis, and each edge **214** forms an angle of 54° 44′ with the cube axis.

As is best seen in FIG. **15**, the apexes **216** of the reflector elements **211** define an imaginary surface **218** which is substantially part spherical and substantially parallel to the front surface **191** of the reflector **190**. The cube axis of each reflector element **211** is substantially perpendicular to the tangent to the imaginary surface **218** at the apex of that reflector element **211**. The imaginary surface **218** in any given zone **207***a* is curved in the direction of elongation so as to be parallel to the associated portion of the front surface **191**. However, for reasons to be explained hereinafter, the imaginary surface **218** in the direction normal to the direction of elongation is substantially flat. Thus, by increasing the number of zones **207***a*, the better the entire imaginary surface **218** approximates the surface of a sphere. However, the greater the number of zones **207***a*, the more boundary lines **208***a*, which boundary lines **208***a* adversely affect the immediately adjacent reflector elements **211**.

It should be apparent that with this type of construction the cube axes of the reflector elements **211** are all substantially radially directed, that is, aligned with the center of curvature of the front surface **191** and substantially with the center of curvature of the imaginary surface **218**. Light emanating from a light source positioned at that center of curvature will impinge the reflector elements and will be retrodirectively returned by the reflector elements **211** back to the source. This mode of operation is particularly shown in FIG. **16** wherein a filament **136** constituting a light source emits a ray of light **136***a* directed parallel to the cube axis **219** of the reflector element **211**, which ray strikes one of the faces **215** of that reflector element **211**. In a known way, the light ray **136***a* strikes the other faces **215** of that reflector element **211** and is returned as a light ray **136***b* disposed parallel to the ray **136***a* and to the cube axis **219**. Although the light is shown returning to a point spaced from the filament **136**, it should be understood that the reflector element **211**, in practice, is very tiny, on the order of 0.040 inch, so that the maximum displacement of the returned light from the source would be 0.040 inch.

If the filament **136** is displaced downwardly so as to emit a ray of light **136***c* which is not parallel to the cube axis **219**, but is rather at an acute angle with respect thereto, the reflector element **211** redirects the ray **136***c* so as to return as a ray **136***d*, again parallel to the incoming ray **136***c* but displaced therefrom by a maximum of 0.040 inch. As long as the angle formed by the incoming ray **136***c* and the cube axis **219** is less than a critical angle, the reflected ray **136***d* will return substantially to the source. In a cube-corner reflector, in which the front surface is smooth and a cube corner projects from the rear surface, and is composed of methyl methacrylate resin, this critical angle is about 19°. Thus, as long as the incoming ray forms an angle of ±19° with respect to the cube axis **219**, the light will be returned substantially to the source thereof. This feature, as will be explained further, facilitates placement of the bulb **135**. Specifically, if the filament **136** is precisely at the center of curvature of the reflector **190**, all the light rays which impinge on the reflector **190** will be retrodirectively returned to the filament **136**, since the cube axes **219** are radially directed. However, even if the filament **136** is slightly removed from the center of curvature, the light will still be returned by the reflector **190** to the filament **136** by virtue of the phenomenon described with respect to FIG. **16**.

Referring now to FIGS. **3** and **4**, the manner in which the reflector **190** is mounted will be described. A pair of openings is drilled in the central dioptric ring **142***a* respectively on either side of the boss **148**. The reflector **190** is then placed in position as shown such that the outer ends of the fingers **200** and **201** engage the interior surface **141** of the lens **140**. The finger **200** is shorter than the finger **201**, as the result of the lens **140** having a frusto-conical shape. A pair of headed studs **220** is inserted through the holes just formed in the central dioptric ring **142***a* and through the mounting holes **198** in the reflector **190**. A pair of push-on fasteners **221** is applied respectively to the headed studs **220** to secure the reflector **190** in place. In this condition, the

sighting hole **199** in the reflector **190** will be aligned with the window **152.**

The manner in which the light bulb **135** is positioned in the marine latern **100** will be described. Referring first to FIGS. **3** and **4,** the installer removes the screws **123***a* to permit the frame member **120** to be pivoted and expose the wing nuts **132.** The installer looks through the window **152** which is aligned with the sighting hole **199** in the reflector **190,** the X-shaped mark **154** being diametrically opposite the window **152.** The installer looks through the window **152** and adjusts the wing nuts **132** to raise or lower the changer mechanism **133** until the filament **136** of the bulb **135** is aligned with the X-shaped mark **154.** The changer mechanism **133** can be moved laterally to enable lateral alignment of the filament **136.** Then, the installer looks through the window **151** and readjusts the wing nuts **132** until the filament **136** is in alignment with the X-shaped mark **153.** Since this latter adjustment may have affected the initial adjustment, the installer then looks through the window **152** and so on until the filament **136** is aligned in both directions. When that occurs, the filament **136** is precisely at the intersection of the conical axis of the lens **140** and the plane passing through the central dioptric ring **142***a*. It is important that the filament **136** be accurately placed in respect to the dioptric rings **142,** which is accomplished as above explained. If the filament **136** is not located at the focal point of the dioptric rings **142,** the light will not be properly collimated by the lens **140.**

As previously explained, the reflector **190** is so designed that its center of curvature will fall generally at the focal point of the dioptric rings **142.** Thus, positioning the filament **136** accurately, as above described with reference to FIGS. **17** and **18,** to place it at the focal point of the dioptric rings **142,** results in the filament **136** being also approximately at the center of curvature of the reflector **190.** However, the placement of the filament **136** with respect to the reflector **190** is not critical, by virtue of the ability of a cube-corner reflector element to return light to its source within an angle of as much as ±19°. It should be understood that, if the reflector **190** had a simple spherical surface, the filament **136** would have to be placed accurately with respect to both the dioptric rings **142** and the reflector **190,** an almost impossible task, since there is only one degree of freedom to satisfy two parameters.

Referring now to FIGS. **19** and **19A,** the details as to the manner in which the marine lantern **100** functions will be described. Light rays **136***e* from the filament **136** strike the reflector **190,** and, by virtue of its retrodirective reflecting capabilities, those light rays are returned back to the filament **136,** so as to reinforce the light therefrom. The light rays **136***e* being emitted directly by the filament **136** and/or reinforced by light reflected by the reflector **190** strike the interior surface **141** of the lens **140** and are refracted and then refracted again when they strike the dioptric rings **142,** so as to emerge as light rays **136***f* disposed horizontally. Thus, the lens **140** serves to condense in at least one direction (that is, vertically in the form shown) the light emitted by the filament **136.** Although only light rays **136***f* are shown in FIG. **20,** it is to be understood that the lens **140** emits a solid beam of light extending from the uppermost light ray **136***f* to the lowermost light ray **136***f*. If the angular extent of the reflector **190** measured in the horizontal plane is 60°, then the angular extent of the beam would be about 300°, there being no light emitted in the region of the reflector **190.** Thus, in the region where no light is needed, light is not emitted, but, rather, is used to reinforce and intensify the light emitted in the useful region. Accordingly, the wattage of the bulb **135** may be less than what would be needed if the reflector **190** were not used, or the same wattage bulb could be used and thereby increase the intensity of the light within the desired region.

The angular extent of the reflector **190** in the vertical direction (in the direction of its elongation) is such that a light ray **136***e* from the filament **136** that strikes the upper end edge **194** will be retrodirectively reflected back to the source and thence to the lowermost dioptric ring **142.** Stated in another way, a point on the upper end edge **194** of the reflector **190,** the filament **136,** and a point on the lowermost dioptric ring **142** should lie in a straight line. Similarly, a point on the lower end edge **195** of the reflector **190,** the filament **136,** and a point on the uppermost dioptric ring **142** should lie in a straight line. If the angular extent of the reflector **190** were any greater, the light rays striking the extremities of the reflector **190** would be retrodirectively reflected back through the filament **136** and then along a path which does not intersect the lens **140.**

In order that each point on the upper end edge **194** of the reflector **190** have a corresponding point on the lowermost dioptric rings **142,** the upper end edge **194** should lie in a plane parallel to the horizontal planes which define the upper and lower boundaries dioptric rings **142.** Similarly, the lower end edge **195** of the reflector **190** should lie in a horizontal plane parallel to the planes defining the dioptric rings **142.**

It should be pointed out that if the light bulb **135** is sufficiently close to the lens **140,** some of the dioptric rings would have to be of the catadioptric type in which both reflection and refraction occurs to bend the rays sufficiently.

Referring to FIG. **20,** which plots angular position as the abscissa and light level readings as the ordinate, the curve **230** represents the condition when the reflector **190** is masked. The curve **230** deviates from a theoretically flat curve due to shielding by the bulb support and nonuniform output by the bulb **135.** The curve **231** represents the condition with the reflector **190** unmasked. Within approximately the 60° opposite the 60° range of the reflector **190,** there is substantial improvement in light output. It should be understood that the ordinate does not represent actual light levels but rather relative meter readings. Thus there is about a 30 percent improvement in light intensity within the 60° opposite the 60° range of the reflector **190.**

The dip in the curve **231** at 0° is due to the discontinuities in the reflector **190** caused by the sighting hole **199** and the fingers **200** and **201.**

The marine lantern **100** is constructed to be usable in an environment such as shown in FIG. **1,** that is, on a piece of land that juts into the water and only a narrow angular region does not require light. If the region not requiring light were expanded, additional reflectors **190** can be utilized. Reference is made to FIG. **21** which illustrates three reflectors **190** arranged side by side and all mounted to the lens **140.** In this case, light rays **136***h* from the filament **136** directed toward the left, as viewed in FIG. **21,** will strike one of the reflectors **190** and retrodirectively will be returned to the fil-

ament **136.** Light emanating directly from the filament **136** or being retrodirectively returned thereto is emanated in the form of rays **136***g*. Thus, light which is otherwise wasted is returned to the filament **136,** to reinforce the light therefrom that is directed to the desired region.

In lining up the bulb **135** when three reflectors are mounted in the marine lantern **100,** the middle reflector **190** will be in the same position as that shown for the single-reflector embodiment of FIGS. **1** to **20.** Accordingly, the window **152** is aligned with the hole **199** in the middle reflector **190,** thereby permitting to enable viewing of the X-shaped mark **154.** The window **151** is disposed immediately to the right of the lowermost reflector as viewed in FIG. **21,** and the X-shaped mark **153** is immediately to the right of the uppermost reflector **190** as viewed in FIG. **21.** Accordingly, there is provided a line of vision between the window **151** and the X-shaped mark **153** to permit the requisite adjustment of the bulb **135.**

It is to be understood that two reflectors **190** may be utilized and it would, of course, depend upon the specific need as to whether one, two, or three reflectors **190** would be required. With no reflectors, the light distribution will be as shown in FIG. **22A.** With one reflector a 60° zone will be blacked out and the light projected into the opposite 60° zone will be intensified (see FIG. **22B**). With two reflectors, a 120° zone is blacked out and the light projected into the opposite 120° zone is intensified (see FIG. **22C**). With three reflectors, a 180° zone is blacked out and the light projected into the remaining 180° zone is intensified (see FIG. **22D**). Of course, whatever zone is blacked out will appear dark so as not to be a nuisance to persons living in the area near the marine lantern. Also, by preventing light from being projected into an unnecessary zone and utilizing that light in another zone, a lesser wattage light bulb may be utilized and still achieve the same light intensity, at least in a portion of the zone. Of course, a lesser wattage light bulb consumes less power and therefore costs less to operate. If a battery is used, this would mean an increased life for the battery.

As was previously explained, the planes respectively containing the side edges **192** and **193** of the reflector **190** are not perpendicular to the plane passing through the holes **198** and **199,** that is, a horizontal plane. Thus, when the reflector **190** is mounted, such that the holes **198** and **199** are horizontal, the side edges **192** and **193** are skewed, that is, the planes containing these side edges are not arranged vertically. When two or more reflectors **190** are butted together, the side edge **192** of one of the reflectors will abut and perfectly match the side edge **193** of the other reflector **190.** In this way, the juncture between the adjacent reflectors **190** is not disposed in a vertical plane. If the line were in a vertical plane, a viewer, standing at a point on a line passing through the filament **136** and that vertical line, would see a substantial decrease in light intensity over that which he would see on either side of that point.

The zones **207***a* and **207***b* are horizontally arranged for similar reasons. If the zones were vertically arranged, then the boundaries **208***a* and **208***b* would be disposed in vertical planes, and there would be a number of angular positions at which the light intensity would be substantially reduced. By arranging these zones **207***a* and **207***b* horizontally, the amount of light at any angular position is only very slightly affected, since the viewer sees a narrow, vertically arranged strip of light which appears vertically continuous by virtue of the action of the dioptric rings **142.**

By constructing the edges **194** and **195** such that they are in planes parallel to each other and horizontally disposed when the reflector **190** is mounted in use, when two or more reflectors **190** are butted together, the upper and lower edges will continue to be in horizontal planes. This means that each point on the upper edge of the reflectors **190** will have a corresponding point on the lowermost dioptric ring **142.** Similarly, each point on the lower edge of the abutting reflectors **190** will have a corresponding point on the uppermost dioptric ring **142.**

In practice, the Fersnel lens **140** does not collimate the light perfectly, first, because the dioptric rings **142** are not perfect in formation and, second, because the filament **136** is not a point source of light. Rather, it has length so that a ray of light emitted from one portion of the filament would be deviated slightly when it is retrodirectively reflected by the reflector **190.** The inaccuracies in the dioptric rings **142** and the fact that the filament **136** is not a perfect point source, causes the beam from the marine lantern **100** to spread vertically slightly.

Although the reflector **190** finds particular use in a marine lantern **100** of the type described, it is to be understood that such reflector has a great number of other uses. The reflector may, for example, be cylindrical, in which case the imaginary surface defined by the apexes of the cube-corner elements is part cylindrical, and the cube axes would be perpendicular to the imaginary surface. Also, it is to be noted that although the reflector **190** has cube-corner elements of a square outline, elements having a hexagonal outline or a triangular outline are contemplated, although the square outline is preferred.

Turning now to FIGS. **23** to **44,** the details of the method for making the reflector **190** will be described. Referring specifically to FIG. **23,** there is shown a block **240** in the shape of a rectangular parallelepiped. The block **240** is divided into 12 segments **241,** the width of each of which increases from left to right, as viewed in FIG. **23.** A rod **242** is positioned through the segments **241** and another pair of rods with threaded ends are also positioned through the segments **241,** nuts **243** being threaded onto the rods. The rods hold the segments **241,** as shown. A part-spherical surface **244** is formed on the top surface of the block **240,** as shown in FIG. **24.** Each segment **241** has a pair of sides **245** lying in parallel planes, whereby the upper surface of each segment **241** defines a zone **246.** The thickness of the segments **241** varies in order that the lateral (measured transverse to the sides **245**) arc length of each zone **246** is equal. Thus, a segment **241** with substantial angle will be thinner than a segment **241** with less angle.

The next step is to form a cube-corner member. To that end, there is provided a die **250,** as shown in FIG. **26,** having four side walls **251** rectangularly arranged and a bottom wall **252.** Mounted within the side walls **251** is a part **253** having therein a multiplicity of cube-corner units **254** (FIG. **27**). Each cube-corner unit has four cube-corner cavities **255,** each being rotated 90° with respect to the adjacent cube-corner cavity. Each cube-corner cavity **255** is comparable to that shown in FIGS. **13** through **16,** but, however, in the form of a

cavity instead of a projection. To make the part **253**, an array of pins are held together. Reference is made to FIG. **28** which illustrates a single pin bundle **257** made up of four pins **258**, each having a square outline and a cube-corner projection **259** at the outer end thereof. Each cube-corner projection **259** is made up of three mutually perpendicular faces **261** having a common apex **260**. When a number of the pin bundles **257** are grouped together, they may be placed in a plating tank in which nickel or the like is deposited or electroformed onto the cube-corner projections **259**. After a period of time, a sufficient thickness of material has been electroformed onto the cube-corner projections to render the electroform self-supporting. At that time, it is pried off of the pins **258**, and the electroforming that is separated therefrom, after being cut and otherwise treated, becomes the part **253** in the die **250**. Of course, the steps of electroforming are known in the art, whereby the above description is a sketchy one, simply to describe the over-all process. It is to be understood that there may be a great many steps in the process of forming the pins into the desired array, all the way up to obtaining a rectangular electroform for use in the die **250**.

The exposed surface of the part **253** which has therein the cube-corner cavities **255** is then plated with chrome or other suitable separating medium. The die **250** is then inserted in a plating tank, whereby nickel or other plating material is deposited or electroformed onto the chrome-plated surface of the die **250**. The plating is carried on for a sufficient amount of time to generate a metal member having a crudely configurated rear surface **271** and a precisely configurated front surface **272** (FIGS. **29** and **30**). In a construction of the present invention, the thickness of the metal member **270** was **0.007** inches in the areas of the apexes of the cube-corner elements **255** and **0.004** inches in the region of the valleys of the cube-corner projections **255**. This variant thickness is a characteristic of the electroforming process. Of course, the front surface **272** has therein a multiplicity of cube-corner projections, like the pin bundle shown in FIG. **28**.

Turning now to FIGS. **32** and **33**, an epoxy backing **275** is applied to the rear surface **271** of the metal member **270**. In order to obtain the desired shape of the epoxy **275** when it dries, a suitably shaped form should be provided. The epoxy **275** assures that the metal member **270** will retain its shape during subsequent steps, particularly prying it off the die **250**.

Referring to FIG. **34**, the next step involves placing a piece of tape **277** on the zone **246** of each segment **241**. The tape **277** is then cut so as to conform precisely to the zone **246**. The tape is then removed and is applied to the configurated surface **272** of the epoxy-backed metal member **270**. Five such pieces of tape are shown in FIG. **35** whereby additional epoxy-backed metal members **270** would have to be provided to cover the other seven segments. The configurated surface **272** is then painted, preferably by spray. The pieces of tape are then removed, and the epoxy-backed metal member **270** is then cut along the boundaries between the painted and unpainted areas. Preferably, each piece **279** (FIG. **36**) thus cut out, is slightly larger than the zone **246** of the associated segment **241**. Each epoxy-backed piece **279** is then heated to soften the epoxy **275** and then a tool **281**, such as shown in FIG. **37**, is used to separate the piece **279** from its epoxy backing.

As depicted in FIG. **38**, the piece **279** is then bent onto the zone **246** of the associated segment **241**. It should be understood that each zone **246** is part spherical and, as a practical matter, it is impossible to bend the piece **279** both longitudinally and laterally entirely to conform to the zone **246**. Instead, the piece **279** is bent only longitudinally to conform to the zone **246** in that direction, and the piece **279** is left essentially flat in the lateral direction. By constructing the segments **241** to be reasonably narrow, the over-all lateral surface will approximate a spherical curvature.

Referring now to FIG. **39**, there is provided a press **282** having a concave surface **283** to which is secured a rubber strip **284**. Adhesive is then applied to the rear surface **271** of the piece **279** and to the zone of the associated segment **241**. The press **282** is positioned, as shown in FIG. **39**, and pressure applied thereto and maintained until the piece **279** is secured. Since the piece **279** was cut over-size, its edges **280** overhang the associated zone, which edges **280** are then ground, so that the piece **279** has precisely the right shape.

A similar process to that depicted in FIGS. **36–39** is performed in respect to each piece **279** and each segment **241**. The segments **241** are then reassembled, as shown in FIG. **40**. The outer surface of each piece **279** becomes a continuation of the outer surface of the adjacent piece **279**, thereby forming a continuous configurated surface **286** having a multiplicity of cube-corner projections thereon.

Turning now to FIG. **40**, the exposed surface **286** is covered with chrome or other suitable separating medium. After the unit shown in FIG. **40** is suitably masked, it is inserted in the plating tank to plate a quantity of nickel or other material onto the surface **286**. After a suitable thickness of nickel has been built up, the unit shown in FIG. **40** may be removed, the front surface of the built-up part masked and then returned to the plating bank for back-up. The completed mold **290** is shown in FIG. **41**. The mold **290** has a configurated front surface **291** consisting of a multiplicity of cube-corner cavities. The mold **290** has a pair of side edges **292** and **293** respectively lying in planes containing the center of curvature of the surface **291**. The mold **290** further has a pair of end edges **294** and **295** respectively lying in chordal planes which are disposed parallel to each other and do not pass through the center of curvature of the surface **291**. The front surface **291** is divided into a plurality of zones **296**, separated by boundary lines **297**. The planes containing the boundary lines **297** are disposed parallel to one another and do not pass through center of curvature of the surface **291**. The boundary lines **297** result from the slight discontinuities from the various pieces **279** that make up the surface **286**. Of course, each zone **296** is spherically curved in the longitudinal direction, but is flattened in the lateral direction, since that is the basic shape of the pieces **279** which make up the surface **286**. A hole **298** is formed in the mold **290**, which hole **298** forms the fingers **200** and **201** in the finished product. Suitable projections may be mounted at the end edge **295** to enable formation of the holes **198** and **199** in the completed product.

Turning now to FIG. **42**, the mold member **290** provides the lower half of a mold assembly incorporating an upper mold member **300**. The mold member **300** has a smooth part-spherical surface **302** and a gate **301**. When in position, as shown in FIG. **42**, molten acrylic

is admitted into the space between the configurated surface **291** of the mold member **290** and the smooth surface **302** on the mold member **300**, in the usual manner. After the mold member **300** is separated from the mold member **290**, a reflector section **205***a* (FIG. **43**) is withdrawn. A second molding cycle is performed, utilizing the mold assembly shown in FIG. **42** to provide a second reflector section **205***b*. The reflector section **205***b* is an exact duplicate of the section **205***a*, but is oriented 180° with respect to section **205***a*, all as shown in FIG. **42**. As previously explained, the sections respectively have longer edges **206***a* and **206***b*, both of which lie in planes containing the same center of curvature, whereby they may be mated, as shown in FIG. **44**, and then welded together. The reflector **190** shown in FIG. **44** is the reflector previously described herein, except for the absence of flanges on the outer end edges **194** and **195**. If desired, these ends, which are used for stripping purposes, would be added during the molding operation. Each reflector **190** is made in two sections **205***a* and **205***b* so as not to exceed the draft angle necessary to withdraw the part from the mold.

The boundary lines **208***a* and **208***b* result from the corresponding boundary lines **297** in the mold member **290**. Each zone **207***a* and **207***b* will be part-spherical in the longitudinal direction, but substantially flattened laterally since that is the characteristic of the mold member **290**.

Turning now to FIGS. **45–50**, the details of a second method of making a curved reflector will be described. The same die **250** utilized in the first process is also used in this alternative process. Acrylic is molded onto the surface, having the cube-corner cavities **255**, to provide a reflector **310** having an over-all thickness, for example, of 0.080 inch, as shown in the right-hand side of FIG. **46**. The reflector **310** has a flat rear surface **311** and has a configurated front surface **312** which has therein a multiplicity of cube-corner projections, much like the pin bundle shown in FIG. **28**. The rear surface **311** may then be ground down, if desired, the resulting surface being labeled with a number **313**. Of course, FIG. **46** represents the grinding process while it is being performed, so that, when completed, the entire rear surface will be at a level represented by the number **313**. The amount of grinding would be that necessary to render the reflector **310** substantially pliable. If the overlay (distance between the surface **313** and the lowest point in the surface **312**) were about **0.010** inch, the reflector **310** would be sufficiently pliable.

As was done in respect to the first process described, pieces of tape **277** are respectively applied to the zones **246** of the segments **241**. After the tape **277** is cut to conform precisely to the associated zone **246**, it is removed and applied to the configurated surface **312** of the reflector **310**, as shown in FIG. **47**. Five such pieces of tape respectively conforming to different ones of the segments **241** are applied to the surface **312**. The configurated surface **312** is then painted, and the pieces of tape are removed. The reflector **310** is then cut along the boundaries between the painted and unpainted areas. Preferably, each piece **320** (FIG. **48**) thus cut out, is slightly larger than the zone **246** of the associated segment **241**. As depicted in FIG. **48**, each piece **320** is then bent onto the zone **246** of the associated segment **241**. It should be understood that each zone **246** is part-spherical and, as a practical matter, it is impossible to bend the piece **320** both longitudinally and laterally entirely to conform to the zone **246**. Instead, the piece **320** is bent only longitudinally to conform to the zone **246** in that direction, and the piece **320** is left essentially flat in the lateral direction. The fact that the pieces **320** are relatively narrow results in the over-all lateral surface approximating a spherical curvature. Adhesive is applied to the rear surface of the piece **320** and to the zone of the associated segment **241**. A press similar to the press **282** is used to hold the piece **320** until it is secured. Since the piece **320** was cut oversize, its edges **321** overhang the associated zone, which edges **321** are then ground, so that the piece **320** has precisely the desired shape.

A similar process is performed in respect to each piece **320** and each segment **241**. The segments are then reassembled, as shown in FIG. **49**. The outer surface of each piece **320** thereby becomes a continuation of the outer surface of the adjacent piece **320**, thereby forming a configurated surface **323** having a multiplicity of cube corner projections thereof.

The exposed surface **323** is made conductive by depositing thereon a metallic medium by vacuum metallizing or other process. After the unit shown in FIG. **49** is suitably masked, it is inserted in the plating tank to plate a quantity of nickel or other material onto the surface **323**. After a suitable thickness of nickel has been built up, the unit shown in FIG. **49** may be removed, the front surface of the built-up part masked and then returned to the plating tank for back up. The completed mold member **330** is shown in FIG. **50**. The mold member **330** has a configurated front surface **331** consisting of a multiplicity of cube-corner cavities. The mold member **290** has a pair of side edges **332** and **333** respectively lying in planes containing the center of curvature of the surface **331**. The mold member **330** further has a pair of end edges **334** and **335** respectively lying in chordal planes which are disposed parallel to each other and do not pass through the center of curvature of the surface **331**. The front surface **331** is divided into a plurality of zones **336**, separated by boundary lines **337**. The planes containing the boundary lines **337** are disposed parallel to one another and do not pass through the center of curvature of the surface **331**. The boundary lines **337** result from the slight discontinuities from the various pieces **320** that make up the surface **323**. Of course, each zone **336** is spherically curved in the longitudinal direction but is flattened in the lateral direction since that is the basic shape of the pieces **320** which make up the surface **323**. A hole **338** is formed in the mold member **330**, which hole **338** forms the fingers **200** and **201** in the finished product. Suitable projections may be mounted at the end edge **335** to enable formation of the holes **198** and **199** in the completed product.

Turning now to FIGS. **51–54**, there will be explained a second alternative process for making a curved reflector incorporating therein the features of the present invention. This particular embodiment is useful in making a reflector which is curved in but one direction as opposed to a spherical reflector which is curved in more than one direction. FIG. **51** illustrates a cylinder **340** and a segment **341** thereof, having a part-cylindrical surface **342**. A plurality of pins, such as those shown in FIG. **28**, are arranged in an array, as previously explained. The array is placed in a plating tank to enable a quantity of nickel or the like to be de-

posited or electroformed onto the cube-corner projections **259** of the pins **258.** The electroforming operation is continued until a thickness of, for example, 0.007 inch is obtained. The array of pins **258** and the electroform secured thereto are then withdrawn from the tank and an epoxy or the like is applied to the electroform so as to retain its shape while it is being pried off the pins **258.** The electroform and epoxy cast thereon are then removed from the pins. The metal member **345** thusly formed has a rear surface **346** and a front surface **347,** which front surface **347** has a multiplicity of cube-corner cavities therein, having the general arrangement shown in FIG. **27.** The metal member **345** is then placed with the surface **347** on the part-cylindrical surface **342** and bent to conform to the shape thereof. The member **345** is placed into the plating tank to apply additional nickel onto the surface **346** to back up the member **345.** Referring to FIG. **53,** the mold **350** thusly formed has a surface **347** with a multiplicity of cube-corner cavities therein. The mold **350** is then placed in a molding machine into which is applied acrylic. The reflector **360** thus formed is shown in FIG. **54,** having a smooth front surface **361** and a configurated rear surface **362** with a multiplicity of cube-corner projections thereon. Suitable studs or the like may be provided in the mold for forming holes **363** and **364.** The reflector **360,** as shown in FIG. **54,** has an angular extent of 60°, although any desirable size may be provided. Light from a light source, such as, for example, an elongated fluorescent light disposed along the axis of the cylindrical reflector **360** will strike the reflector **360** and be retrodirectively returned to the source.

It is believed that the invention, its mode of construction and assembly, and many of its advantages should be readily understood from the foregoing without further description, and it should also be manifest that, while the preferred embodiment of the invention has been shown and described for illustrative purposes, the structural details are, nevertheless, capable of wide variation within the purview of the invention, as defined in the appended claims.

What is claimed is:

**1.** A lantern comprising a reflector having therein a multiplicity of cube-corner reflector elements, each of said reflector elements having an apex and a cube axis, the apexes of said reflector elements defining a surface which is part annular, the cube axis of each of said reflector elements being substantially perpendicular to said surface at the apex of the associated reflector element, and a socket for carrying a source of light at a location with respect to said surface to cause the light from the source that impinges on said reflector to be returned by said reflector substantially back to said location.

**2.** The lantern set forth in claim **1,** wherein said surface is part spherical, the cube axis of each of said reflector elements is radially directed, and said socket is arranged to carry the source of light substantially at the center of curvature of said surface.

**3.** A lantern comprising a reflector having therein a multiplicity of cube-corner reflector elements, each of said reflector elements having an apex and a cube axis, the apexes of said reflector elements defining a surface which is part-spherical, the cube axis of each of said reflector elements being substantially radially directed, a socket for carrying a source of light substantially at the center of curvature of said surface, whereby light from the source that impinges on said reflector will be returned by said reflector substantially back to said location, and means for condensing the light from the source in at least one direction.

**4.** The lantern set forth in claim **3,** wherein said reflector is mounted on said condensing means.

**5.** A lantern comprising a reflector including a part-spherical plate-like body and a multiplicity of cube-corner reflector elements thereon, each of said reflector elements having an apex and a cube axis, said plate-like body being constructed of transparent material and having a substantially smooth part-spherical front surface, said reflector elements projecting rearwardly from said body, the apexes of said reflector elements defining a substantially part-spherical surface, the cube axis of each of said reflector elements being substantially radially directed, a socket for carrying a source of light substantially at the center of curvature of said surface, whereby light from the source that impinges on said reflector will be returned by said reflector substantially back to said center of curvature, and means for condensing the light from the source in at least one direction.

**6.** The lantern set forth in claim **5,** wherein said body has a pair of side edges respectively lying in planes containing the center of curvature of said surface.

**7.** The lantern set forth in claim **5,** wherein said body has a pair of side edges respectively lying in planes containing the center of curvature of said surface, said planes being skewed with respect to the vertical.

**8.** The lantern set forth in claim **5,** wherein said reflector has an extent in one direction of between 60° and 180°.

**9.** A lantern comprising an annular sidewall having thereon a plurality of dioptric rings defined by planes disposed substantially normal to an axis about which said sidewall is symmetrically arranged, a reflector including a part-spherical plate-like body and a multiplicity of cube-corner reflector elements thereon, each of said reflector elements having an apex and a cube axis, said plate-like body being constructed of transparent material and having a substantially smooth part-spherical front surface, said reflector elements projecting rearwardly from said body, the apexes of said reflector elements defining a substantially part-spherical surface, the cube axis of each of said reflector elements being substantially radially directed, a socket for carrying a source of light substantially at the focal point of said dioptric rings and substantially at the center of curvature of said surface, whereby light from the source that impinges on said reflector will be returned by said reflector substantially back to said center of curvature and light from the source that impinges on said dioptric elements will be condensed thereby in at least one direction.

**10.** The lantern set forth in claim **9,** wherein said annular sidewall is substantially frusto-conical.

**11.** The lantern set forth in claim **9,** wherein each of said dioptric rings extends substantially 360° around said annular sidewall.

**12.** The lantern set forth in claim **9,** wherein said body has a pair of end edges respectively lying in planes disposed substantially parallel to each other and to the planes defining said dioptric elements.

**13.** The lantern set forth in claim **9,** wherein said body has a pair of side edges respectively lying in

planes containing the center of curvature of said surface.

**14.** The lantern set forth in claim **9**, wherein said body has a pair of end edges respectively lying in end planes disposed substantially parallel to each other and to the planes defining said dioptric elements, and said body has a pair of side edges respectively lying in side planes containing the center of curvature of said surface, said side planes being skewed with respect to said end planes.

**15.** The lantern set forth in claim **9**, wherein said reflector includes a plurality of elongated zones, the boundaries between adjacent zones being disposed respectively in planes substantially parallel to each other and substantially parallel to the planes defining said dioptric rings.

**16.** The lantern set forth in claim **9**, wherein said body has a pair of end edges respectively lying in end planes disposed substantially parallel to each other and to the planes defining said dioptric rings, a point on the upper one of said end edges and a point at the source of light and a point substantially on the lowermost one of said dioptric rings lying substantially on a straight line, the point on the lower one of said end edges and a point at the source of light and a point substantially on the uppermost one of said dioptric rings lying substantially on a straight line.

**17.** A lantern comprising an annular sidewall having thereon a plurality of dioptric rings defined by planes disposed substantially normal to an axis about which said sidewall is symmetrically arranged, a plurality of butting reflectors each including a part-spherical plate-like body and a multiplicity of cube-corner reflector elements thereon, each of said reflector elements having an apex and a cube axis, said plate-like body being constructed of transparent material and having a substantially smooth part-spherical front surface, said reflector elements projecting rearwardly from said body, the apexes of said reflector elements defining a substantially part-spherical surface, the cube axis of each of said reflector elements being substantially radially directed, a socket for carrying a source of light substantially at the focal point of said dioptric rings and substantially at the center of curvature of said surface, whereby light from the source that impinges on said reflector will be returned by said reflector substantially back to said center of curvature and light from the source that impinges on said dioptric elements will be condensed thereby in at least one direction.

**18.** The lantern set forth in claim **17**, wherein each of said bodies has a pair of side edges respectively lying in planes containing the center of curvature of said surface, the edges of one of said bodies butting against and mating with the associated side edge of the adjacent one of said bodies.

**19.** The lantern set forth in claim **17**, wherein each of said bodies has a pair of end edges respectively lying in planes disposed substantially parallel to each other and to the planes defining said dioptric rings, adjacent ones of said end edges lying in substantially the same plane.

**20.** The lantern set forth in claim **17**, wherein each of said bodies has a pair of side edges respectively lying in planes containing the center of curvature of said surface, the edge of one of said bodies butting against and mating with the associated side edge of the adjacent one of said bodies, each of said bodies having a pair of end edges respectively lying in planes disposed substantially parallel to each other and to the planes defining said dioptric rings, adjacent ones of said end edges lying in substantially the same plane, the planes containing the said side edges being skewed with respect to the planes containing said end edges.

**21.** The lantern set forth in claim **17**, wherein said reflectors are arranged side by side.

**22.** The lantern set forth in claim **17**, wherein there are two reflectors provided.

**23.** The lantern set forth in claim **17**, wherein three said reflectors are provided.

**24.** The lantern set forth in claim **17**, wherein each of said reflectors is 60° measured in a plane substantially normal to the planes defining said dioptric rings.

**25.** A lantern comprising an annular sidewall having thereon a plurality of dioptric rings defined by planes disposed substantially normal to an axis about which said sidewall is symmetrically arranged, a reflector including a part-spherical plate-like body and a multiplicity of cube-corner reflector elements thereon, each of said reflector elements having an apex and a cube axis, said plate-like body being constructed of transparent material and having a substantially smooth part-spherical front surface, said reflector elements projecting rearwardly from said body, the apexes of said reflector elements defining a substantially part-spherical, the cube axis of each of said reflector elements being substantially radially directed, a socket for carrying a source of light substantially at the focal point of said dioptric rings and substantially at the center of curvature of said surface, whereby light from the source that impinges on said reflector will be returned by said reflector substantially back to said center of curvature and light from the source that impinges on said dioptric elements will be condensed thereby in at least one direction, said sidewall having a window therein horizontally aligned with the focal point of said dioptric rings, a mark being disposed on said sidewall 180° away from said window and horizontally aligned with said focal point, adjusting means for said socket to enable movement thereof while viewing through said window at said mark until the source of light is in alignment with said window and said mark.

**26.** The lantern set forth in claim **25**, wherein said reflector is mounted on said sidewall between said window and said mark, said reflector having a hole therethrough and aligned with said window and said mark.

**27.** The lantern set forth in claim **25**, wherein said sidewall has a further window therein spaced 90° from said first mentioned window and horizontally aligned with the focal point of said dioptric ring, a further mark being disposed on said sidewall 180° away from said further window and horizontally aligned with said focal point, said adjusting means being further operated to move said socket while viewing through said further window at said further mark until the source of light is in alignment with said further window and said further mark.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,818,218 Dated June 18, 1974

Inventor(s) Sidney A. Heenan, Joseph A. Ciccolella, Norbert Majewski and Anthony J. Montalbano

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 7, line 39, "211c" should be -- 211d --.
Col. 9, line 4, "latern" should be -- lantern --.
Col. 12, line 15, "Fersnel" should be -- Fresnel --.
Col. 20, line 30, after "part-spherical" insert -- surface --.

Signed and sealed this 24th day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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