June 10, 1969 R. W. BASIL ET AL 3,449,561

ACONIC COLLECTOR

Filed July 3, 1967 Sheet 1 of 2

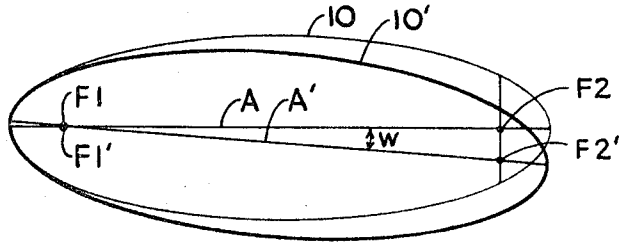


FIG. 1

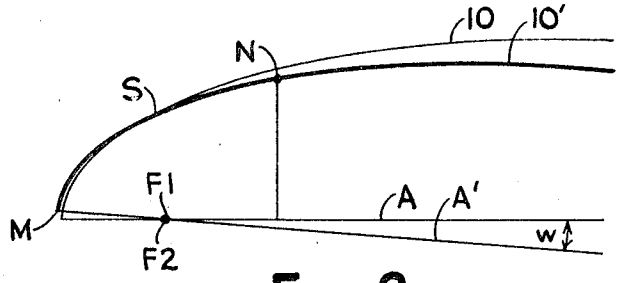


FIG. 2

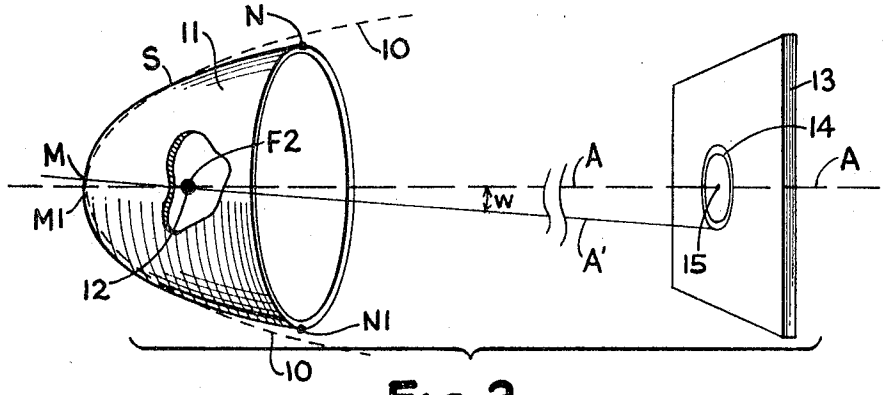


FIG. 3

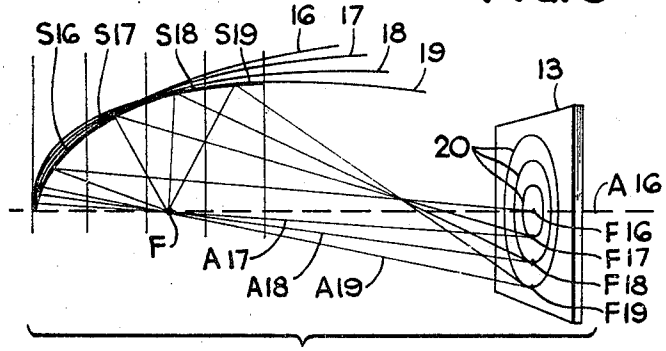


FIG. 4

INVENTOR.
RICHARD W. BASIL
FREDERIC N. BENNING
BY Elliott & Pastoriza
ATTORNEYS

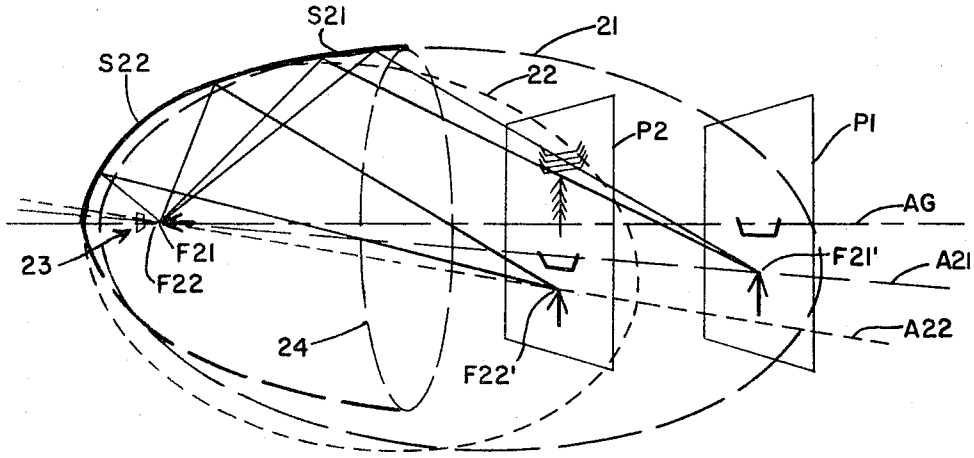


FIG. 5

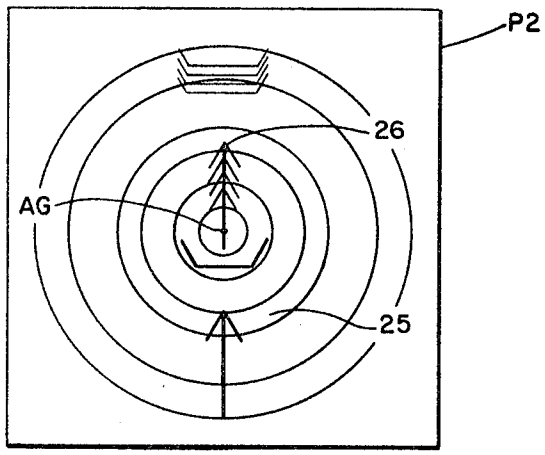


FIG. 6

INVENTORS
RICHARD W. BASIL
FREDERIC N. BENNING
BY
Elliott & Pastoriza
ATTORNEYS

United States Patent Office

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ACONIC COLLECTOR

Richard W. Basil, Canoga Park, and Frederic N. Benning, Chatsworth, Calif., assignors to Textron Electronics, Inc., a corporation of Delaware

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Int. Cl. F21v 7/08

U.S. Cl. 240—103 5 Claims

ABSTRACT OF THE DISCLOSURE

A light collecting mirror for directing radiant energy from a source such as an arc lamp onto a given area wherein the shape of the collecting reflector is such as to compensate for finite source size of the radiant energy to provide a desired uniform illuminance on the area or, if desired, provide a predetermined graded illuminance. The collector is formed by revolving about a generating axis curved line segments which constitute in part portions of ellipses whose major axes lie at different acute angles to the generating axis. The secondary foci of the ellipses are thus radially spaced from the generating axis so that ring patterns are formed at the area illuminated. By using a large number of such segments for generating the collector, a series of concentric rings of decreasing radii may be provided in the test area with the result of fairly uniform illuminance. Further uniformity and compensation is achieved by having some of the secondary foci fall beyond the plane of the test area such that the images provided at the test area serve to fill in desired darker portions to provide the uniform illuminance.

This application is a continuation-in-part of copending application Ser. No. 291,079, filed June 27, 1963, now abandoned and entitled Aconic Collector.

This invention relates generally to energy collecting and directing surfaces and more particularly, to a novel collector for directing energy from a source onto a given area to provide a desired illuminance on any test object positioned in said given area.

Energy collecting surfaces are well known in the art and generally take the form of an ellipsoid. With such a collector, a source of energy is placed at one focus and a test body having a given area to be irradiated is positioned at the conjugate focus. By this arrangement, all of the energy from the source will be directed to the conjugate focus. If the given area to be irradiated is of substantial size, there will be lacking a uniform or desired gradation of illuminance of the body. In other words, since an ellipsoid collector necessarily directs energy from the source to the conjugate focal point, there will develop a "hot spot" at this particular point. Thus, part of the energy is wasted in overconcentration at one point and underconcentration at adjacent areas. In many instances, it would be desirable to irradiate a given area fairly uniformly rather than concentrate all of the energy at one particular point.

Further, and as a practical matter, light energy sources do not constitute point sources and as a result, the refocussed energy is distributed in a manner corresponding to the geometry of the light source itself. Since this geometry is not uniform, there is again presented the problem of a nonuniformly irradiated area.

With the foregoing in mind, it is a primary object of this invention to provide a collecting and directing surface capable of distributing energy over a given area in a predetermined manner to the end that "hot spots" are avoided.

More particularly, it is an object to provide a collector and directing device for distributing energy over a given area so designed that the illuminance of the area may be rendered uniform or graded as desired and in a manner to compensate for the geometry of finite sized light sources.

Briefly, these and other objects and advantages of this invention are realized by avoiding the use of an ellipsoid type reflecting surface and instead employing an aconic surface. An aconic surface may be defined briefly as a surface of revolution generated by revolving a curved line segment which, in itself, may or may not constitute part of a conic section, about a given straight line axis different from the axis of the particular curved line segment if such happens to constitute a portion of a conic section.

In one embodiment of the invention, the aconic collector surface is defined by revolving a curved line segment about a straight line axis passing through the source and the center of the given area to be irradiated. This curved line segment constitutes a portion of an ellipse having a first focus coincident with the source and its conjugate focus lying in a plane normal to the referred to straight line axis, the major axis of the ellipse forming an acute angle with the straight axis. The plane includes the given area to be irradiated. Because of the inclination of the major axis of the ellipse of the curved line segment to the straight line axis about which the curved line segment is revolved to generate the aconic surface, the conjugate focus of the ellipse will describe a ring when a source is placed at the focus of the resulting aconic surface. There will thus be provided a distribution of energy following a ring about the center of the given area.

In other embodiments of the invention, a plurality of curved line segments successively connected together may be caused to rotate about a given straight line axis passing through the source and the center of a given area to be irradiated. These successive curved line segments may constitute portions of a series of ellipses all having their first foci coincident with the source and their conjugate foci successively radially spaced from the center of the given area as a consequence of having their major axes successively inclined at varying acute angles with respect to the straight line axis. The resulting aconic collector surface will distribute energy in a pattern of concentric rings so that the energy from the source is fairly uniformly distributed over the given area. By initially adjusting the relative lengths of the series of curved line segments forming the aconic collector, the illuminance of the given area may be graded so that certain areas will receive more radiation than other areas.

It is evident from the foregoing that the surface may be designed to compensate for the geometry of a finite light source such as an arc lamp to provide a desired uniformity. Further finite source size compensation may be realized by utilizing segments of ellipses having major axes of different lengths in addition to different angular relationships to the generating axis for the collector.

A better understanding of the invention will be had by now referring to preferred embodiments thereof as illustrated in the accompanying drawings, in which:

FIGURE 1 is a diagrammatic showing useful in explaining the principles of forming the aconic collector surface of this invention;

FIGURE 2 is a greatly enlarged portion of the diagram of FIGURE 1;

FIGURE 3 illustrates in perspective view a first embodiment of an aconic collector in accordance with the invention;

FIGURE 4 is a further diagrammatic representation

useful in explaining the principles of forming another embodiment of the aconic collector;

FIGURE 5 is a diagrammatic illustration of the invention including a finite source geometry for which compensation of nonuniformity of the source is realized; and,

FIGURE 6 is a schematic view of the image resulting from the collector of FIGURE 5.

Referring first to FIGURE 1, there is shown an ellipse **10** having a first focus F1 and a conjugate focus F2. The major axis of this ellipse is designated A. In conventional ellipsoid type collectors, an energy source would be positioned at the focus F1 and a target or test body to be illuminated would be positioned at the conjugate focus F2. By the properties of the ellipsoid, all of the energy radiated from the source at F1 would be reflected and concentrated at the conjugate focus F2. There would thus develop a concentrated radiation at the point on the object coinciding with the conjugate focus F2 and an underconcentration of energy at adjacent points with the result that the energy would not be used efficiently.

In order to provide a collector in accordance with the present invention which will distribute the energy over a given area at which a target or test body is positioned, the collecting surface may be formed by providing a second ellipse indicated at **10'**. This second ellipse is constructed to have its first focal point F1' coincident with the focal point F1 of the first ellipse **10** and thus be coincident with the position of the source of radiant energy. However, the major axis of the second ellipse, indicated at A', is inclined at an acute angle W to the major axis A of the first ellipse **10**. As a consequence, the conjugate focal point F2' of the second ellipse **10'** will fall substantially in a plane including the focal point F2 but spaced therefrom, this plane being normal to the major axis A of the first ellipse **10**.

With particular reference to FIGURE 2, a segmental portion of the second ellipse **10'** is indicated by the heavy line S extending between points M and N. If this curved line segment S is now revolved about the axis A corresponding with the major axis of the first ellipse **10**, an aconic surface will be generated.

The resulting surface is illustrated at **11** in FIGURE 3. As shown, after the curved line segment S has been revolved about the axis A 180 degrees the points M and N will assume the positions M1 and N1 which fall inside a conventional ellipsoid collector formed by the first ellipse **10**. If a source of radiant energy **12** is now positioned at the focus F2 of this collector surface **11**, the energy will be directed and distributed over a body **13** as indicated by the shaded area **14**. This distribution is in the form of a ring having a center corresponding to the center of the given area to be illuminated as indicated by the numeral **15**. Thus, the axis about which the curved line segment S is caused to revolve corresponds with a straight line axis A passing through the source **12** and the center of the given area **13**, the major axis A' of the ellipse from which the curved line segment S was derived and described in conjunction with FIGURE 2 being inclined at the acute angle W to the straight line axis A.

In actual practice, it is not possible to provide a point source of radiant energy. As a result, there will not result a narrow ring of concentrated energy in the plane of the second focus, but rather a broad ring area fairly uniformly illuminated.

To render the distribution even more uniform or even to grade the illuminance on a given area, the aconic collector may be generated from a series of connected curved line segments corresponding to portions of a series of ellipses. Thus, with particular reference to FIGURE 4, there is illustrated a series of portions of ellipses **16**, **17**, **18**, and **19** all having a common first focal point F coincident with a desired source of radiant energy (not shown). The major axes of these ellipses indicated at **A16**, **A17**, **A18** and **A19** form successively increasing

acute angles starting at zero with respect to a straight line axis passing through the source at focal point F and the center of the body **13**. Thus, the conjugate focal points of the series of ellipses are spaced at increasing radial distances from the center of the plane of the target area, these conjugate focal points being indicated at **F16**, **F17**, **F18**, and **F19**.

If now given curved line segments are selected from these respective ellipses and successively connected together, such as indicated at **S16**, **S17**, **S18**, and **S19**, there will result an overall curved line segment which may be revolved about the axis **A16** corresponding to the straight line axis passing through the focal point F and the center of the target. The resulting aconic collector will then serve to distribute the radiant energy at the focal point F over a pattern described by a plurality of concentric rings such as indicated at **20**. Again, because of the actual physical size of the radiation source as opposed to a theoretical point source, a clear definition of concentric rings will not result but generally they will merge into each other to form a relatively uniform distribution of illuminance on the target **13**.

In forming the aconic surface as described in FIGURE 4, the length of the various curved line segments **S16** through **S19** may be adjusted prior to generating the surface so that different surface areas for these respective line segments are provided in the composite complete aconic collector thereby resulting in different concentrations of energy from these various segments. Thus, the energy distribution over the target area may be graded as desired.

Referring now to FIGURE 5, there is illustrated a further embodiment of the invention wherein there is defined a generating axis AG and a first line segment **S21** constituting part of a first ellipse **21** having a first focal point **F21** lying on the generating axis AG and a second focal point **F21'** falling in a plane **P1** normal to the generating axis. As indicated, the second focal point **F21'** is radially spaced from the generating axis in the plane **P1**.

A second line segment **S22** in turn is defined by part of a second ellipse **22** having a first focal point **F22** coincident with focal point **F21** in a finite source **23**. The second focus for the second ellipse **21** is indicated at **F22'** and lies a given radial distance from the generating axis AG in a second plane **P2** spaced from the first plane **P1**. It will be noted that the major axes of the respective ellipses lie at different acute angles relative to the generating axis AG.

The line segments **S21** and **S22** may be smoothly connected together and are shown in heavy lines in FIGURE 5. If these two lines are now revolved about the generating axis AG, there will result an aconic collector shown in dashed lines at **24**.

The particular finite source **23** depicted in FIGURE 5 is for an arc lamp and is designated for simplicity by means of the small arrow and a cooperating electrode. The end of the arrow for the arc lamp constitutes a very intense light source the radiation over the area of the source decreasing towards the spaced electrode. Thus, considering the tip of the arrow of the source **23**, from the first revolved line segment **S21**, there will result at the second focus **F21'** an image of the arrow as shown in plane **P1**.

The image from the second segment **S22** of the arrow representing the hot point of the arc lamp source will appear in the plane **P2** at **F22'** as shown in FIGURE 5. In this same plane **P2**, there will also be a certain illuminance as a consequence of the first ellipse line segment **S21** but this will not quite be in focus because of the spacing of the plane **P2** from the focal point **F21'** in the plane **P1**. Further, it will be spaced radially closer to the generating axis line AG than the image at the second focus **F21'** in the plane **P1**.

It will be evident from the foregoing that as a con-

sequence of the complete reflecting surfaces formed by revolving the line segments S21 and S22 about the generating axis, the resulting ring type images, as they appear in the area defined by the plane P2, will be substantially similar to that illustrated in FIGURE 6.

Referring specifically to FIGURE 6, the ring of illuminance at the radial distance 25 from the generating axis AG is shown as greater than the somewhat out-of-focus image of the arrow formed by the segment S21 when viewed in the plane P2. Thus, rotation of the images to form the concentric rings results in a fairly uniform illuminance of the area.

The only difference between the embodiment illustrated in FIGURES 5 and 6 and that described in conjunction with FIGURE 4 is the fact that the generating line segments are defined by ellipses having different length major axes such that the secondary foci may lie in different planes all normal to the generating axis AG but spaced along the generating axis relative to each other. By this further variation in the refocussing of the collected radiation from the source, a further control over the final illumination in the desired area is realized.

From the foregoing description, it will be evident that the present invention has provided a greatly improved radiant energy collecting and directing surface structure. Not only is a greater portion of the emitted energy collected as a consequence of the particular form of the aconic surface, but as a consequence of the distribution of the energy over the given area to be irradiated, the energy is efficiently used and the formation of concentrated hot spots and the like as a result of finite sources is wholly avoided.

Minor modifications falling clearly within the scope and spirit of this invention will occur to those skilled in the art. The aconic collector is therefore not to be thought of as limited to the exact embodiments set forth merely for illustrative purposes.

What is claimed is:

1. An aconic collector for distributing energy from a source onto a given area in accordance with a predetermined illuminance, comprising, in combination: at least two reflecting surfaces positioned together to form a composite collector generated by revolving at least two curved line segments about a straight line generating axis passing through said source and the center of said given area, said curved line segments constituting portions of at least two ellipses, respectively, having first foci coincident with each other and said source and second foci

spaced given distances from said source and at different radial distances from said generating axis, respectively, the major axes of said ellipses forming different acute angles with said straight line generating axis.

2. An aconic collector according to claim 1, in which said source is of a finite size to provide nonuniformly irradiating light from different spaced portions on said source, said curved line segments defining said reflecting surfaces when revolved about said generating axis being dimensioned such that said predetermined illuminance on said given area is substantially uniform.

3. An aconic collector according to claim 1, in which the second foci of said ellipses lie substantially in a single plane normal to said generating axis.

4. An aconic collector according to claim 1, in which the second foci of said ellipses lie respectively in parallel planes spaced along the generating axis and normal thereto, said given area coinciding with one of said planes.

5. An aconic collector for distributing energy from a source onto a given area in accordance with a predetermined illuminance, comprising, in combination: a series of concave reflecting surfaces connected together to form a composite collector generated by revolving a series of successive curved line segments about a straight line axis passing through said source and the center of said given area, said curved line segments successively constituting portions of a series of ellipses having first foci all coincident with each other and said source and second foci substantially in planes spaced along and normal to said straight line axis, said second foci being spaced at different radial distances in said planes from said straight line generating axis respectively, the major axes of said ellipses forming successively varying acute angles with said straight line axis.

References Cited

UNITED STATES PATENTS

1,275,120	8/1918	Ballman et al.	
1,756,084	4/1930	Caughlan	240—41.37
1,819,725	8/1931	Wood	240—41.37
3,028,486	4/1962	Simmon	325—113

NORTON ANSHER, *Primary Examiner.*

RICHARD M. SHEER, *Assistant Examiner.*

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