

- [54] APPARATUS AND METHOD FOR UNIFORM ILLUMINATION OF A SURFACE

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- [63] Continuation of Ser. No. 774,898, Nov. 12, 1968,
abandoned.

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350/296

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313/113; 350/293, 296; 240/41.35 R, 41.35 E,
103 R, 104, 41.37; 250/88

- [56]
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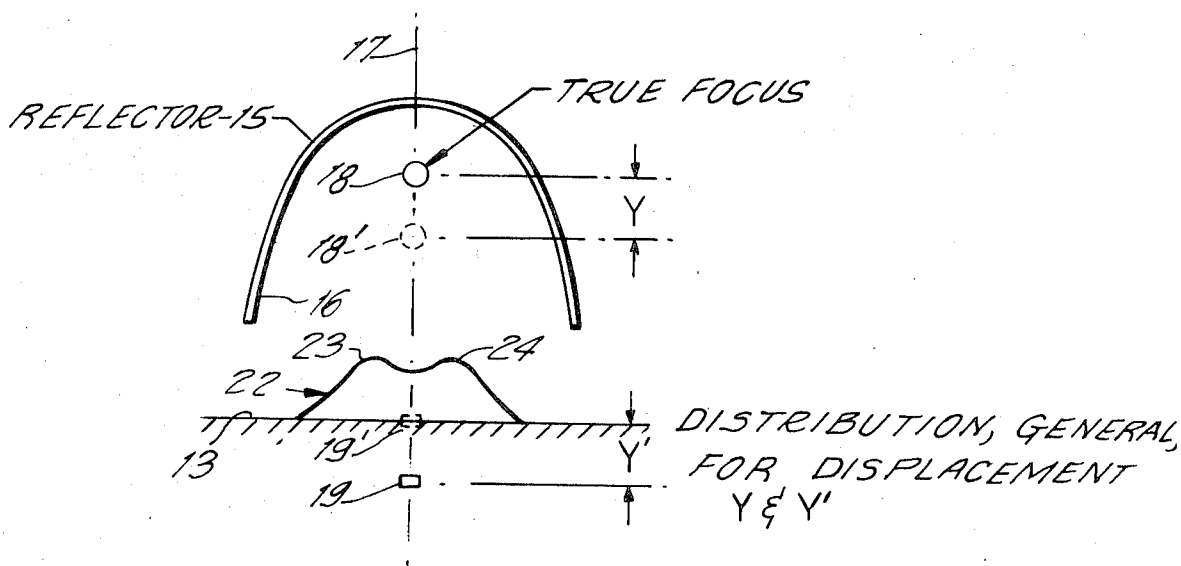
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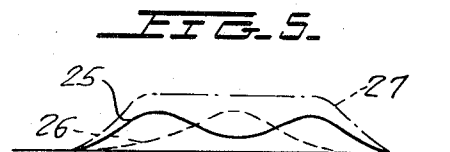
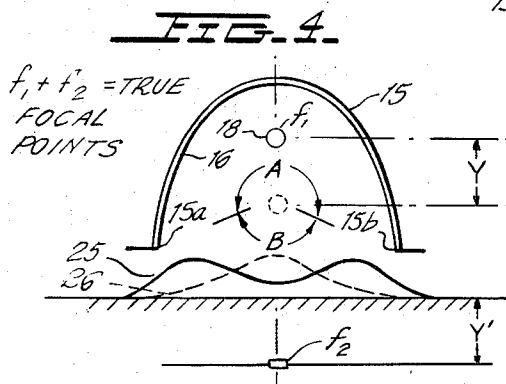
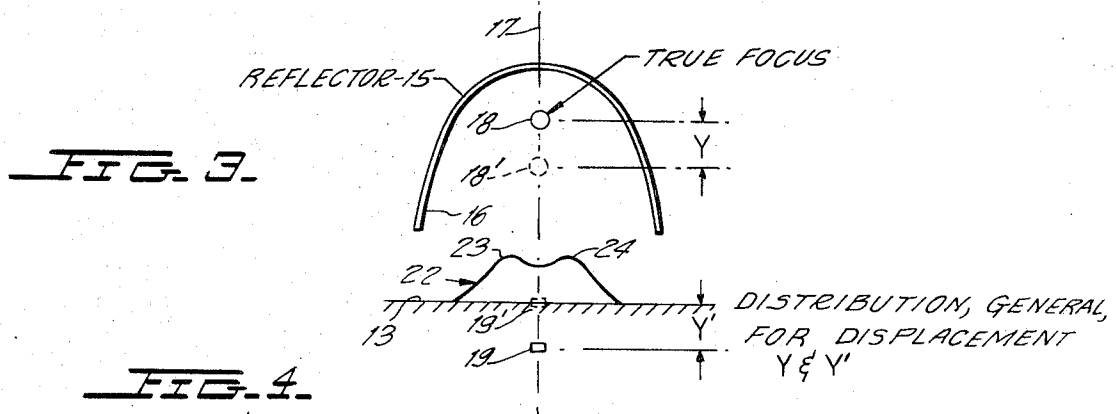
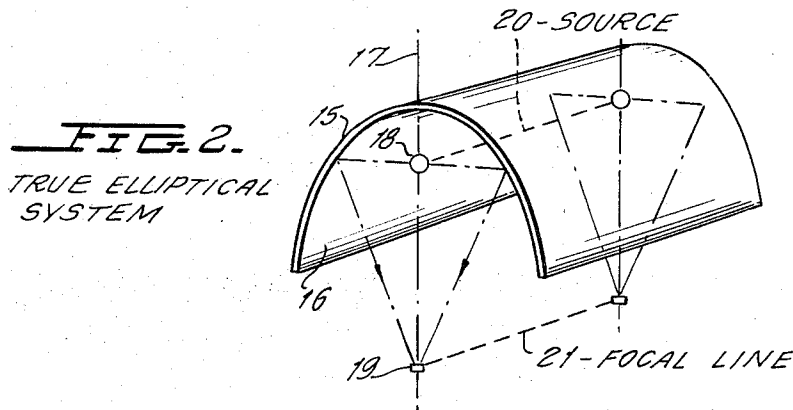
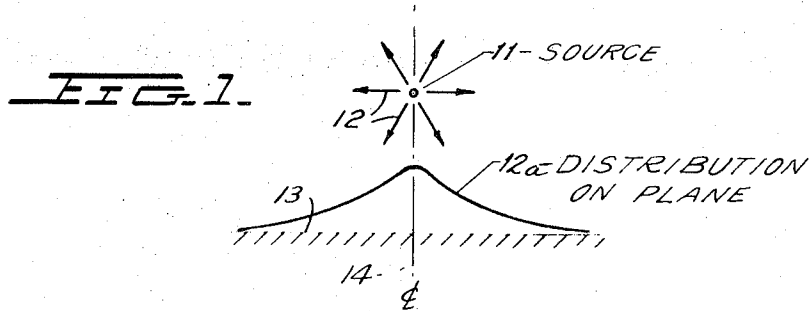
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ABSTRACT

A technique for irradiating a substantially large surface area so as to obtain substantially uniform radiation density over the entire surface area to be irradiated through the use of prismatic elements including elliptical shaped reflector means and a line radiation source, wherein the line radiation source and the image plane of the surface area to be irradiated are positioned at predetermined locations displaced from the normal primary and secondary focal points to cause the entire surface area to be irradiated in a substantially uniform manner.

5 Claims, 5 Drawing Figures





25= DISTRIBUTION OF A- REFLECTED
26= DISTRIBUTION OF B- DIRECT

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APPARATUS AND METHOD FOR UNIFORM ILLUMINATION OF A SURFACE

This is a continuation of application Ser. No. 774,898, filed Nov. 12, 1968, now abandoned.

The present invention relates to irradiation devices and more particularly to a novel method and apparatus for irradiating a flat surface area through the use of prismatic elements so as to expose the entire surface area to substantially uniform irradiation.

In certain types of processes it is most desirable to be able to illuminate planar surfaces uniformly. Such types of processes would include both heating processes and photographic exposure processes as well as other processes of a similar nature. Conventional methods have already been developed to provide for the uniform illumination of a precisely defined substantially narrow area using kaleidoscopic techniques in conjunction with a focused radiant energy assembly. Methods of this type are described in detail in copending application Ser. No. 710,546 filed Mar. 5, 1968 now U.S. Pat. No. 3,522,407 issued Aug. 4, 1970 by the inventor of the present application. The apparatus described therein employs a collector for substantially uniformly irradiating a surface wherein the irradiated portion is substantially well defined and is small in total surface area.

Another technique employed in irradiating a planar surface of substantially large surface area is comprised of providing irradiating apparatus for irradiating a portion of said surface area and scanning said surface area from one end to the other to expose it to radiation. This is time consuming and also does not provide a uniform surface density of radiation as well as being complex in that it requires a mechanism for performing the scanning operation.

The present invention employs a highly reflective member of a predetermined curved configuration and a line source of irradiation positioned a predetermined distance from the reflecting member along the major axis of the reflecting member. The image plane supporting the surface to be irradiated is located a predetermined distance above the image focal point, which image plane is aligned perpendicular to the major axis of the reflecting member. The direct radiation from the line source of radiation and the reflected radiation emitted from the image source upon the reflecting surface and reflected downwardly to the image surface, combined to irradiate the image surface in a highly uniform manner over substantially its entire surface area which in one preferred embodiment described herein is only 15 percent narrower than the distance measured between the edges of the reflecting member defining the open end thereof. The substantially uniform irradiating density is also capable of reaching maximum irradiation from a cold start in less than one second making the operation extremely rapid in addition to providing extremely uniform irradiation density across the irradiated surface.

It is therefore one object of the present invention to provide a novel apparatus and method for uniformly irradiating a substantially planar surface of rather large surface area without the use of collector apparatus other than a single reflecting surface.

Another object of the present invention is to provide a novel apparatus and method for rapidly irradiating a planar surface of rather large surface area in a substan-

tially uniform manner over the entire surface area to be irradiated.

Still another object of the present invention is to provide a novel apparatus and method for rapidly irradiating a planar surface in an extremely uniform manner over the entire surface area thereof which is comprised of an elliptical prismatic reflective member and a line source of irradiation positioned a predetermined distance from the reflective member along the major axis thereof wherein said distance substantially deviates from the primary focal point of the reflective member.

Still another object of the present invention is to provide a novel apparatus and method for rapidly irradiating a planar surface in an extremely uniform manner over the entire surface area thereof which is comprised of an elliptical prismatic reflective member and a line source of irradiation positioned a predetermined distance from the reflective member along the major axis thereof wherein said distance substantially deviates from the primary focal point of the reflective member and wherein the image plane of the surface being radiated is located a substantially similar distance above the image or secondary focal point of the reflective member in order to achieve extremely uniform irradiation density across the entire area of the surface being irradiated.

These as well as other objects of the present invention will become apparent when reading the accompanying description and drawings in which:

FIGS. 1 and 2 show apparatus which may be employed to irradiate a surface.

FIG. 3 shows an apparatus further showing the orientation of the apparatus relative to the surface being radiated as well as a distributional curve depicting radiation density across the surface.

FIGS. 4 and 5 respectively show radiation apparatus in conjunction with a surface to be radiated in which the apparatus is arranged in the manner taught by the present invention and curves depicting the radiation density across the irradiated surface.

BACKGROUND OF THE INVENTION

The uniform illumination of planar surfaces for heating, photographic or other like processes has been found to be difficult to achieve through the use of simple systems. As one example, plane to plane radiant transfer systems, which have been found to provide uniform radiation, are impractical due to the size and thermal mass of the systems making them very cumbersome and expensive.

For the purpose of the present invention the following description will be limited to rapid response systems for the irradiation of planar surfaces located a given distance from the system. Rapid response is herein defined as the ability to reach maximum irradiation, from a cold start, in a time interval of less than one second.

To provide a system with the radiating of rapid response requires the use of a small radiating source having low thermal capacity. The need to achieve these characteristics is for the purpose of minimizing thermal inertia to bring the source to the desired temperature level. However, a small source radiating uniformly in all directions is incapable of uniformly irradiating a planar surface. The points of closest proximity to the radiation surface are found to receive more energy than those points located further away from the source. For example, FIG. 1 shows a point source 11 having an om-

ni-directional radiation characteristic depicted in FIG. 1 by the arrows 12. The rays 12 directed generally downwardly strike a surface 13 located a spaced distance therefrom in such a manner that the points of closest proximity of surface 13 receive more energy than those points further removed from the point source. For example, the highest energy density lies along the phantom line 14 passing through source 11 which is perpendicular to planar surface 13. The energy density tapers off at points lying to the left and to the right of line 14 resulting in an energy density curve which is a Gaussian type of distribution as depicted by curve 12a.

The use of classical reflective or refractive manipulation techniques have been found to be of limited value, since the resultant distributions have been found to be still Gaussian in nature.

The present invention is characterized by providing a reflector-source combination that eliminates most of the problems and complexities of existing systems. radiation system that

The system of the present invention employs a prismatic reflector having an elliptical cross-section and having parallel plane ends which are perpendicular to the prismatic axis. The source is a thin linear filament extending the length of the reflector. FIG. 2 is a perspective view showing an elliptical radiation system. The reflector member 15 is provided with a highly reflective surface along its concave side 16. The reflective member has an elliptical cross-sectional configuration whose major axis is represented by the phantom line 17. The geometry of an ellipse is such that the ellipse has two true focal points namely, a primary focal point 18 along which is positioned a thin linear filament 18 employed as a line source of radiation in the elliptical system. The secondary focal point 19 represents the point at which the radiation is focused to form an image of the line source. Due to the length and configuration of the elliptical reflector and line source, the image is a focal line 21 which is parallel to the line radiating source 20, is perpendicular to the major axis 17 of the ellipse and which intercepts the major axis at point 19. One suitable reflector which may be employed is an elliptical-cylindrical reflector having a gold reflective surface. The line source may, for example, be a mercury arc, a tungsten filament, a carbon filament, or any material having stability at elevated temperatures.

The components described hereinabove may be identical to the CONRAY line heating systems manufactured by the Argus Engineering Company and referred to as CONRAY line heaters. Conray is a trademark of the Argus Engineering Company. Obviously any other components may be employed.

A true elliptical system will produce an image of the radiator placed at the primary focus. The image will be distorted by inherent aberrations in the elliptical system but will not be remarkably larger than the source. In existing systems such as those commercially available systems referred to above, the width of the focal zone is less than one-tenth of an inch.

If a planar surface is placed at the secondary focus parallel to both the minor axis of the ellipse and to the primary focus, the radiation distribution may be observed by thermal or visual means. With the type 91 CONRAY system, a clearly defined line of light (0.150 × 6 inches) may be observed at the secondary focus.

The distribution of energy across this line is accurately represented by a Gaussian curve.

By the manipulation of the system described hereinabove it is possible to achieve an area of uniform irradiation which is much larger than that given at the true focus.

FIG. 3 shows an elevational view of such a system wherein like components are designated by like numerals as compared with FIGS. 1 and 2. The primary and secondary focal points are designated by the numerals 18 and 19 in FIG. 3. In the arrangement shown therein the irradiation source positioned at focal point 18 is displaced downwardly a distance y from the true primary focal line in a direction toward the secondary focal line and along the major axis 17 so that the line or radiation source is now located at point 18'. The intercepting planar surface 13 is similarly displaced upwardly an equal distance y' from the secondary focal point in a direction toward the primary focus so as to intersect the major axis at point 19' and lie perpendicular thereto. This displacement provides a larger focal zone than that previously described for a true elliptical system. The focal zone will have a distorted distribution that provides two regions of greater intensity than the surrounding regions. The distributional curve designated by numeral 22 is shown to have two regions (generally designated by the numbers 23 and 24 of greater intensity in which the surrounding regions (lying to the left and right thereof) are of lesser intensity. The regions generally designated by the numerals 23 and 24 can be seen to lie equi-distant from a plane containing the true focal lines of the elliptical system and more specifically to lie equi-distant from a plane perpendicular to planar surface 13 and containing the points 18, 18', 19 and 19'. In spite of the displacement described above, it can clearly be seen that, whereas the irradiated surface is larger than the irradiated surface in the true elliptical system the irradiation density across the surface being irradiated is clearly non-uniform.

If the displacements of the line source 18 and the intercepting plane 13 are further increased to the values Y and Y' as shown in FIG. 4, it is found that the irradiation becomes much more uniform across the zone of illumination. This is due to the combined effect of direct radiation from the source located at 18' and the radiation from reflector 15.

The radiation in FIG. 4 may be divided into two groups: A and B. A designates the reflected energy while B designates the direct energy. At certain displacements, Y and Y' from the true focus, it has been found that the summation of the A and B groups of radiation produce a region of radiation that is very uniform in energy density. Curve 25 represents the energy distribution along surface 13 of the reflected energy while curve 26 represents the distribution of energy along surface 13 due to the direct energy impinging upon the surface. The summation of these two curves is represented by curve 27 which can be seen to be quite uniform across a substantially large surface area of the irradiated surface 13. The uniform region of irradiation was found to be approximately 15 percent narrower than the opening of the reflector 15 measured across its straight parallel edges 15a and 15b which define the edges of the opening.

The displacements Y and Y' downwardly and upwardly respectively from the true focal points f_1 and f_2 need not be precisely equal. It has been found that ex-

cellent results are obtained when the line source is positioned downwardly from the primary focal point by a distance equal to at least half the distance between the focal point and the minor axis of the ellipse, (which is perpendicular to the major axis). Likewise excellent results have been obtained when the irradiated surface is positioned by a distance above the secondary focal point or image point equal to at least half the distance between the secondary focal point and the minor axis. The displacements Y and Y' need not be precisely equal and slight variations from the positions described herein may be made depending upon the size of the line source.

Two applications for the system described herein which may use the system to great advantage are substrate heating and photocopying.

In the field of substrate heating, many processing procedures employed in the manufacture of electronic and magnetic devices require uniform heating of planar surfaces. Conduction or convection techniques have been found to yield only marginal success due to the variations in the gap or distance between the heater and the work surface. A radiation system employed for use in substrate heating has been developed and tested. The system under experimentation has been found to provide very uniform energy distribution for use in substrate heating.

In the photocopying field, copying methods which require the use of light and heat have been in use for some time. Most of the systems presently in use employ a linear focusing technique similar to present day apparatus as embodied in the CONRAY line heating devices presently being sold by The Argus Engineering Company. Other techniques employ small prismatic reflectors having a parabolic cross section. Uniform irradiation is achieved by moving the radiation device transverse to its axis and parallel to the plane of the copy paper. This scanning technique achieves uniform exposure of each point on the paper by integration across the radiant zone.

The primary drawbacks of the systems described above are their slow operation speed and excessive mechanical hardware required to perform uniform scanning. The system described herein eliminates all of the above problems.

Although the invention has been described above with respect to its preferred embodiments, it will be understood that many variations and modifications will be obvious to those skilled in the art. It is preferred therefore that the scope of the invention be limited not by the specific disclosure herein but only by the appended claims.

What is claimed is:

1. An apparatus for uniformly irradiating a substantially planar surface of a member comprising an elongated substantially linear source emitting radiant energy in a substantially omnidirectional manner, said radiant energy being directed in radial fashion about the longitudinal axis of the source; reflector means comprising a curved shell open at one end thereof and having a substantially elliptical cross-section; the concave surface of said shell having high reflectivity characteristics;

said line source lying in a plane containing the major axis of the ellipse defined by said cross-section and containing a pair of said focal lines;

means for aligning said member whereby said planar surface is aligned substantially perpendicular to said plane;

said line source being positioned a first spaced distance from the focal line of said ellipse which lies closest to said reflector means toward the other focal line and parallel to same;

said aligning means further positioning said planar surface a second spaced parallel distance from the focal line furthest removed from said reflector means and intermediate said focal lines;

said second spaced distance being selected to provide substantially uniform radiation density across the surface irradiated by said line source, said first and second spaced distances being substantially equal.

2. The apparatus of claim 1 wherein the distance between said line source and the focal point closest to said reflector means is substantially equal to one-half the distance between the focal line closest to said reflector means and the minor axis of said ellipse, which minor axis is perpendicular to said major axis.

3. The apparatus of claim 1 wherein said line source is comprised of a radiant source of low thermal capacity capable of producing radiant energy sufficient to rapidly heat said irradiated surface to the desired temperature level in less than one second.

4. The apparatus of claim 1 wherein said shell has a truncated elliptical cross section; the edges of said shell at said open end being arranged in spaced parallel fashion;

the dimensions of the elliptical shell being selected so that the distance between said edges is about 15 percent greater than the dimensions across that portion of the planar surface measured transverse to said edges which is to be irradiated.

5. An apparatus for uniformly irradiating a member having a substantially planar surface comprising an elongated substantially linear source emitting radiant energy in a substantially omnidirectional manner, said radiant energy being directed in radial fashion about the longitudinal axis of the source;

reflector means comprising a prismatic shell having an elliptical cross-section, said elliptical shape being hemicircloidal and defined by the prolate section of said ellipse, said shell being open at a plane passing through the minor axis of the ellipse and having substantially plane and parallel end surfaces perpendicular to the focal lines described by all focal points of said elliptical cross-sections;

the concave surface of said shell having high reflectivity characteristics;

said line source lying in a plane containing the major axis of the ellipse defined by said cross-section and containing a pair of said focal lines;

mean for aligning said member so that said surface is aligned substantially perpendicular to said plane;

said line source being positioned a first spaced distance from the focal line of said ellipse which lies closest to said reflector means toward the other focal line and parallel to same;

said aligning means further positioning said member so that said planar surface is positioned a second spaced parallel distance from the focal line furthest removed from said reflector means and intermediate said focal lines;

said second spaced distance being selected to provide substantially uniform radiation density across the surface irradiated by said line source and being substantially equal to said first spaced distance.

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