

[54] **UNIFORM VARIABLE LIGHT SOURCE**

[75] Inventor: **Henry P. Squyres**, El Monte, Calif.

[73] Assignee: **California Institute of Technology**,
Pasadena, Calif.

[22] Filed: **Dec. 4, 1970**

[21] Appl. No.: **95,189**

[52] U.S. Cl. **240/46.13**, 240/41 R, 240/41.35 R,
356/236

[51] Int. Cl. **F21m 7/00**

[58] Field of Search 240/41 R, 41.2, 41.35, 41.4,
240/46.01, 46.13, 2 M; 356/236; 250/228;
355/67, 71; 353/85; 240/103, 41.3

[56] **References Cited**

UNITED STATES PATENTS

3,371,202	2/1968	Moore et al.	240/46.13
3,385,962	5/1968	Freeman	240/41 R
1,566,127	12/1925	Rundquist	240/41.4 D
3,170,636	2/1965	Nordquist	240/46.49 R
2,186,619	1/1940	Sauer	355/71
2,558,964	7/1951	Kliegl	240/46.13
1,633,228	6/1927	Rogers	355/67

2,469,781	5/1949	Peters	355/71
2,038,514	4/1936	Hummert	240/46.13
2,076,240	4/1937	Levy	240/46.13
3,432,243	3/1969	Hardesty	356/236 X
3,374,706	3/1968	Weisglass	355/71

Primary Examiner—Samuel S. Matthews

Assistant Examiner—Alan A. Mathews

Attorney—Lindenberg, Freilich & Wasserman

[57] **ABSTRACT**

A uniform stable light source comprising a special lamp with a built in reflector which projects stable and uniform luminous flux with unvarying spectral characteristics with a distribution temperature of about 3,000 degrees K. The uniform luminous flux flows into a conical cavity through an iris diaphragm whose diameter is controllable. A uniform light diffuser is positioned at the opposite end of the conical cavity. The level of luminance which is transmitted through the diffuser is controlled by controlling the diaphragm diameter.

11 Claims, 4 Drawing Figures

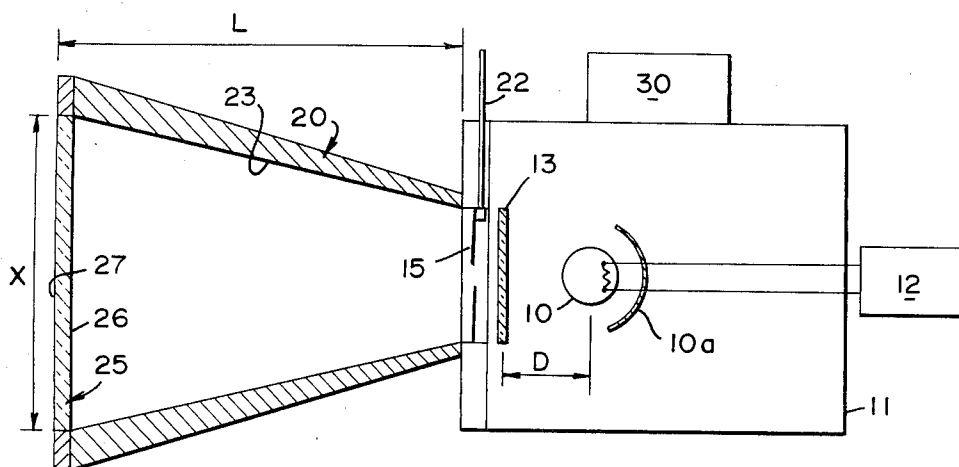


FIG. 3

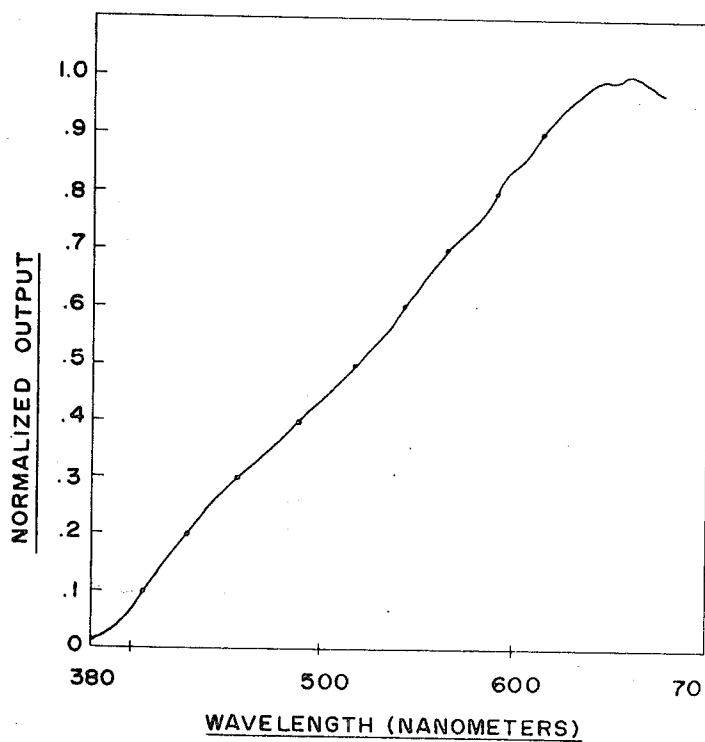
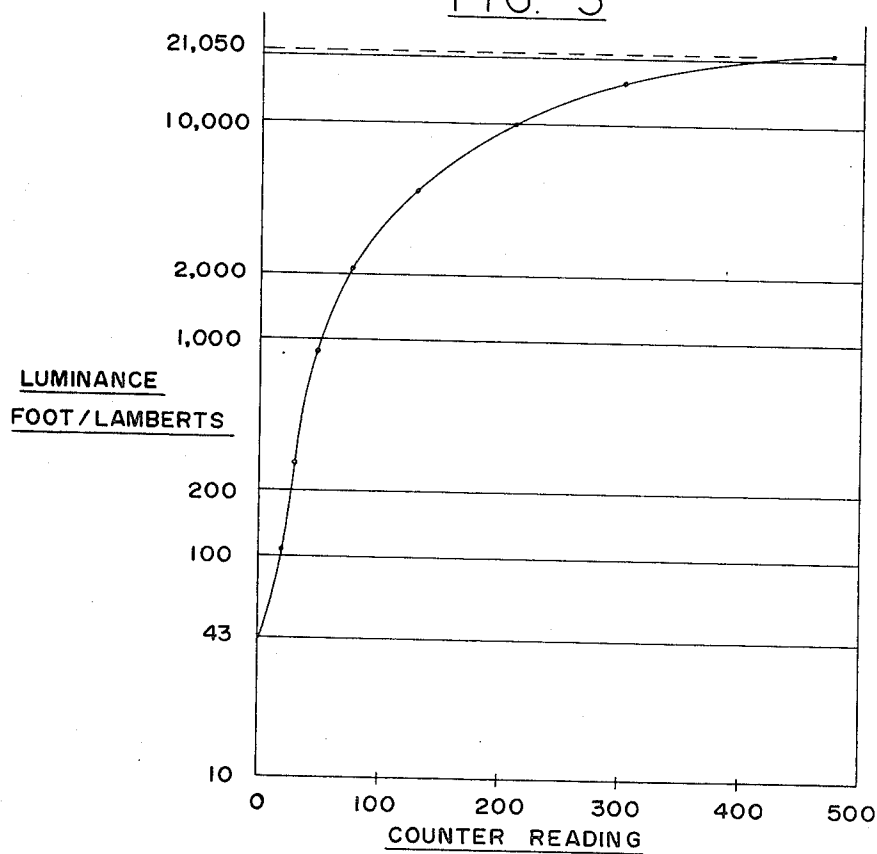


FIG. 4

HENRY P. SQUYRES
INVENTOR.

BY

London, Fresh & Harman
ATTORNEYS

UNIFORM VARIABLE LIGHT SOURCE

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457)

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to optical devices and, more particularly, to a source of uniform variable light of the type which is useful for calibration of optical instruments.

2. Description of the Prior Art:

It is often necessary to calibrate optical instruments by measuring their output, such as an output voltage, in response to changes in the level of luminance with which the instrument is illuminated. In some calibration applications it is necessary to be able to continuously adjust the luminous level over a very wide range without varying the spectral characteristic of the luminance or light. Furthermore, it is generally desired that the luminance be uniform over a specified area to a very close tolerance. For example, it is always necessary to calibrate a television camera for use in space exploration which may be subjected to sunlight at varying levels of luminance over the entire light sensitive aperture of the camera, before flight time. This is necessary in order to be able to determine from the camera's output the level of luminance with which the camera is illuminated. For such a calibration it is necessary to provide a source of light which approximates sunlight as much as possible and which is controllable to provide continuous adjustment of luminous levels over a very wide range. It is also important that the luminance be highly uniform over a significant field, such as circular area of several inches in diameter, to correspond to the camera's aperture or field of view. Although various light sources for instrument calibration are in existence, none has such desired characteristics.

OBJECTS AND SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a new improved light source for instrument calibration.

Another object of the present invention is to provide a source of light whose luminous level is adjustable over a very wide range without varying the spectral characteristics of the light.

A further object is to provide a source of light in the range of 3,000 degrees K, the light being of uniform luminance over a field of several inches in diameter to within several percent and having a luminous level which is continuously adjustable over a wide range.

Still a further object of the invention is to provide a source of light in the range of 3,000 degrees K, the light being of uniform luminance over a field of several inches in diameter to within several percent and having an intensity which is continuously adjustable from 45 to 20,000 ft/lamberts with no spectral variation.

These and other objects of the invention are achieved by providing a light source which produces uniform light which approximates solar light over a

chosen area, e.g., one inch in diameter, at a known distance therefrom. At this distance a diffuser is located. Adjacent the diffuser is positioned an iris aperture whose opening area is either manually or mechanically controllable. Extending from the iris aperture, also referred to as the diaphragm, is a diverging cone-shaped member with a conical cavity. One end of the conical cavity has a diameter corresponding to that of the largest diameter of the iris aperture. The opposite end of the conical cavity supports a light diffuser, whose diameter is chosen as a function of the desired diameter of the field on which uniform luminance is to be produced. The interior surface of the conical cavity is coated with reflective paint to provide a uniformly randomly light reflective surface. The diffuser, at the output end of the conical cavity, is chosen to reflect some of the light back into the cavity while serving as an efficient light transmitter to transfer the luminous flux to the outside.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of the present invention;

FIG. 2 is an isometric view of one embodiment of the invention; and

FIGS. 3 and 4 are diagrams useful in summarizing the advantages of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As diagrammed in FIG. 1, the novel apparatus of the present invention includes a source 10 of light, such as a lamp with a built in reflector 10a, which provides highly uniform light similar to solar light over a relatively small area at a distance D from it. The lamp is shown mounted in a lamp housing 11, with power being supplied to the lamp from a source 12. Located at the distance D from the lamp 10 is a ground quartz diffuser 13 which in one embodiment assumed the form of a quartz disc with No. 180 finish on both sides.

Light passing through diffuser 13 is directed to an iris aperture of diaphragm 15 which enables light to pass through its variable diameter into a light integrating cavity 20. The diameter of iris aperture 15 may be varied manually by means of a lever 22. As will be pointed out hereafter, the lever 22 may be coupled to a servo unit by means of a gear-worm arrangement to provide electromechanical control of the diameter of the iris opening 15.

The integrating cavity 20 assumes the form of an outwardly diverging conical cavity with an interior surface 23 and of length L along its longitudinal axis. The diameter of the end of cavity 20 at plate aperture 15 corresponds to the maximum diameter of diaphragm 15. The greater diameter of the opposite or outer end of the cavity 20, designated X, corresponds to the diameter of a light diffuser 25, with an inner surface 26 and an outer surface 27. It is surface 27 through which the desired output luminance is transmitted.

To enhance the efficiency of the cavity 10, it is preferable to coat the surface 23 with a highly reflective paint, and one which does not affect adversely either the desired spectral radiance or the distribution temperature. One type of paint which has been found to be especially advantageous is the White Reflectance Paint, sold by Eastman Kodak Company of Rochester, New York. This paint is a composition of barium sulfate, binder and solvent with a high spectral reflectance through the ultraviolet, visible and part of the near infrared regions of the spectrum. It is characterized by high stability and nearly perfect diffuse reflection.

To insure that the luminous flux entering cavity 20 through iris aperture 15, it is necessary to select a highly stable lamp which provides the desired degree of uniform light, at the distance D therefrom, whereat diffuser 13 is located. Although different lamps may be employed, one lamp which was found to be very satisfactory is Quartzline unit No. E.J.N., manufactured by General Electric. This lamp provides uniform light over a 1-inch diameter area at 2 inches ($D=2$) therefrom. A second lamp manufactured by Varian/Eimac Division has been used, Model 150x8S - Xenon. It produces about 18,000 foot lamberts at 5,000°K. Stability of operation is enhanced by controlling the temperature of the lamp in housing 11 by means of an airblower 30.

It is appreciated that the amount or quantity of the highly uniform luminous flux which is permitted to flow into the conical cavity 20 from diffuser 13 is controlled by controlling the area or diameter of iris aperture 15. In cavity 20 the luminous flux is further uniformly and randomly reflected by multiple reflections from the interior surface 23. This surface is preferably coated with a spectrally flat, highly reflective paint. As a result, a highly uniform flow of luminous flux at a high degree of efficiency is directed to the diffuser 25. The latter is chosen to have uniform light transmission properties over most of its surface so that the level of luminance at surface 27 of diffuser 25 is uniform to within the desired degree of tolerance over a majority of its area.

In one particular embodiment the diffuser 25 consists of a thin sheet, about 3mm thick, of a cast thermoplastic acrylic resin, such as polymethylmethacrylate, with white pigment. Such a material is available commercially, one source being Rohm and Haas of Philadelphia Pennsylvania. In order to produce a highly uniform light diffuser it is necessary to remove all glossiness from such a material. This may be accomplished by honing the two surfaces 26 and 27 of the diffuser, such as with a liquid honing machine. Honing the surfaces with a mixture of an abrasive of 220 grit and water in a 1 to 3 ratio at a pressure of 30-60 lbs has been found to produce satisfactory results.

The foregoing described apparatus of the invention may be summarized as comprising a conical cavity with a first uniform light diffuser at one cavity end. At the other cavity end is located an aperture of a variable diameter through which stable and uniform luminous flux enters the cavity. The amount of flux which enters the cavity is controlled by controlling the aperture diameter. The stable and uniform luminous flux is provided by a stable source of light with unvarying spectral characteristics and with a substantially constant dis-

tribution temperature in a selected range. The source of light is a lamp which provides highly uniform light of a selected area at a fixed distance therefrom, at which a second light diffuser is located. It is the light passing through the latter which enters the conical cavity through the variable diameter aperture. The teachings of the present invention have been employed to provide uniform white light with stepless variation in intensity from 100 to 20,000 ft/lamberts with no spectral variation. This was achieved with aforementioned General Electric lamp and with a conical cavity 20 having dimension $L=2.8$ inch, $X=2$ inches and the diameter at the iris aperture 15 of 1.25 inch. The lamp was housed in housing 11 with dimensions of $4 \times 2 \times 2$ inches.

The embodiment actually reduced to practice is shown in FIG. 2. Therein, the top of lever 22 is shown entrapped between fingers 32 and 33, connected to a gear segment 34 which is in mesh with a gear-worm 35 on a shaft 37. The latter is assumed connected at one end to a servo drive unit 40 and at another end to a multidigit, e.g., 3, readout counter 42. Thus, as unit 40 rotates shaft 37, the latter rotates worm 35 which causes gear segment 34 to rotate. Consequently, the fingers attached thereto proportionately advance the iris lever 22 to enlarge or reduce the diameter of the iris aperture 15.

FIG. 3 to which reference is now made is a graph of luminance of light source in foot/lamberts versus corresponding counter readings which are directly related to aperture diameter, while FIG. 4 is a spectral radiance calibration graph for the particular embodiment actually reduced to practice.

There has accordingly been shown and described herein a novel apparatus for providing uniform white light with stepless variation in intensity over a wide range, e.g., 45 to 20,000 ft/lamberts with no spectral variation. Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. A light apparatus comprising:

first means having first and second ends defining therebetween a cavity for the passing of light, said cavity having an interior surface which uniformly and randomly reflects light entering said second end toward said first end;

second means disposed at said first end for transmitting some of the light which is directed thereto through said cavity with the transmitted light having a luminance level which is uniform over substantially the entire area of said second means through which the light is transmitted, said second means reflecting some of the light which is directed thereto back into said cavity, said second means having glossless surfaces and uniform light transmission properties over substantially its entire surface at said second end;

third means for providing a uniform distribution of luminous flux in a preselected distribution temperature range with substantially constant spectral characteristics, said third means including a source of luminous flux which is uniform over a

preselected area at a preselected distance from said source; and

control means disposed between said first and third means for variably controlling the amount of the uniformly distributed luminous flux which is admitted from said third means to said first means through said second end to control the level of luminance which is transmitted through said second means over a substantial range without affecting the uniformity of the luminance level which is transmitted over substantially the entire area of said second means.

2. The arrangement as recited in claim 1 wherein said luminance level is controllable over a stepless range of at least one hundred units to one, as a function of the control of said control means.

3. The arrangement as recited in claim 1 wherein the uniformly distributed luminous flux is substantially constant and said control means define an aperture through which the luminous flux enters said first means through said second end, said control means further including means for controlling the area of said aperture to control the amount of luminous flux which enters said first means and thereby control the level of luminance transmitted through said second means.

4. The arrangement as recited in claim 3 wherein said first means comprises a cone-shaped member defining a conical cavity, with said first end having a greater diameter than said second end, and said second means has a surface with an area corresponding to the area of the first end of said conical cavity, said second means being a glossless diffuser having uniform light transmission properties over substantially its entire surface.

5. The arrangement as recited in claim 4 wherein said source of light in said third means provides light with substantially stable spectral characteristics and with a distribution temperature of not less than 3,000 degrees K.

6. A light apparatus comprising:

a first member defining a conical cavity having first and second open ends, said first open end being larger than said second end, said and said having an interior surface coated with a material which uniformly and randomly reflects light entering said second end toward said first end;

a second member disposed at said first end of said

conical cavity for transmitting some of the light which is directed thereto from said cavity through its first end and for reflecting some of the light which is directed thereto back to said cavity, the transmitted light having a luminance level which is uniform within less than 10 per cent over the entire surface of the second member through which it is transmitted, said second member having glossless surfaces and highly uniform light transmission properties over substantially its entire surfaces;

variable aperture control means disposed at said second end of said first member for controlling the effective opening at said second end through which light is transmittable into said cavity; and

light source means adjacent said variable aperture control means and including a lamp for providing light of uniform intensity at a preselected distance from said lamp over a preselected area with at least a portion of the light of uniform intensity being directed to said cavity through the effective opening controlled by said variable aperture control means.

7. The arrangement as recited in claim 6 wherein said variable aperture control means is an iris aperture whose diameter is variable.

8. The arrangement as recited in claim 7 wherein said light source means includes a first light diffuser substantially positioned between said lamp and said iris aperture at said preselected distance from said lamp, and said second member is a second light diffuser having glossless surfaces with uniform light transmission properties over substantially its entire surfaces.

9. The arrangement as recited in claim 6 wherein said second member is a first highly uniform light diffuser with honed surfaces to remove surface glossiness therefrom and the material coating the inner cavity surface forms a highly reflective coating which does not affect adversely the light spectral radiance and the distribution temperature and which uniformly and randomly reflects light.

10. The arrangement as recited in claim 9 wherein said variable aperture control means is an iris aperture whose diameter is variable.

11. The arrangement as recited in claim 10 wherein said light source means includes a second light diffuser substantially positioned between said lamp and said iris aperture at said preselected distance from said lamp.

* * * * *

50

55

60

65