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Haring et al.

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[54] **IRRADIANCE CALIBRATION WITH SOLAR DIFFUSER**

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[73] Assignee: **The Perkin-Elmer Corporation**, Norwalk, Conn.

[21] Appl. No.: **810,792**

[22] Filed: **Dec. 19, 1991**

[51] **Int. Cl.**[5] **G01N 21/33**

[52] **U.S. Cl.** **356/243**; 250/372; 250/252.1

[58] **Field of Search** .... 356/243; 250/252.1 A, 250/372

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,652,761 3/1987 Kerr et al. 250/372

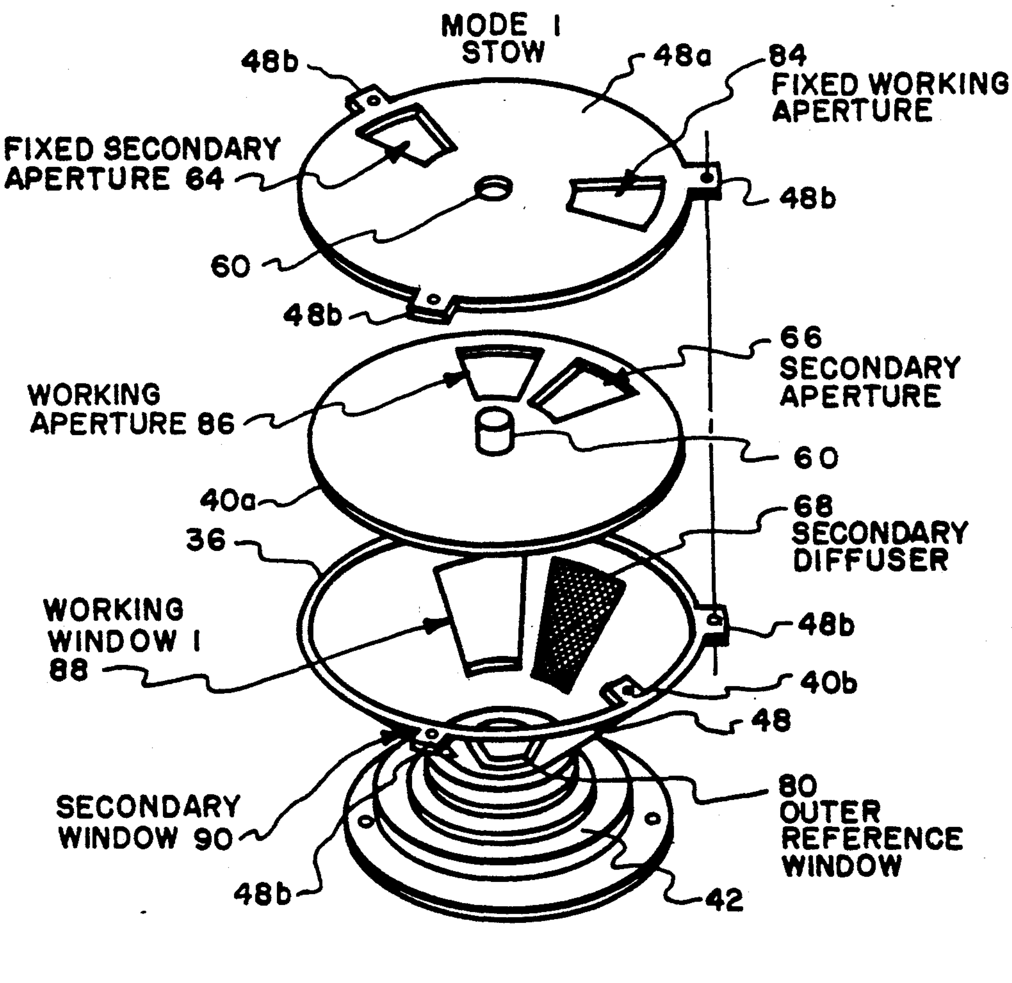
Primary Examiner—Vincent P. McGraw

Attorney, Agent, or Firm—Edwin T. Grimes; Joseph R. Dwyer

[57] **ABSTRACT**

The sun's energy is used in combination of movable and fixed diffuser plates, windows and apertures which are positioned in a series of test sequences (modes) for reflectance monitoring and calibration without the use of man-made sources. There are three embodiments, or implementations, of the invention—one embodiment uses two diffusers—a working diffuser and a secondary diffuser—the second embodiment uses three diffusers, a working diffuser, a secondary diffuser and a reference diffuser—and the third embodiment uses two diffusers—a working diffuser and a secondary diffuser, the latter also functioning as a cover for the working diffuser. The movable diffusers are mounted on rotatable cones and, in all embodiments, the sun is blocked from reaching the diffusers when not in use. Thus, the sun is used as a stable source for calibration and monitoring and the sun/diffuser combination is used in such a way that the response of all elements of the optical subsystem of the TOMS can be unambiguously and efficiently characterized with high accuracy and precision.

14 Claims, 9 Drawing Sheets



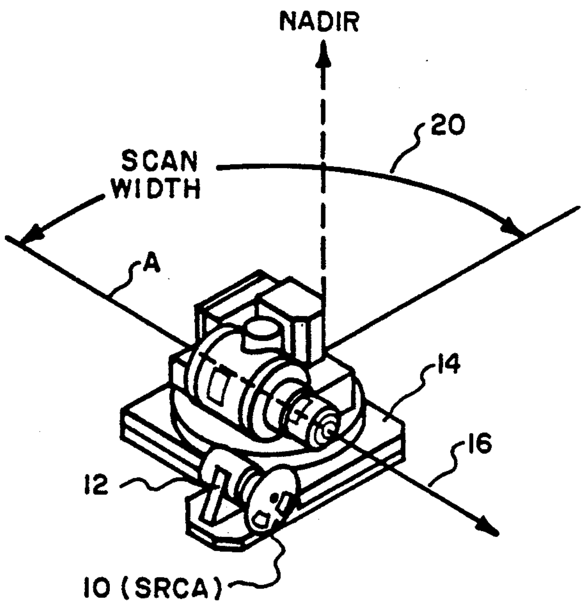


Fig. 1.

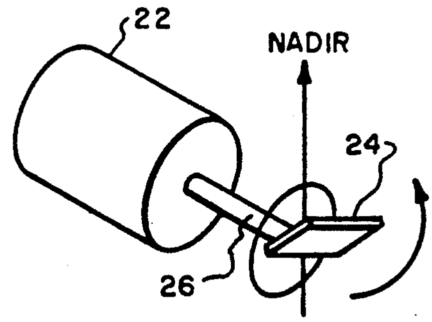


Fig. 1a.

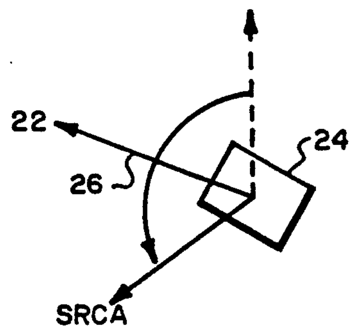


Fig. 1b.

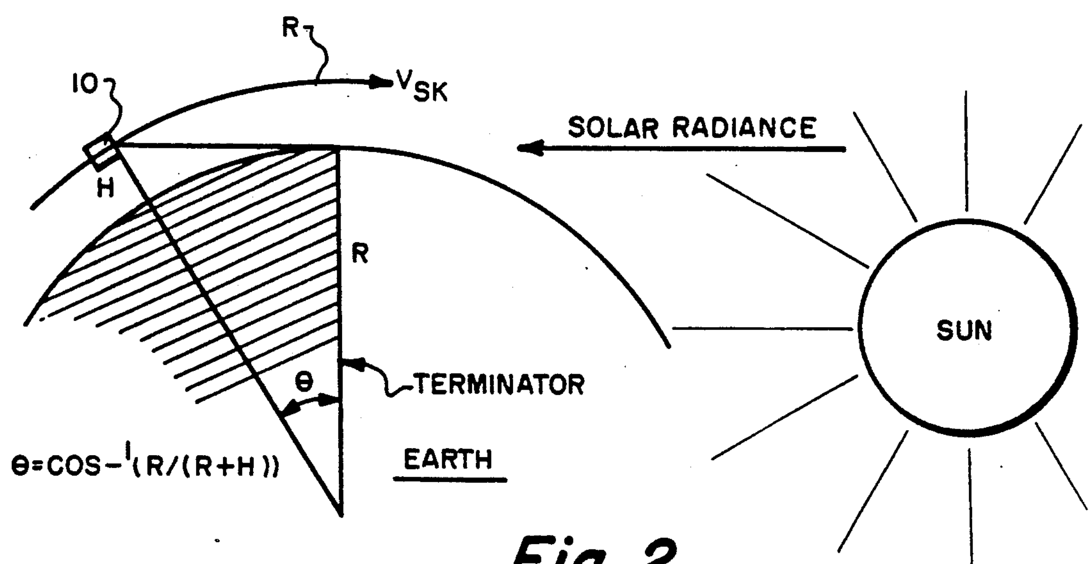


Fig. 2.

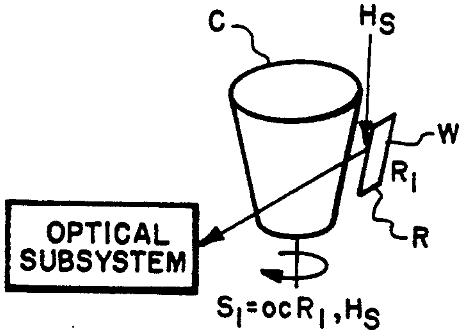


Fig. 3a.

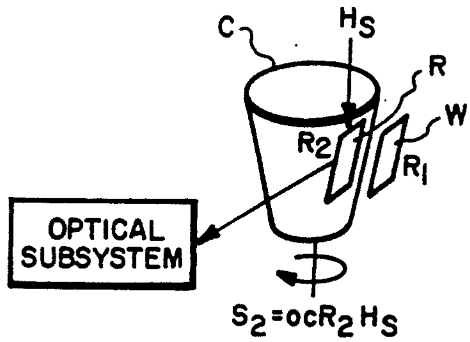


Fig. 3b.

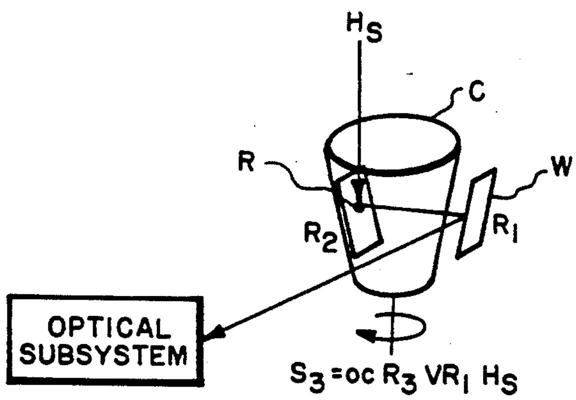


Fig. 3c.

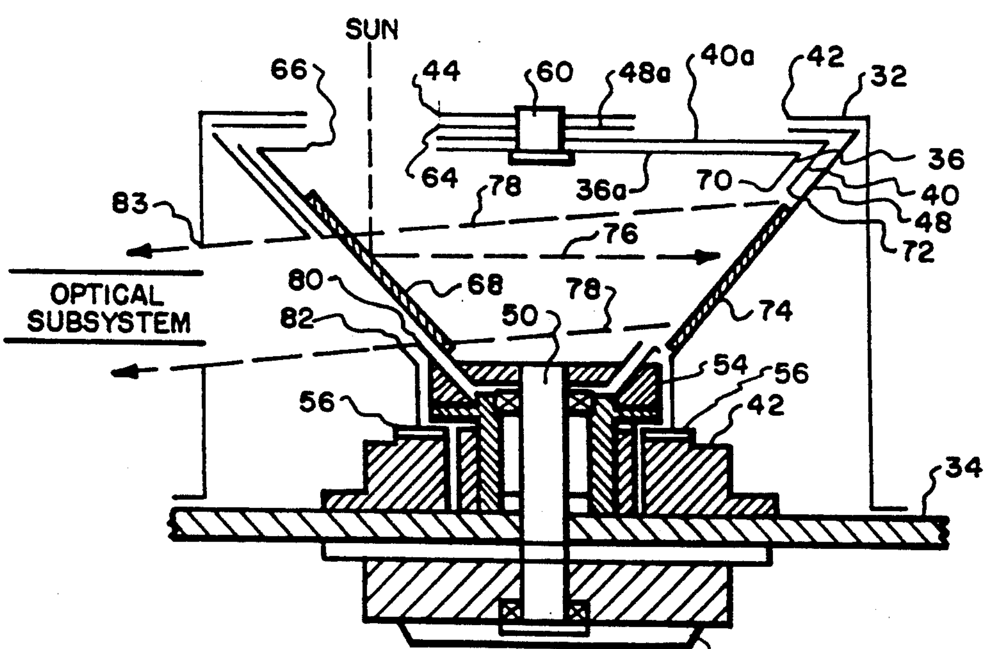


Fig. 4.

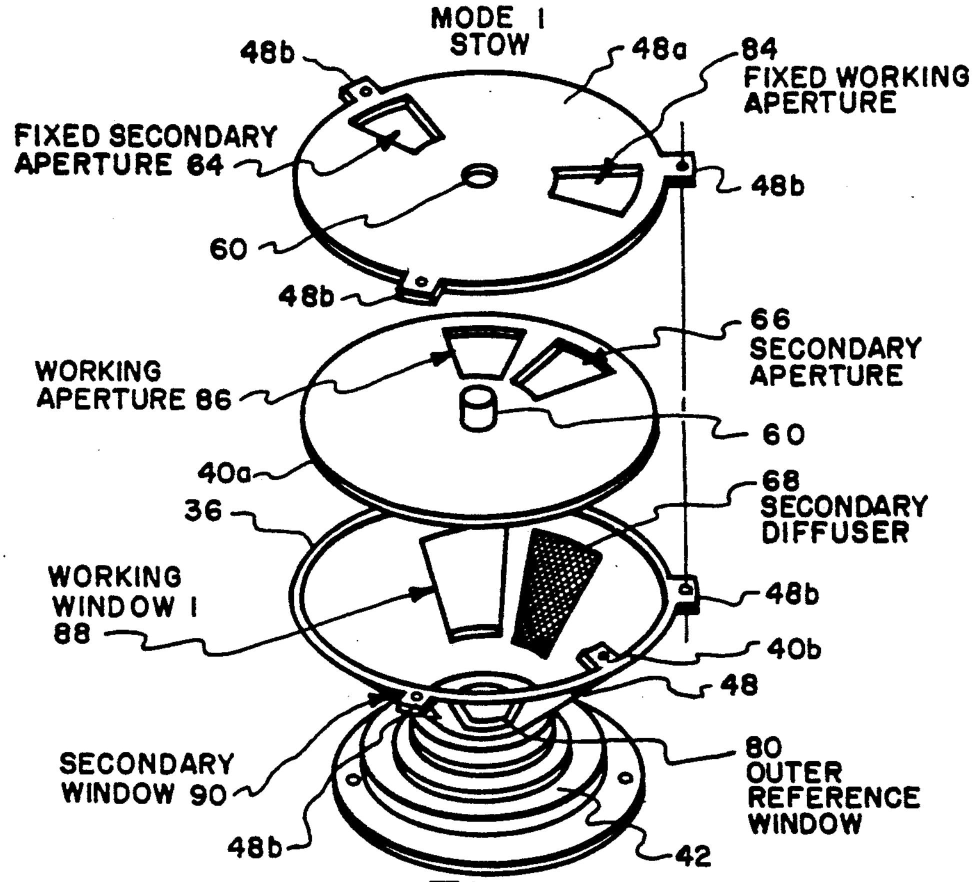

MODE 1
STOW
48b
48a
84
FIXED WORKING
APERTURE
FIXED SECONDARY
APERTURE 64
48b
60
48b
66
SECONDARY
APERTURE
WORKING
APERTURE 86
60
40a
68
SECONDARY
DIFFUSER
36
WORKING
WINDOW 1
88
48b
40b
48
SECONDARY
WINDOW 90
80
OUTER
REFERENCE
WINDOW
48b
42

Fig. 5a.

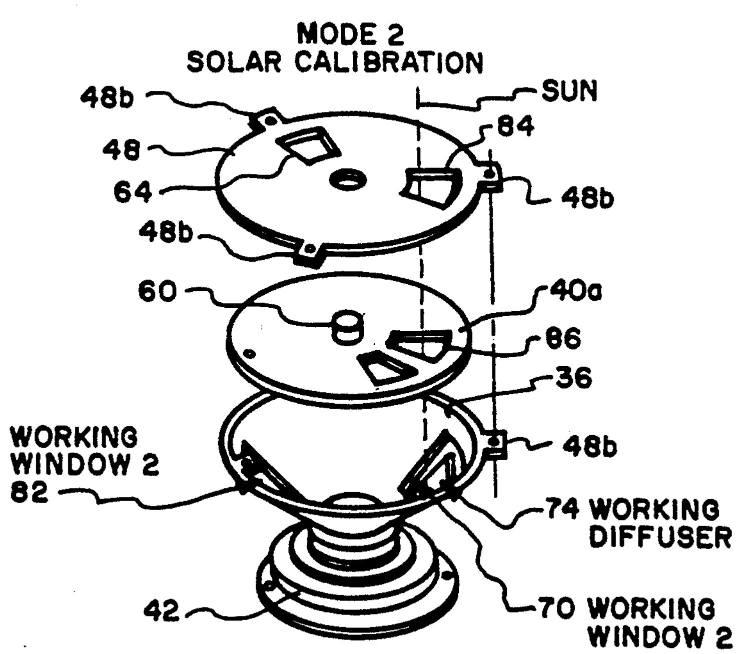

MODE 2
SOLAR CALIBRATION
48b
SUN
84
48
64
48b
48b
60
40a
86
36
WORKING
WINDOW 2
82
48b
74 WORKING
DIFFUSER
42
70 WORKING
WINDOW 2

Fig. 5b.

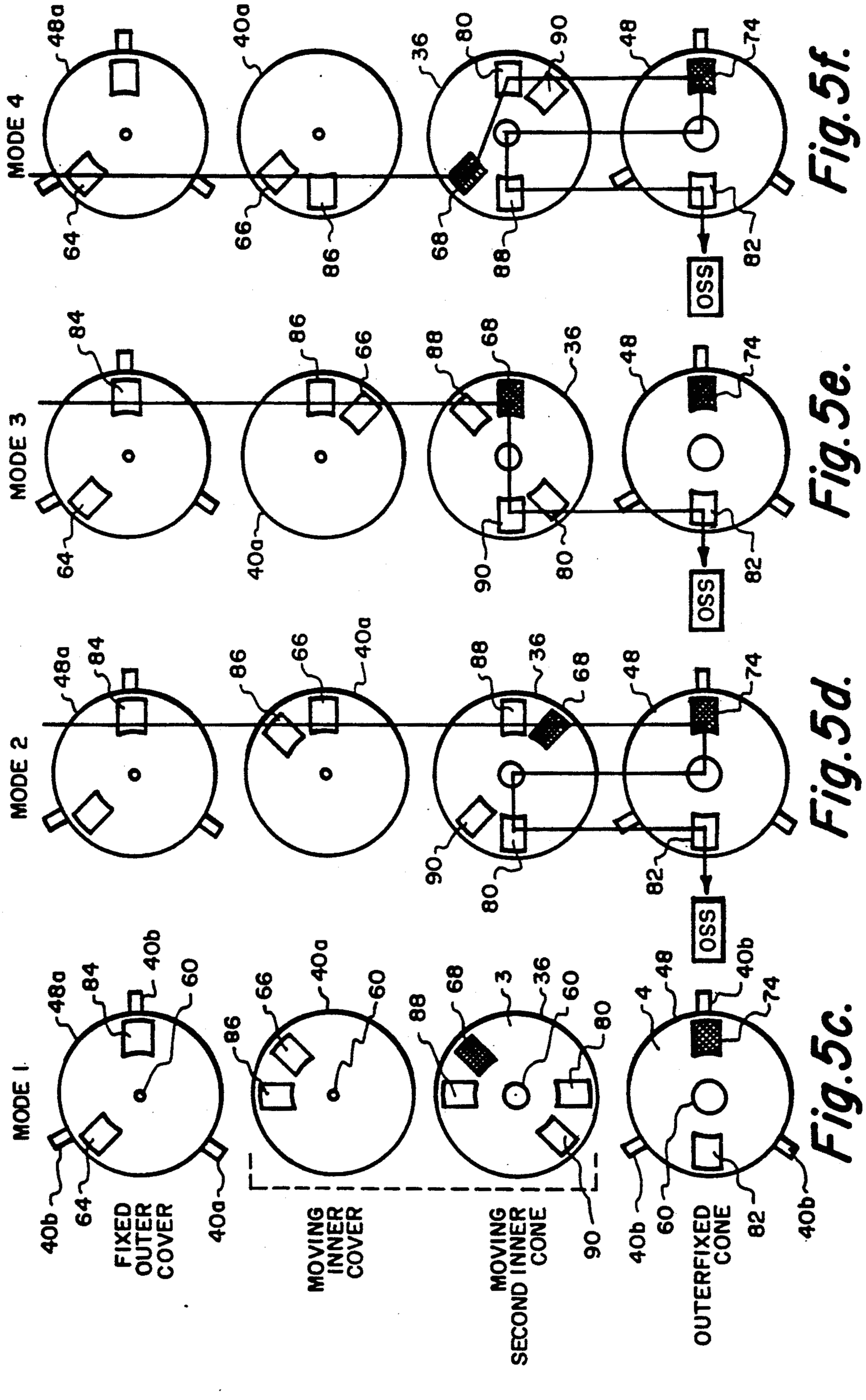


Fig.5c. Fig.5d. Fig.5e. Fig.5f.

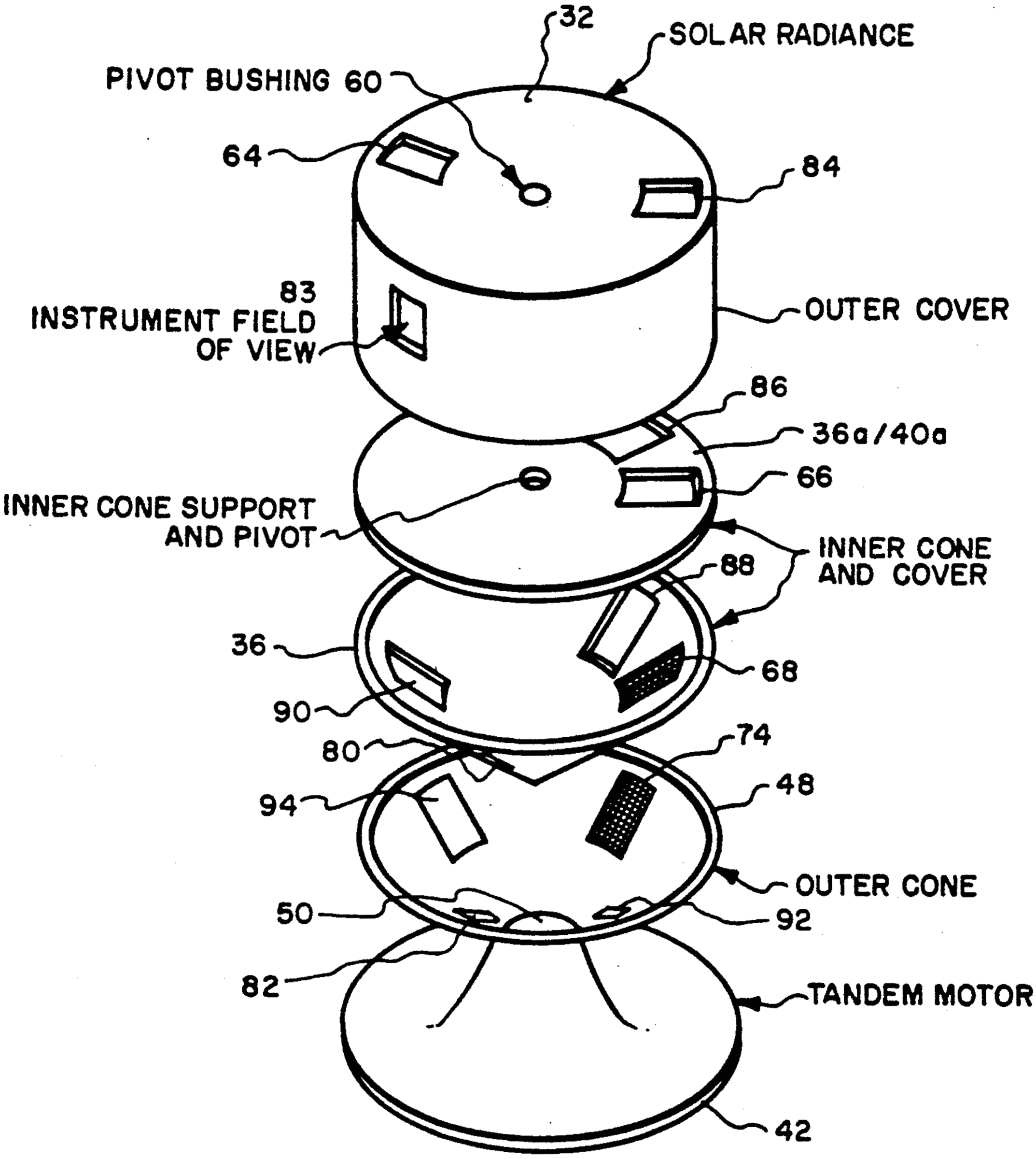

32
SOLAR RADIANCE
PIVOT BUSHING 60
64
84
83
INSTRUMENT FIELD
OF VIEW
OUTER COVER
86
36a/40a
66
INNER CONE SUPPORT
AND PIVOT
INNER CONE
AND COVER
88
36
68
90
80
74
94
48
OUTER CONE
50
92
82
TANDEM MOTOR
42

Fig. 6.

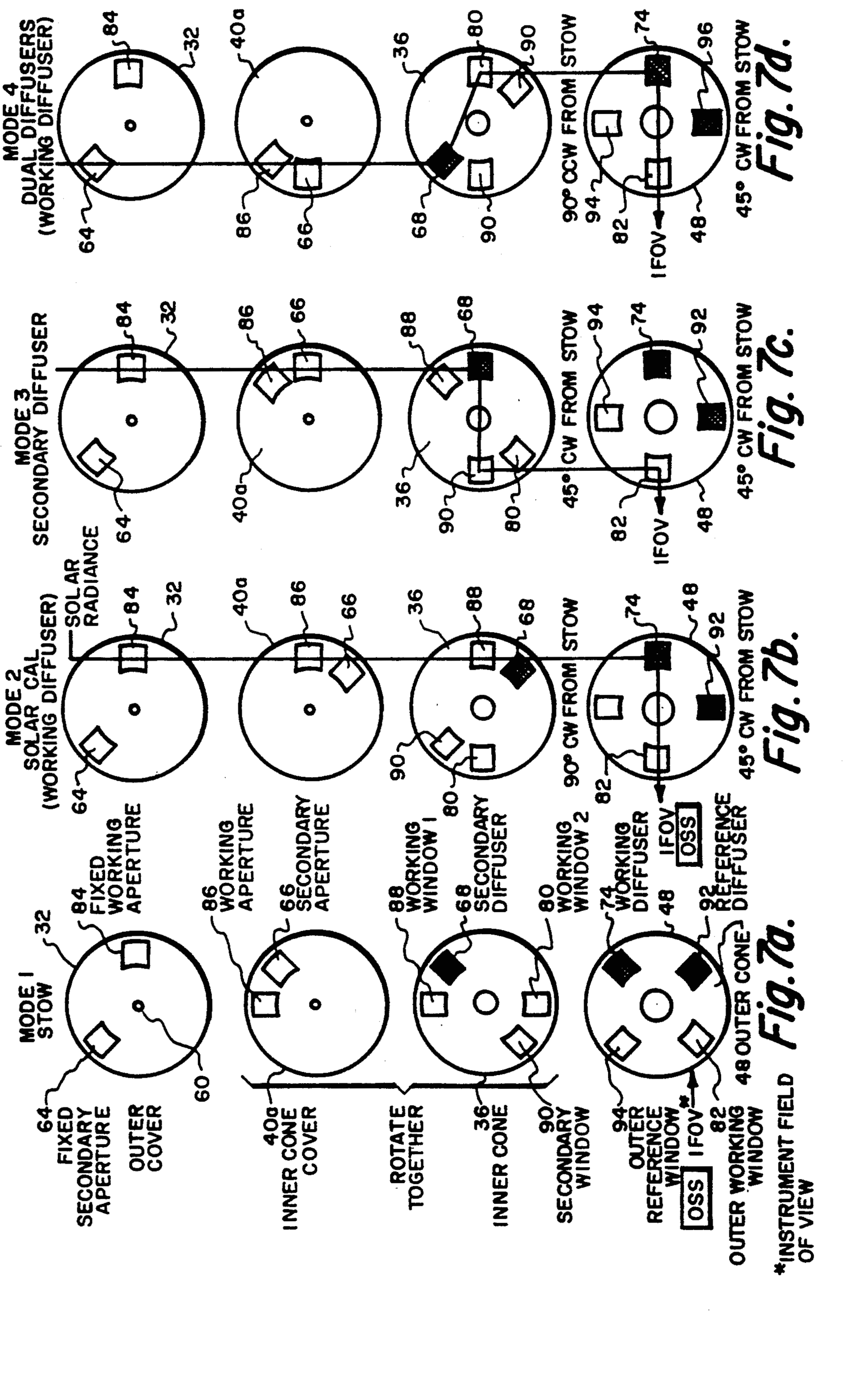


Fig. 7a. Fig. 7b. Fig. 7c. Fig. 7d.

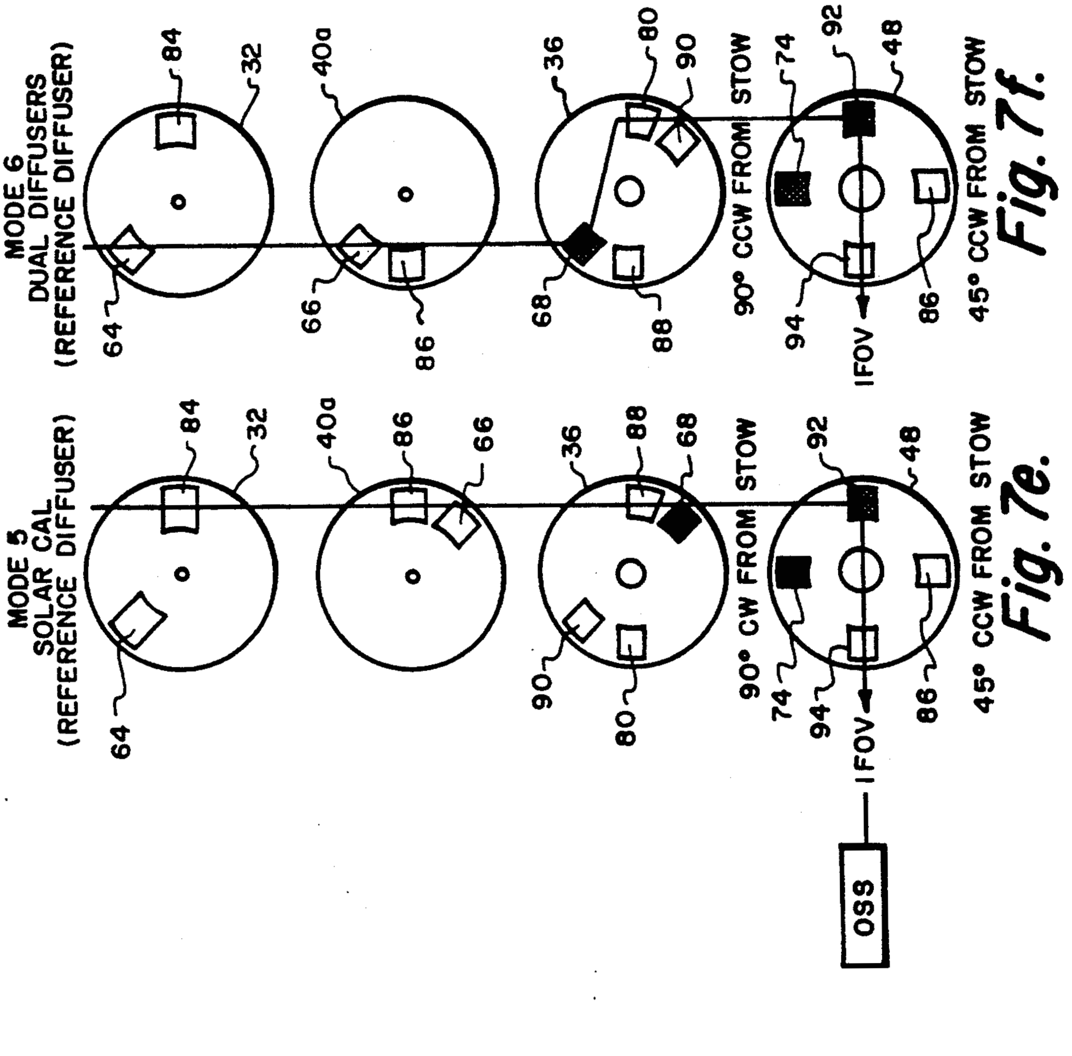

MODE 5
SOLAR CAL
(REFERENCE DIFFUSER)
90° CCW FROM STOW
45° CCW FROM STOW
IFOV
OSS
MODE 6
DUAL DIFFUSERS
(REFERENCE DIFFUSER)
90° CCW FROM STOW
45° CCW FROM STOW
IFOV

Fig. 7e.

Fig. 7f.

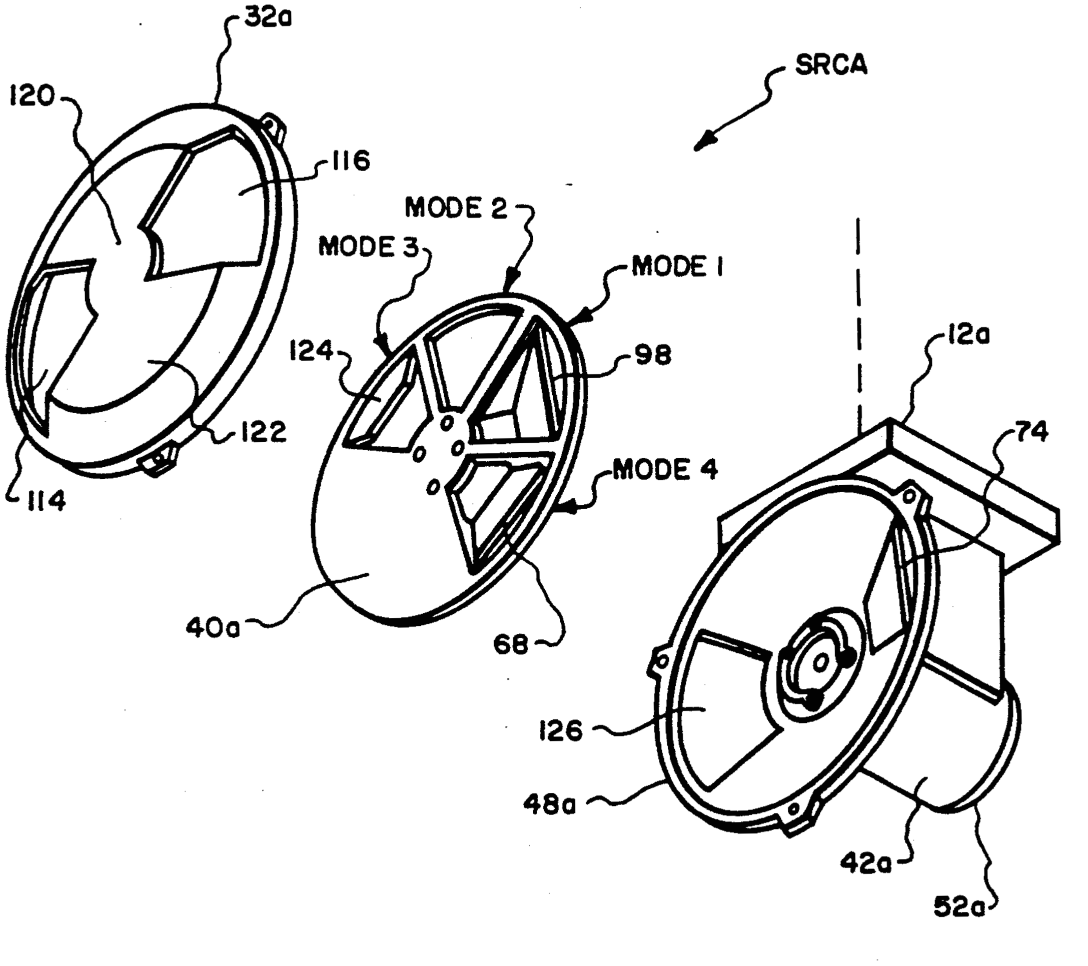

32a
SRCA
120
116
MODE 2
MODE 3
MODE 1
124
98
12a
122
74
114
MODE 4
40a
68
126
48a
42a
52a

Fig. 8.

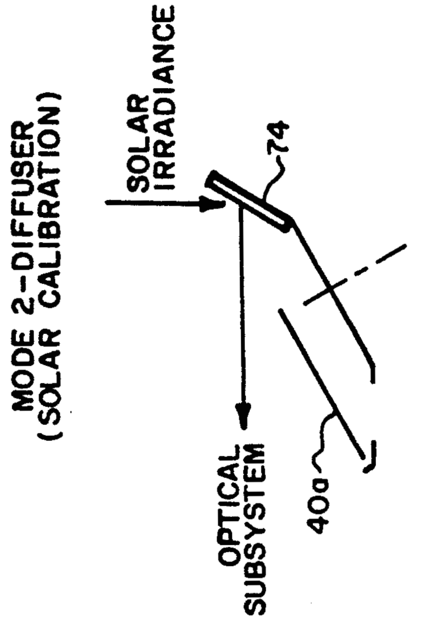


Fig. 9b.

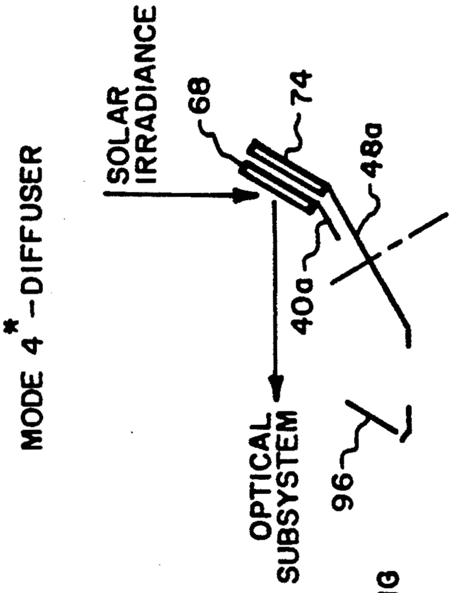


Fig. 9d.

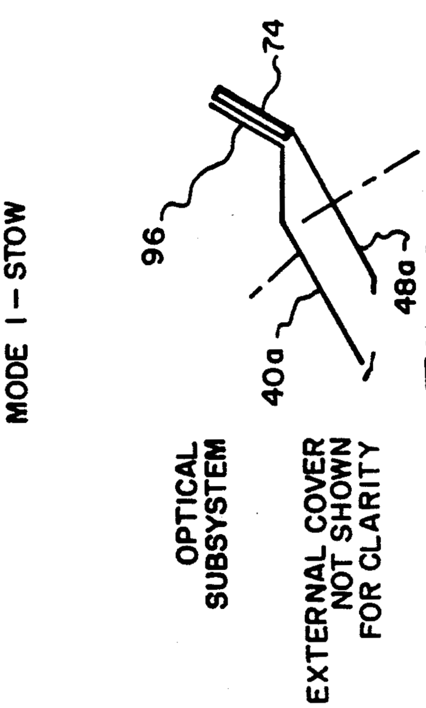


Fig. 9a.

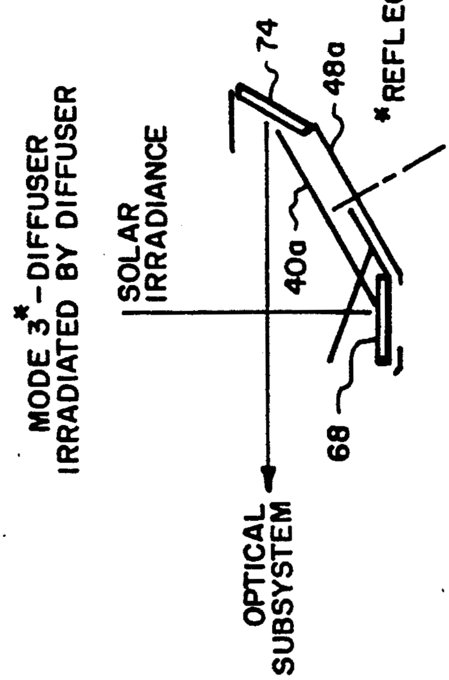


Fig. 9c.

IRRADIANCE CALIBRATION WITH SOLAR DIFFUSER

GOVERNMENT RIGHTS

The invention described herein was made in the performance of work under NASA Contract No. NAS5-30517 and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

This invention relates, in general, to a means of calibrating a space borne spectrometer and thus improve the operation of the Total Ozone Mapping Spectrometer (TOMS) for measuring stratospheric ozone variations from a satellite.

This improvement removes the effects of spectral changes and stability variations in the calibration source (heretofore man-made) and in the diffuser plate required in the TOMS.

The TOMS basically measures changes in signal levels which are changes in the amount of radiation entering the TOMS and consists of two main subsystems, optics and electronics. As radiation enters the TOMS, the energy passes through the optical subsystem before being processed as an electronic signal in the electronic subsystem. The electronic subsystem can be readily calibrated in space, however, the optical subsystem is not readily characterized and obviously both must be calibrated for the TOMS to provide valid ozone data.

Also, the optical subsystem components in the TOMS are subject to degradation due to contamination and aging. There is no direct way of establishing the amount of degradation. This is usually measured by directing the energy of a known source (man-made) through the optical subsystem and measuring the electronic subsystem response. Theoretically, the TOMS has on-board calibration features which establish the optical subsystem response to known stimuli (source), and in this way, changes in the electronic and optical subsystem response can be segregated. In practice, however, one difficulty is in finding a source which can reliably perform those measurements for years in space without itself degrading and failing. Man-made sources, such as mercury, hydrogen and tungsten lamps, which heretofore have been used to calibrate optical subsystems in the ultraviolet wavelength region, have limited life and are subject to failure. In addition, these man-made sources consume power.

In the past, the sun's energy has been used to calibrate the TOMS with the required diffuser plate directing the energy into the optical subsystem and subsequently into the electronic subsystem, but any change in diffuser plate reflectance was indistinguishable from optical and electronic substances response changes.

Therefore, it is an object of this invention to provide the TOMS with a Solar Reflectance Calibration Assembly (SRCA) which will enable the optical subsystem of the TOMS to be monitored and calibrated over a long time period.

SUMMARY OF THE INVENTION

The present invention which meets the foregoing object utilizes the sun's energy with a unique combination of movable and fixed diffuser plates, windows and apertures which are positioned in a series of test sequences (modes) for reflectance monitoring and calibration without the use of man-made sources.

There are three embodiments, or implementations, of the invention—one embodiment uses two diffusers—a working diffuser and a secondary diffuser—the second embodiment uses three diffusers, a working diffuser, a secondary diffuser and a reference diffuser—and the third embodiment uses two diffusers—a working diffuser and a secondary diffuser, the latter also functioning as a cover for the working diffuser. The movable diffusers are mounted on rotatable cones and, in all embodiments, the sun is blocked from reaching the diffusers when not in use.

Thus, the sun is used as a stable source for calibration and monitoring and the sun/diffuser combination is used in such a way that the response of all elements of the optical subsystem of the TOMS can be unambiguously and efficiently characterized with high accuracy and precision.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of the TOMS and the SRCA and their orientation with respect to the spacecraft orbit and the sun,

FIG. **1***a* is an enlargement of the scan motor and mirror of FIG. **1** with the instrument mirror oriented toward NADIR for ozone mapping.

FIG. **1***b* shows the scan motor and mirror of FIG. **1***a* rotated to direct solar flux to the SRCA for solar calibration.

FIG. **2** shows the solar calibration geometry with respect to the earth and sun,

FIGS. **3***a*-**3***c* are simplified schematic illustrations of the diffuser reflectance analysis utilizing a working diffuser and a secondary diffuser.

FIG. **4** is a cross-sectional view of the first embodiment of the SRCA,

FIGS. **5***a* and **5***b* are exploded view of the SRCA to more clearly show the locations of the diffusers, windows and apertures and the modes used in its calibration,

FIGS. **5***c*-**5***f* schematically illustrate the calibration modes for the solar calibration of the SRCA of FIGS. **4**, **5***a* and **5***b*,

FIG. **6** is an exploded view of the second embodiment of the SRCA showing the locations of the diffusers (including an additional reference diffuser), windows and apertures,

FIGS. **7***a*-**7***f* schematically illustrate the modes used in solar calibration of the SRCA of FIG. **6**,

FIG. **8** is an exploded view of the third embodiment of the SRCA, and

FIGS. **9***a*-**9***d* illustrate the modes used in solar calibration of the SRCA of FIG. **8**.

DETAILED DESCRIPTION

FIG. **1** shows the SRCA on a mounting bracket **12** attached to the TOMS **14**. This Fig. also shows the spacecraft velocity vector **16** and scan width **20**.

FIG. **1***a* shows a scan motor **22** with a mirror **24** of the SRCA of FIG. **1** mounted on a hollow shaft **26**. Mirror **24** is normally oriented within the scan width in the ozone mapping mode as in FIG. **1***a* so that the solar irradiance will be directed through the hollow shaft **26** into the TOMS and as shown in FIG. **1***b* is then rotated 90° to direct the reflected solar irradiance toward the SRCA for the SRCA mode.

FIG. 2 shows the solar calibration geometry where only a short portion of the orbit time is used (about 8 minutes). Day-night terminator, shown as radius R, defines the shadowing from the sun and as the TOMS approaches the terminator, it first sees the sun at point H where the sun is now incident on the diffusers to use the SRCA for solar calibration. After point R, the TOMS returns to its normal scan mode for mapping ozone.

The data required for normal solar calibration can be obtained in less than 5 seconds. For the diffuser reflectance measurement, data is obtained over multiple orbits and integrated to obtain the required accuracy.

FIGS. 3a-3c illustrate schematically the diffuser reflectance monitoring analysis. Solar radiance uniformly illuminates all of the diffusers, uses no power, is temporally and spectrally stable and is constantly monitored to a high degree of accuracy by other instruments. The method for monitoring the reflectance of both a working diffuser W with reflectance R_1 and a secondary diffuser S with reflectance R_2 located relative to a cone C, all representative of the SRCA of this invention.

FIG. 3a (Mode 1) shows the working diffuser W in its normal operating mode. The solar irradiance H_s impinges upon the working diffuser R which directs the reflected solar irradiance toward a scan mirror (not shown) in the optic subsystem. The signal output S_1 is proportional to the reflectance R_1 of the diffuser W, the solar irradiance H_S and a geometry factor. In FIG. 3b (Mode 2), the secondary diffuser S with exactly the same geometry as the diffuser W is rotated about the axis of a cone such that the solar irradiance is reflected from it into the scan mirror. While in this position, the secondary diffuser S blocks off the working diffuser W. The signal received, S_2, is now proportional to the reflectance R_2 of the secondary diffuser S. FIG. 3c (Mode 3) shows a third mode where the secondary diffuser S is located on the opposite side of the cone C but at the same solar incidence angle as in the other modes. The reflected solar irradiance of the secondary diffuser S now illuminates the working diffuser W. Resulting signal S_3 is therefore proportional to the product of the two reflectances, the same angular geometry factor and a visibility factor V. This visibility factor represents the percentage of energy seen by the working diffuser as it views the secondary diffuser. It is comprised of a view factor and, if angles change, a bi-directional reflectance factor.

In the following paragraphs concerning diffuser measurements, signal-to-noise ratio, etc., reference to the SRCA of FIGS. 3a-3c is made. The secondary diffuser can be considered a reference diffuser in FIGS. 3a-3c and will be referred to as such in the following paragraphs.

The fraction of radiant energy transferred from the reference diffuser S to the working diffuser W during Mode 3 operation affects the signal level and therefore the precision to which the Mode 3 measurements are made. Averaging many measurements improves the precision but there are practical limits since the sun is within the SRCA's field of view for only a fraction of the orbit period and data for Modes 2 and 3 would normally be taken together within this time frame. A practical lower limit for the radiant energy transfer required from reference diffuser S to working diffuser W is 4%.

The efficiency of radiant energy transfer between the reference and working diffusers S and W, can be estimated for various geometries by assuming the diffusers are lambertian and calculating their geometrical configuration factor or view factor. Solutions for many common geometries have been tabulated in reference books on radiative heat transfer. The techniques of configuration algebra allow broader application of the general solutions. A solution for the general geometry involved in the SRCA was found and used to estimate possible efficiencies for radiant transfer between the devices in mode 3 operation. The upper limit for the fraction of reflected solar irradiance listed for the solar diffuser, 8%, is based on diffusers of equal size with one edge in contact. An accurate prediction of the performance of the SRCA can be obtained by numerical integration of the measured bi-directional reflectance function of the diffusers. NBS monograph 160, "Geometrical Consideration and Nomenclature for Reflectance" presents applicable nomenclature for characterizing the bi-directional reflectance function.

The two diffusers S and W can be considered Lambertian, both singly and in combination, to permit absolute determination of reflectance. For:

K = instrument response in counts/Watt onto the detector
= (detector response in A/W) $\times$ (electronics response in counts/A)

T = instrument throughput, fraction of photons into the entrance aperture reaching the detector

where both K and T are assumed a slowly varying function of time that is essentially constant during any particular calibration measurement. Then the radiance illuminating the instrument field of view is:

$$\text{Radiance} = a \times R_n \times H$$

and the instrument signal response in counts is:

$$S_1 = a \times H \times R_1 \times T \times K$$

$$S_2 = a \times H \times R_2 \times T \times K$$

where R_n is the reflectance of diffuser n, a is the angular factor relating radiance to irradiance for a Lambertian surface, and H is the solar irradiance. A third measurement uses the radiance of the working diffuser W to illuminate the reference diffuser S. The instrument signal response in counts in this case is:

$$S_3 = ((a \times H \times R_1) \times V) \times R_2 \times T \times K$$

where V is a mechanical view factor, or visability factor, of the reference diffuser S illuminated by the working diffuser W. This view factor is determined by geometry only, does not change, and can be precisely measured on the ground. From the ratios of the three measurements:

$$S_3/S_1 = V \times R_2$$

$$S_3/S_2 = V \times R_1$$

R_1 and R_2 are determined directly since V is known. With diffuser reflectance R measured, T$\times$K can be calculated since a$\times$H is known and therefore the desired instrument calibration has been fixed. This concept requires three sets of measurements to establish reflectance values, one from each of the two diffusers S and W individually, and one from the two diffusers S and W in "series".

FIRST EMBODIMENT

At the outset it should be noted that FIGS. 4 and FIGS. *5a* and *5b* are schematized essentially to show the path of the diffused solar flux within the SRCA and the location of the diffusers within an actual embodiment of the invention. Therefore, some of the apertures and windows in FIG. 4 are not necessarily oriented as in FIGS. *5c–f* are the top cover of one cone is shown in FIGS. *5a* and *5b* although they are not connected together.

However, FIG. 4 together with the exploded views in FIGS. *5a* and *5b* do show the first embodiment of the SRCA as having a diffuser housing, which comprises a stationary outer cover **32** attached to a base **34**, and two cones, a first inner cone **36** and a second inner cone **40**, both of which are rotatable by a tandem motor **42**. The top of the outer cover **32** has an aperture **44** and a aperture **46**. Also shown is a fixed outer cone **48**. The outer cover **32** and base, however, are not shown in FIGS. *5a* and *5b*, for clarity.

As shown in FIG. 4, the first inner cone **36** has an integral top cover **36***a* and the second inner cone **40** has a top cover **40***a* as will be apparent in FIGS. *5c–4f.* The first inner cone **36** is rotated by shaft **50** within the second inner cone **40** and a position encoder **52** verifies the position of the first inner cone **36**. The second inner cone **40** is mounted on a fixture **54** for rotation and a second encoder **56** verifies the position of cone **40**. The outer fixed cone **48** has a top cover **48***a* attached thereto by suitable means **48***b*, shown as tabs and bolts represented by dashed lines. Not shown are the attaching means for the other top covers but they are essentially the same as attaching means **48***b*. All cones have a cone support pivot **60** located centrally of the outer cover **32** and top cover **36***a*, **40***a*, and **48***a* for stability.

FIG. 4 also shows the solar irradiance entering the SRCA through aperture **44** in cover **32** and through a fixed secondary aperture **64** in top cover **40***a* and through a secondary aperture **66** in top cover **36***a* where the solar flux is diffused by a secondary diffuser **68** (S in FIGS. *3a–3c*) and directed through aperture **70** in the first inner cone **36** and aperture **72** in the second inner cone **40** toward a working diffuser **74** (W in FIGS. *3a–3c*) as represented by arrows **76**. Working diffuser **74** is located on the fixed outer cone **48***a*. Arrows **78** show the path of the diffuse reflected light directed through aperture **80** in the second inner cone **36**, a working window **82** in the outer cone **48** where the diffused radiation is then directed out a field-of-view aperture **83** located in the side of the cover **32**. As mentioned before, the primary purpose of FIG. 4 is to show the path of the solar flux as it is directed out the field-of-view aperture **83**.

Referring now to FIG. *5a*, this figure shows that a fixed working aperture **84** in the top cover **48***a* is located about 135° from the fixed secondary aperture **64**, that a working aperture **84** is in the top cover **48***a* and that a working aperture **86** is located about 45° from the secondary aperture **66** in the top cover **40***a*. In order to more clearly see the first inner cone **36** reference is made to FIGS. *5c–5f.* The cone **40** is not shown in FIGS. *5a* and *5b* nor in FIGS. *5c–4f.*

The first inner cone **36** has a first working window **88** located about 45° from the secondary diffuser **68** and in vertical alignment with apertures **64** and **86**. The first inner cone **36** also has a secondary window **90** located diametrically opposite the secondary diffuser **68**. The outer reference window **80** is diametrically opposite the working window **88**. Note that apertures **44** and **46** in the cover **32** both appear in FIG. 4 even though they are at an angle to each other corresponding to the angle between the fixed aperture **64** and fixed working aperture **84**.

FIG. *5a* (Mode 1) is the stow position for the SRCA. The top cover **48***a* is positioned such that the space between the fixed secondary aperture **64** and the fixed working aperture **84** covers the working aperture **86** and the secondary aperture **66** in the top cover **40***a* thus blocking the sun from entering the SRCA.

FIG. *5b* (Mode 2) is the solar calibration mode for the SRCA as in FIG. *3a.* The second inner cone **40** and its top cover **40***a* have been rotated about 45° so that the working aperture **86** is immediately beneath the fixed working aperture **84** so that the sun may impinge on the working diffuser **74** which in turn directs diffused light out the second working window **82**. This is clearly shown in FIG. *5b.*

FIGS. *5c–5f* show the modes of calibrating the first embodiment of the SRCA.

In these figures, the cover **32** is not shown and the top cover **48***a* and the outer fixed cone **48**, shown separately, are both fixed against rotation. Also, the second inner cone **40***a* is shown but its cone **40** is not shown. Again, cone **40** is used to rotate the top cover **40***a* and will contain apertures and windows where necessary. The moving inner cone **36** is shown without its cover **36***a*. The omission of the above mentioned components is to enable these figures to show the various calibration steps by the rotation of the two inner cones, the location of the various apertures, window, and diffusers, and to show the direction of the solar flux throughout the figures.

Mode 1 (FIG. *5c*) represents the stow position. This corresponds to FIGS. *5a.* The moving inner cone cover **40***a* is located such that the working and secondary apertures **86** and **66** are within the space between the fixed secondary aperture **64** and the fixed working aperture **84** in the outer cover **48***a* so that the solar flux is blocked from reaching any diffuser or window in the cones.

Mode 2 (FIG. *5d*) represents the solar calibration utilizing the working diffuser **74**. This is the normal working mode of the SRCA. the moving inner cone **40***a* has been rotated about 45° clockwise from the stow position (Mode 1) and the moving second inner cone **36** has been rotated about 90° clockwise from the stow position. In this mode, solar flux enters the fixed working aperture **84**, through secondary aperture **66**, through the inner window **88** and impinges upon the working diffuser **74** which directs its reflected diffused radiation through outer reference window **80** and through window **82**.

Mode 3 (FIG. *5e*) represents the secondary diffuser calibration. The moving inner cover **40***a* has been rotated about 45° from Mode 2 position and the moving inner cone **36** has been rotated counter clockwise about 45° from the Mode 2 position. In this Mode, solar flux enters the fixed working window **84** and through the working window **84**, impinges upon the secondary diffuser **68** which directs its diffused reflected radiation through outer reference window **90** and through window **82**.

Mode 4 (FIG. 5*f*) represents the calibration of the working diffuser and in this Mode, the moving inner cover **40***a* has been rotated 180° clockwise, or counter clockwise from Mode 2 position, and the moving second inner cone **36** has been rotated 135° counter clockwise from Mode 3 position so that solar flux may enter through the secondary aperture **66** and impinge upon the secondary diffuser **68**. Reflected diffused solar flux from diffuser **68** enters the outer reference window **80** and impinges upon the working diffuser **74** which directs its diffused reflected radiance out working window **88** and through window **82**.

SECOND EMBODIMENT

In this embodiment, those elements having the same function as in the previous embodiment will be given the same reference numerals for simplicity of description.

Taking FIGS. **6** and 7*a* together, it can be more clearly seen that fixed secondary aperture **64** and the fixed working aperture **84** are located in the top of the cover **32** and the field-of-view aperture **83** is located on the side of the cover **32**. Apertures **64** and **84** are located about 135° apart. The cover **32** is essentially the same as in FIG. **4**. The top of cover **32** also corresponds in function to the top cover **48***a* of FIGS. **5***a*–**5***f*.

Immediately beneath the outer cover **32** is an inner cone cover **40***a* having a working aperture **84** and a secondary aperture **66** located about 45° from the working aperture **84**. This inner cone cover **40***a* is rotated by the inner cone **36** and, as shown in this Fig., the inner cone **36** has a first working window **88**, a secondary window **90** and a second working window **80** (outer reference window in FIGS. **5***c*–**5***f*). Note also that cover **40***a* is identified as such since it is identical to cover **40***a* in FIGS. **5***a*–**5***f* even though it is rotated by cone **36** which corresponds to cone **36** in FIGS. **5***a*–**5***f*. In cone **36**, the first working window **88** and the second working window **80** are located about 180° apart and the secondary window **90** is located about 45° from the second working window **94**. This inner cone **36** also has a secondary diffuser **68** located about 180° from the secondary window **90**. The outer cone **48**, shown below the inner cone **36** in FIG. 7*a*, has the working diffuser **74** and an additional reference diffuser **92** located about 90° therefrom, the outer working window **82** located about 90° from the reference diffuser **92** and an outer reference window **94** located about 90° from the outer working window **82**. The outer reference window **94** and outer working window **82** permit diffused radiation to be emitted through the field-of-view aperture **83** depending on the mode selected.

FIGS. 7*a*–7*f* show the modes of calibrating the SRCA. Since this SRCA has not only a working diffuser **74** and a secondary diffuser **68** but also an additional reference diffuser **92**, more modes are needed to calibrate the three diffusers.

In these FIGS. 7*a*–7*f*, the cover **32** is shown throughout the several steps as stationary, while the inner cover **40***a* and the inner cone **36**, while shown separately, rotate together. The outer cone **48** is shown immediately below the inner cone **36**. These Figs. show the various steps by the rotation of the inner and outer cones and the location of the various apertures, windows and diffusers. These Figs. also show the directions of the solar radiance throughout the various Figs. and the instrument field-of-view aperture **83**.

Mode 1 (FIG. 7*a*) represents the stow position. The inner cone cover **40***a* is located such that the working and secondary apertures **86** and **66** are within the space between the fixed secondary aperture **64** and the fixed working aperture **84** in the cover **32** so that the solar flux is blocked from reaching any diffuser or window in the cones. Similarly, the outer cone **48** is positioned such that no light can enter the instrument field of view aperture **80**. Thus, the diffusers are sealed against sunlight and contamination while not in use.

Mode 2 (FIG. 7*b*) represents the solar calibration utilizing the working diffuser **74**. This is the normal working mode of the SRCA. The inner cone **36** and its cover **40***a* have been rotated 90° clockwise from the stow position (Mode 1) and the outer cone **48** has been rotated 45° clockwise from the stow position. In this mode, solar flux enters the fixed working aperture **84**, the working aperture **86**, the first working window **88** and impinges upon the working diffuser **74** which directs its diffused radiation through the outer working window **82** and out the instrument field-of-view aperture **83** which is aligned with the outer working window **82**.

Mode 3 (FIG. 7*c*) represents the secondary diffuser calibration. The inner cone **36** and its cover **40***a* have been rotated 45° clockwise from the stow position and the outer cone **48** has been rotated 45° clockwise (or remains in the same position as in Mode 2) from the stow position. In this Mode, solar flux is directed through the fixed working aperture **84**, through the secondary aperture **66** and impinges upon the secondary diffuser **68** which directs its diffused radiation through the secondary window **90** and through the outer working window **82** and out the instrument field-of-view aperture **83** which are aligned.

Mode 4 (FIG. 7*d*) represents dual diffuser calibration for calibrating the working diffuser **74**. The inner cone **36** and its cover **40***a* are rotated 90° counter clockwise from the stow position and the outer cone **48** has again been rotated 45° clockwise (or remains in this position from Modes 2 and 3) from the stow position. In this Mode, solar flux is directed through the fixed secondary aperture **64**, through the secondary aperture **66** and impinges upon the secondary diffuser **68** which directs its diffused radiation through the second working window **80** and onto the working diffuser **74**. The latter directs its diffused radiance through the outer working window **82** and through the instrument field-of-view aperture **83** with which it is aligned.

Mode 5 (FIG. 7*e*) is a solar calibration of the additional reference diffuser **92**. The inner cone **36** and its cover **40***a* are rotated 90° clockwise from the stow position and the outer cone **48** is rotated 45° counter clockwise from the stow position. In this Mode, solar flux is directed through the fixed working aperture **84** and through the working aperture **86**, impinging upon the reference diffuser **92** which directs its diffused radiance out the outer reference window **94** and through the field-of-view aperture **83** with which the latter is aligned.

Mode 6 (FIG. 7*f*) is a solar calibration of the reference diffuser **92**. The inner cone **36** and its cover **40***a* are rotated 90° counter clockwise form the stow position and the outer cone **48** is rotated 45° counter clockwise (or remains in position as in Mode 5) from the stow position. In this Mode, solar flux is directed through the fixed secondary aperture **64**, through the secondary aperture **66**, to impinge upon the secondary diffuser **68** which directs its diffused radiation through the second working window **80** onto the reference diffuser **92** and out through the outer reference window **94** and the instrument field-of-view aperture **83** which is in alignment with the outer reference window **94**.

THIRD EMBODIMENT

In this embodiment those components which have identical functions as in the prior embodiments will be given identical reference numerals and other components which have similar functions as in the prior embodiment will be given similar reference numerals but with the suffix a.

This third embodiment of the SRCA is shown in the exploded view in FIG. **8** as having an external cover **32***a*, a rotatable disk **40***a*, a cone **48***a*, a stepper motor **42***a* and one encoder **52***a*, all of which are connected to the TOMS by bracket **12***a*.

The external cover **32***a* is circular and has four quadrant partitions, apertures **114** and **116** in opposite quadrants and solid partitions **120** and **122** in opposite quadrants which act as covers. The external cover **32***a* is non-rotatably fixed to the cone **36***a* by any suitable means.

The rotatable disk **40***a* is circular and is rotatable inside the cone **36***a*. The disk **40***a* has four apertures, identified as Modes 1–4, located on two-thirds of the disk **40***a* with the remaining one-third being solid to act as a cover. Mode 1 aperture contains an additional diffuser **98**, which may also function as a cover. Mode 2 aperture is open (or clear of any impediment), Mode 3 aperture contains an aperture block **124** and Mode 4 aperture contains a secondary diffuser **68**. Mode 3 and 4 apertures are diametrically opposed to match the partitions in the external cover **32***a*.

The cone **48***a* has a fixed working diffuser **74** mounted in a fixed position diametrically opposite an aperture **126**.

The disk **40***a* is driven by the stepper motor **42***a* into various positions which are verified by the encoder **52***a*. The disk **40***a* is rotated so as to move the secondary diffuser **68** relative to the working diffuser **74** for calibration measurements.

As can ben seen in FIGS. **8** and **9***a*–**9***d*, the diffusers are tilted with respect to the axis of the motor **42***a* to perform the same function as diffusers in the prior cones.

There are four Modes of operation for this embodiment of the SRCA, each corresponding to the position of disk **40***a*.

The functions of the four modes are as follows:

Mode 1 (FIG. **9***a*): The stow position for the SRCA. In this Mode, the disk **40***a* is rotated to position the additional reference diffuser **96** over the working diffuser **74** to protect it from degradation. The additional reference diffuser **96**, constantly exposed to space, may be used to calibrate diffuser reflectance, but if it is not needed, it could be a protective cover segment of the disk **40***a*.

Mode 2 (FIG. **9***b*): This is the normal position of the disk **40***a* for solar calibration. The Mode 2 aperture is positioned over the working diffuser **74** allowing the solar flux to impinge on the working diffuser **74**.

Mode 3 (FIG. **9***c*): This is a reflectance calibration Mode. The Mode 3 aperture with its aperture block **124** blocks direct solar flux of the working diffuser **74**, while the solar flux impinges on the secondary diffuser **68** to irradiate the working diffuser **74**. The secondary diffuser **68** is mounted on the disk 180° opposite the Mode 3 aperture.

Mode 4 (FIG. **9***d*): The secondary diffuser **68** is rotated 180° from the mode 3 position so that it now covers the working diffuser **74**. The solar flux illuminates the secondary diffuser **68** in this position for calibrating the secondary diffuser **68**.

We claim:

1. In a space borne instrument for stratospheric measurement of ozone variations having electrical and optical subsystems and where the optical subsystem responds to solar flux and provides signals which are measured in the electrical subsystem as a means of identifying said variations, the improvement in the means of calibrating the optical subsystem by using solar flux while in space comprising,

a working diffuser fixed relative to said instrument and oriented to receive the solar flux and reflect diffused flux onto the optical subsystem to provide a first signal,

a reference diffuser movable relative to said instrument and to said working diffuser and oriented to one position to receive solar flux and to reflect diffused flux onto the optical subsystem to provide a second signal and to another position to receive solar flux and to reflect diffused solar flux onto the working diffuser which directs its received diffused flux onto the optical subsystem to provide a signal difference from the first and second signals as a means for calibrating the optical subsystem.

2. The improvement as claimed in claim **1** further including means for blocking solar flux from reaching the diffusers.

3. The improvement as claimed in claim **1** further including a second reference diffuser movable relative to said instrument and to the working and first reference diffuser and oriented to one position to receive solar flux and to reflect diffused solar flux onto the optical subsystem to provide a fourth signal and to still another position to receive reflected solar flux from the first reference diffuser and reflect the received reflected flux onto the optical subsystem to provide a fifth signal as a means of calibrating the optical subsystem.

4. The improvement as claimed in claim **3** further including means for blocking the solar flux from reaching all of the diffusers.

5. A method for calibrating a space borne instrument for measuring stratospheric ozone variations wherein the space borne instrument has an electrical subsystem and an optical subsystem, the steps in calibrating the optical subsystem while in space comprising,

orienting a working diffuser relative to the sun to receive and diffuse solar flux and direct this diffused flux toward the optical subsystem to provide a first signal,

measuring the signal generated by the optical subsystem during the first step,

orienting a reference diffuser relative to the sun to receive and diffuse solar flux and direct the diffused solar flux onto said optical subsystem to provide a second signal,

means measuring the signal generated by the optical subsystem during the second step,

orienting a first reference diffuser relative to the sun to receive and diffuse solar flux and direct this diffused flux toward the working diffuser which

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,218,416

DATED : June 8, 1993

INVENTOR(S) : Robert E. Haring, et. al.

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

Column 5, line 68, delete "4f" and insert --5f--

Column 8, line 65, delete "form" and insert --from--

Column 12, lines 66-67, delete "flux from reaching the diffuser".

Signed and Sealed this

Twenty-second Day of February, 1994

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks