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Application S/N 11,227
Filed: 02/13/70
Contract No. NAS7-100
Caltech/JPL

AWARDS ABSTRACT

Inventors:	Thomas I. Harris Melvin N. Wilson	~~JPL Case No.: 11096~~ NASA Case ~~No.~~: NPO-11096
Contractor:	Jet Propulsion Laboratory	January 28, 1970

OPTICAL SYSTEM FOR SPACE SIMULATOR

The invention relates to an optical system for producing solar simulation within a space simulator which is capable of increasing the intensity of the light beam while maintaining the ability of varying the beam diameter. The optical system includes a stacked lens system positioned on the exit side of an optical mixer that is capable of reducing the angular subtense of the exit beam with respect to the angular subtense of the entrance beam, thereby producing the capability of increasing the exit beam intensity over that of the inlet intensity as derived from the inherent source of brightness.

The optical system includes a condenser lens which relays the energy exiting from the optical mixer onto an intermediate lens. The intermediate lens accepts the first total uniform image in the system and relays the image of the condenser lens to a projection lens which functions as a penetration window. The projection lens is positioned approximately at the focal point of the mirror to enable the projected beam to be collimated within the design limits fixed by the relay lens and mirror optical properties.

A second embodiment of the present invention includes a variable lens system wherein the intermediate lens is also movable along the optical axis. The second lens is also preferably separated into two lens units, both of which are axially movable, to split the power of the lenses for acceptable power requirements at both extreme operating positions thereof, and to aid the incorporation of second order shape factors to improve the ultimate uniformity as desired.

FIG. 1

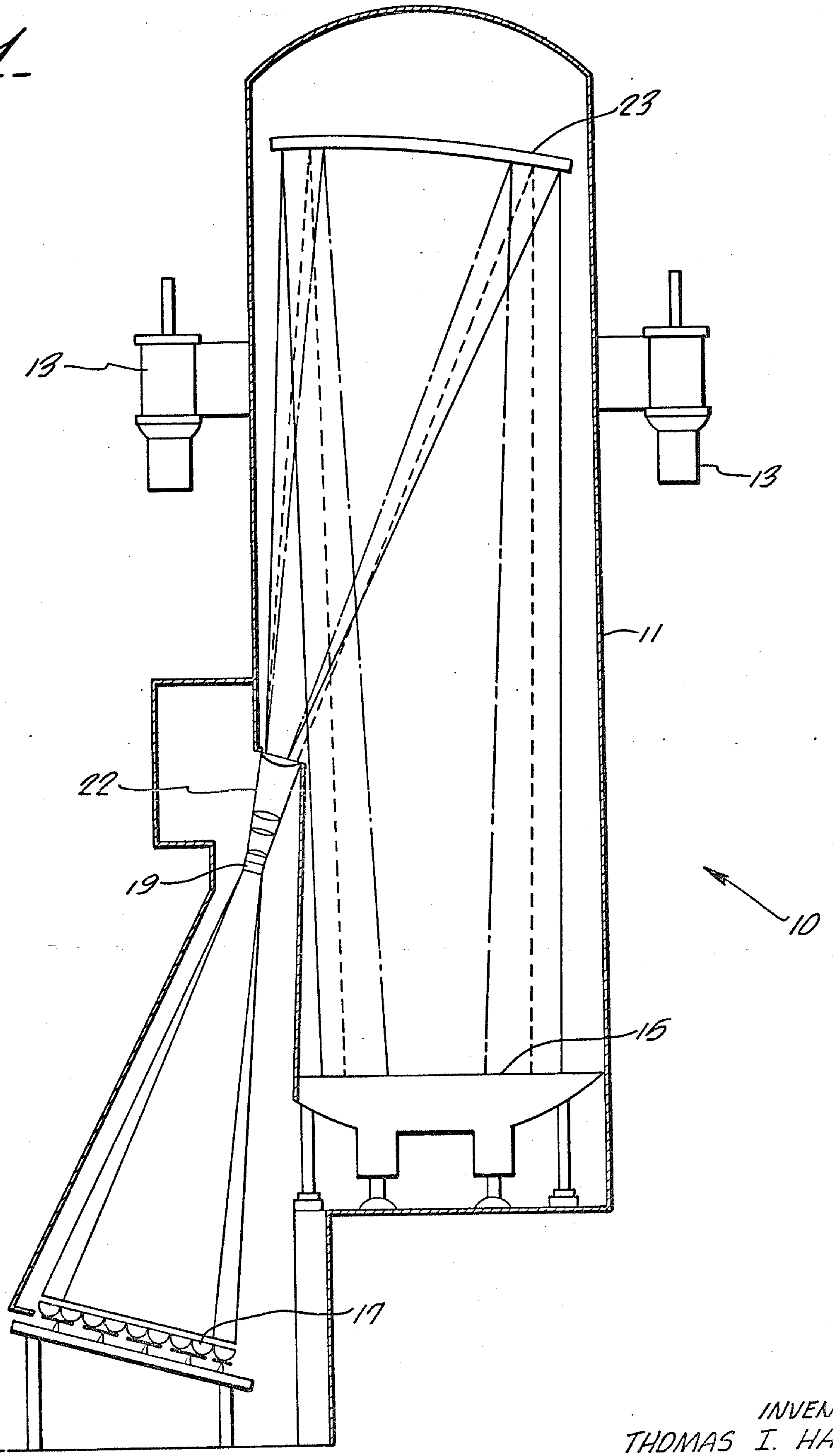

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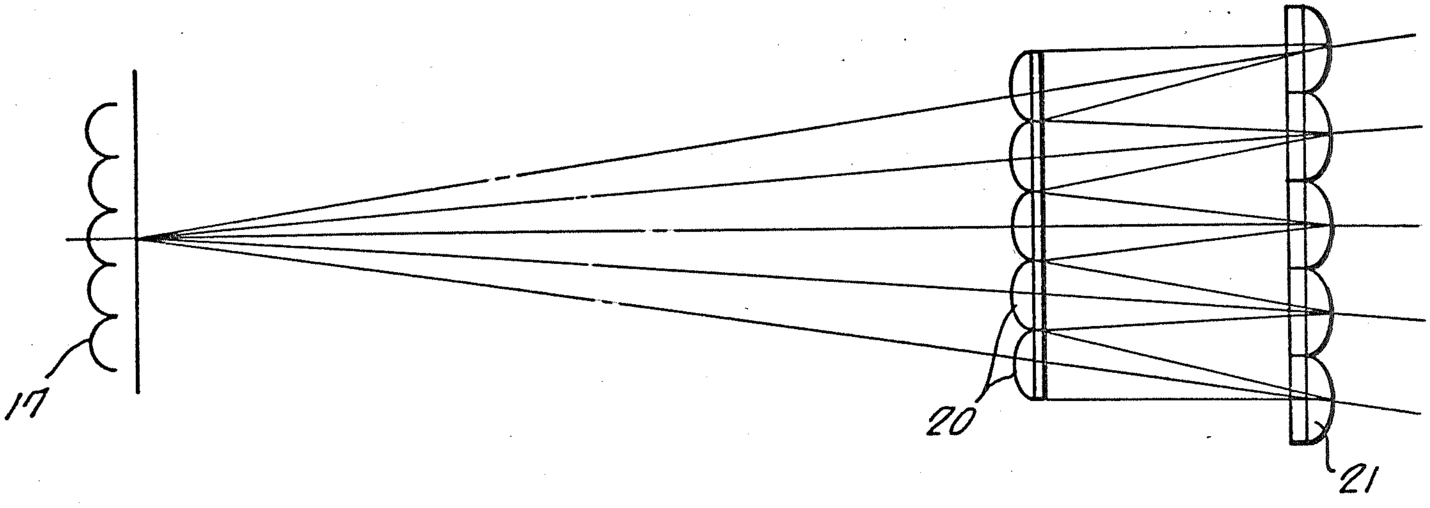
FIG. 2



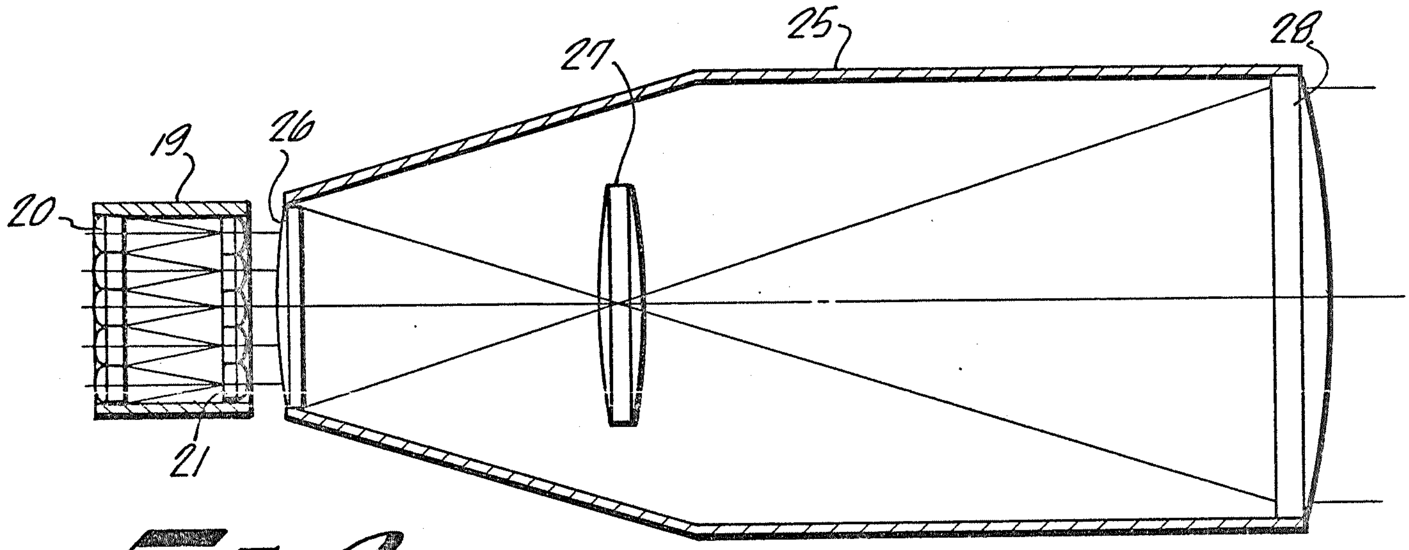


FIG. 3

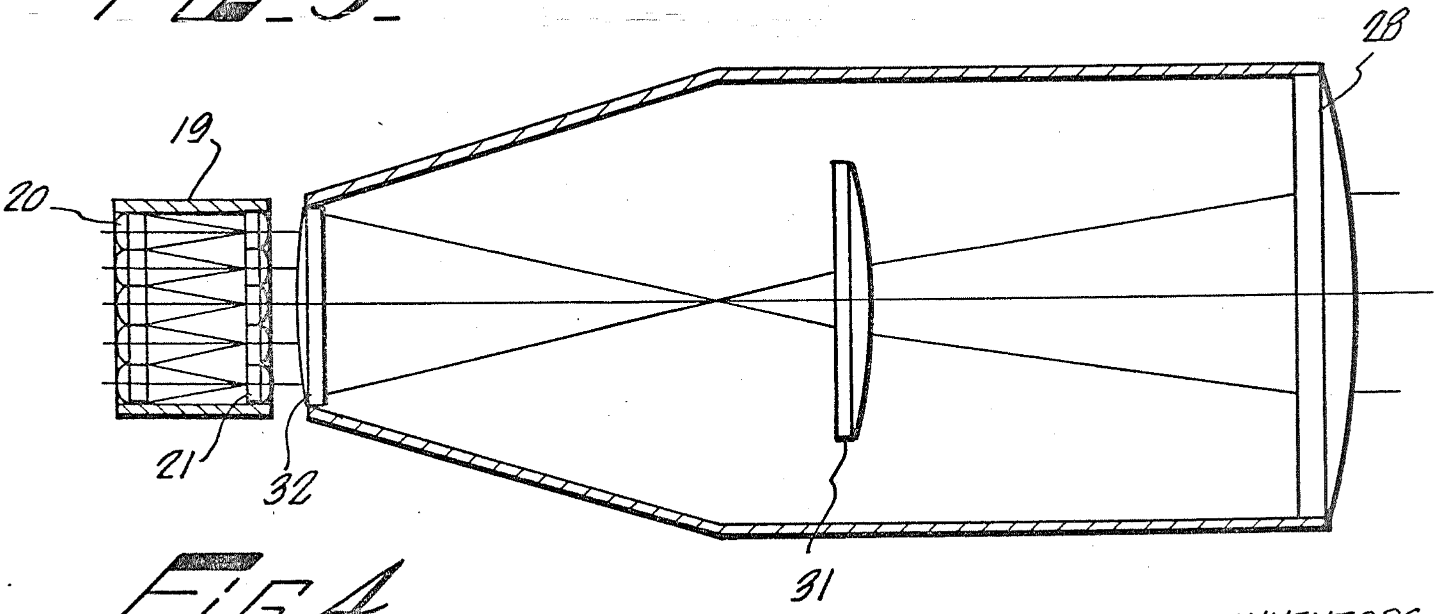


FIG. 4

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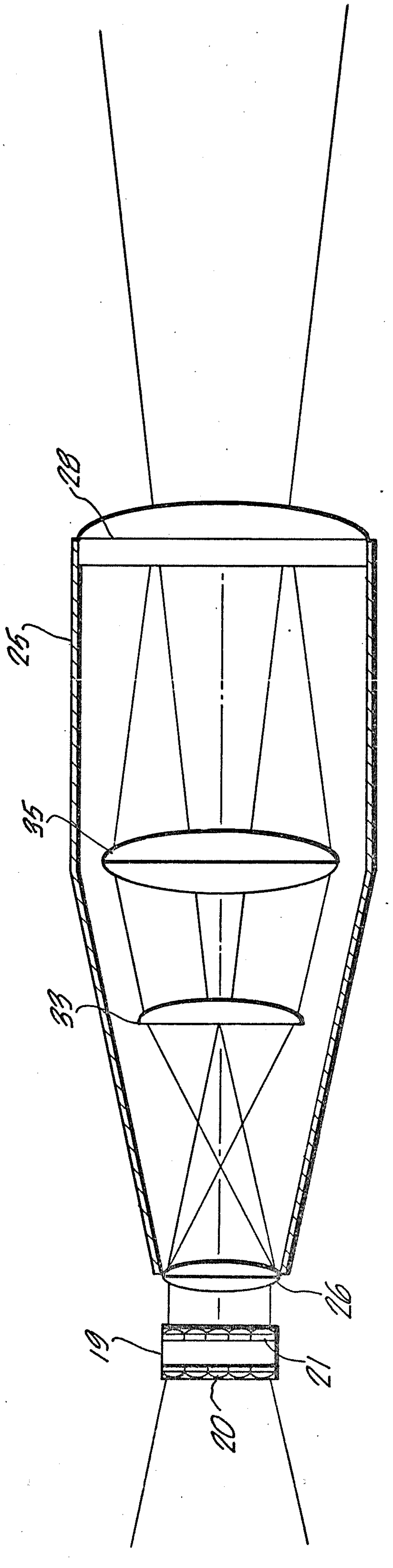

FIG_5_

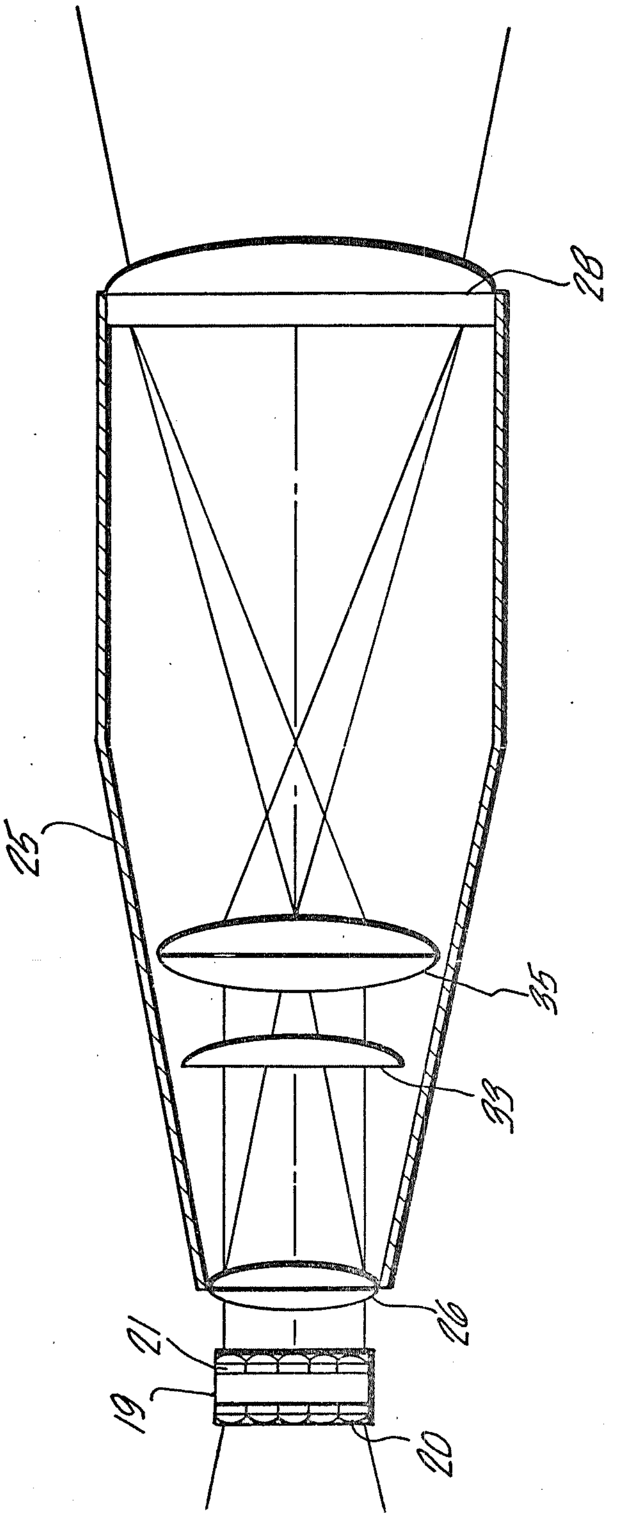

FIG_6_

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493

NPO-11096

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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT THOMAS I. HARRIS and MELVIN N. WILSON, citizens of the United States of America, residing at Pasadena, in the County of Los Angeles, and La Canada, in the County of Los Angeles, State of California have invented a new and useful

OPTICAL SYSTEM FOR SPACE SIMULATOR

of which the following is a specification:

ABSTRACT OF THE DISCLOSURE

An optical system is disclosed for producing solar simulation within a space simulator which is capable of increasing the intensity of the light beam while maintaining the ability of varying the beam diameter. The optical system includes a stacked lens system positioned on the exit side of an optical mixer that is capable of reducing the angular subtense of the exit beam with respect to the angular subtense of the entrance beam thereby producing the capability of increasing the exit beam intensity over that of the inlet intensity as derived from the inherent source of brightness. The various embodiments include both fixed lens and variable lens systems.

ORIGIN OF THE 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 a solar simulation apparatus which projects a collimated beam of light onto a test area located within a space simulator. More particularly, the present invention relates to means for increasing the intensity of the projected beam of light while maintaining a capability of varying the beam diameter.

2. Description of the Prior Art

Space simulators have become an important tool in the testing and qualifying of spacecraft. In a typical simulator, a test volumne is provided to accommodate such spacecraft. Also provided is a radiant energy system capable of producing a uniform, collimated, spectrally matched beam of light which simulates the true solar intensity on the various planets. The source of radiant energy normally consists of a bank of lamps consisting of a plurality of high intensity Xenon or Mercury-Xenon arc lamps arranged in a closely packed or hexagonal pattern. These lamps project, via elliptical reflectors, their output energy onto the front face of an optical mixer, or integrator, in a typical gaussian distribution.

The gaussian intensity distribution formed by the lamps on the mixer entry face is unsuited for relaying onto a test plane, since it is not uniform. The optical mixer solves this problem by splitting up the distribution and overlaying each of the parts in such a fashion that the combined distribution is uniform. The use of a nested hexagonal array of a plurality of two lens systems is used for this mixing function. The front face of the mixer usually consists of a plurality of hexagonal lenses followed by a second plane of an equal number of corresponding circular or hexagonal lenses. Both sets of lenses are closely packed and together provide a plurality of nonparallel but separate light paths through the mixer. A relay lens is used to correct for the nonparallel paths through the mixer, its power being specified to fit the system-collimating mirror geometry. Because of the different angular orientation of the energy distribution patterns covering the various light paths through the system, the mixer lens system causes the multiple images to superimpose on the mirror, thereby averaging the various energy contributions of each of the paths so as to produce a single uniform light image for a collimating mirror to reflect as a sharp test beam.

The large temperature-controlled collimating mirror is located at the top of the space simulator and serves to focus and project the uniform light beam onto the test area.

Since the images of all of the lamps are superimposed at the mixer face, it is clearly possible to reduce beam intensity by either turning off the individual lamps or by reducing power levels until the desired intensity is reached. However, these actions do not change the uniformity, collimation, size, or any other geometric characteristic of the beam, only the intensity is reduced below the design maximum.

There has been recent requirements to test spacecraft up to the solar intensity levels of Mercury (900 $\frac{\text{Watts}}{\text{ft}^2}$). Present solar simulators, as presently configured, are effective facilities for testing spacecraft only in the intensity ranges approaching that of Venus.

Various proposals have been suggested to increase the intensity level in present solar simulators.

An obvious approach would be to increase the radiant intensity level of the source by (1) increasing the number of lamps and (2) increasing the power levels thereof. However, this does not solve the problem because solution 1) merely results in a larger beam but at the same intensity, while solution 2) is limited by inherent source brightness that current technology can not exceed.

Another proposal is to provide a smaller collimating mirror in the present simulator, along with its cooling means, at a position nearer the solar source energy penetration lens. Although the resulting increased intensity would be accomplished with some descrease in uniformity and collimation, such a fabrication would be undesirable because extensive modifications would have to be made of the present mirror cooling system and an entirely new mirror provided at the new location which would be very expensive. Furthermore, extensive shut-down periods would be necessary every time it was desired to change test programs from the larger Venus solar beam intensity to the smaller Mercury intensities and vice versa.

As a consequence, it would be advantageous if variable beam diameters could be projected, while maintaining the ability to change beam intensity to suit the specific test item without having to make extensive changes to the present solar simulators.

Another method capable of varying the solar beam diameter is to vary the spacing of the two sets of lenses in the optical mixer. However, conventional solar simulators, using condenser-projector lens mixers only, have fixed geometrical input/output characteristics because they are rather sensitive to the spacing between the lens elements. This is because the image of the lamp bank is nominally contained within the second lens. If these lenses are separated further, this image over-fills the second lens and energy is lost. If these lenses are brought nearer to each other, the image-forming rays of the lamp remain within the second lens, but the projected beam size is rapidly increased, resulting in a loss of beam intensity. Second order effects, resulting from lens adjustment, shape and orientation, also occur causing changes in uniformity and skirt losses. As a result, present optical systems in solar simulators cannot be made to reduce the diameter of the uniform projected beam of light while increasing its intensity inversely at the square. The only change to the current simulators that can be made is to produce beam sizes slightly larger than the basic design size at lower intensities.

OBJECTS AND SUMMARY OF THE INVENTION

The present invention obviates the above-mentioned shortcomings by providing an optical system for a solar simulator that is capable of increasing beam intensities within the simulator by achieving the ability to vary the diameter of the beam without physical changes to the mechanical elements.

A primary object of the present invention is to provide an optical system that is capable of increasing the intensity of the light beam within a solar simulator with little or no physical changes to the present construction or source array thereof.

Another object of the invention is to provide an optical system for a space simulator that is relatively simple in construction, economical in fabrication, and that will permit the beam intensity to be increased even during a test run.

The new optical system provides an additional on-axis "stacked" single large lens system that receives all the light energy from the integrating mixer, reduces the angular subtense of the exit beam with respect to the angular subtense of the entrance beam, and thus produces the capability of concentrating or increasing the exit beam intensity over that of the inlet intensity as derived from the inherent source brightness.

The optical system includes a plurality of lenses positioned on the exit side of the optical mixer. A condenser lens relays the energy exiting from the mixer onto an intermediate lens. The intermediate lens accepts the first total uniform image in the system and relays the image of the condenser lens to a projection lens which functions as a penetration window. The projection lens is positioned approximately at the focal point of the mirror to enable the projected beam to be collimated within the design limits fixed by the relay lens and mirror optical properties.

A second embodiment of the present invention includes a variable lens system wherein the intermediate lens is also movable along the optical axis. The second lens is also preferably separated into two lens units, both of which are axially movable, to split the power of the lenses for acceptable power requirements at both extreme operating positions thereof, and to aid the incorporation of second order shape factors to improve the ultimate uniformity as desired.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

FIGURE 1 is an elevational view, partially in section, of a space simulator utilizing an optical system of the present invention;

FIGURE 2 is an enlarged plan view of an optical mixer attached to the simulator;

FIGURE 3 is an enlarged plan view of a first embodiment of an optical system of the present invention;

FIGURE 4 is an enlarged plan view of a second embodiment of an optical system of the present invention;

FIGURE 5 is an enlarged plan view of a third embodiment of the present invention showing a variable lens system; and

FIGURE 6 is an enlarged plan view of the variable lens system in a second operating position.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

Referring now to the drawings, FIGURE 1 shows a space simulator 10 which is adapted to accommodate spacecraft for solar testing and qualifying. The space simulator 10 includes a vacuum tank 11 which is an elongated cylinder of approximately eighty feet in height and twenty-seven feet in diameter. The vacuum tank includes a shroud (not shown) for containing liquid nitrogen. The liquid nitrogen functions as a temperature control means, with the temperature ranging from +250 to -320 degrees Fahrenheit.

A plurality of diffusion pumps 13 are operatively connected to the vacuum tank 11 for maintaining the vacuum tank at the desired pressure condition. A test area 15 is located towards the bottom of the tank 11 and is adapted to support spacecraft of any desired size.

A bank of lamps 17 is utilized as the source of radiant energy and is located at a position offset from the vacuum tank 11. This specific bank of lamps 17 comprises a plurality of high intensity Xenon arc lamps arranged in a hexagonal pattern and project, via elliptical reflectors, the resultant radiant energy onto the front face of an optical mixer 19 in a typical gaussian distribution.

As shown in FIGURE 2, the mixer unit 19 consists of an inlet aperture lens plane of a plurality of hexagonal fused silica lenses 20 followed by a second plane of an equal number of corresponding silica lenses 21. Both groups of lenses are closely packed and together provide a plurality of nonparallel but separate light paths therethrough. Each pair of corresponding lenses 20 and 21 are positioned to split up the gaussian distribution and overlay the parts in such a fashion that the combined distribution is uniform.

In such a position, the centerlines of the plurality of lens systems converge to meet at the plane of the lamp array 17. The first lens 20 of each pair has power sufficient to image the lamp array onto the second lens 21. However, the power of each of the second lenses 21 is chosen to create a virtual image of the first lens 20 at the plane of the lamp array 17. Thus all of the images will be superimposed at the plane of the lamp array.

An optical system variable lens unit 22 is positioned on the exit side of the mixer unit 19 and will be described in greater detail with regard to FIGURES 3-6.

A large (usually temperature-controlled) mirror 23 is positioned at the top of the vacuum tank 11 and serves to image the virtual overlayed source distribution sharply onto the test plane 15.

FIGURE 3 shows the first embodiment of the optical system 22 which includes a structure 25 supporting at one end thereof a condenser lens 26. The condenser lens 26 functions to relay the overlapped virtual images projected from the optical mixer 19 to an intermediate lens 27. The image of the lens 26 is then relayed by the intermediate lens 27 onto a projection lens 28. The projection lens 28 functions as the vessel penetration window and is located at approximately the focal point of the collimating mirror 23. The power of the intermediate lens 27 is chosen to image the condenser lens 26 onto the projection lens 28, thus relaying the exit aperture of the multiple lens unit onto the penetration window. The first uniform image is created on lens 27, from whence it is then projected by lens 28 onto the mirror as a single uniform image following usual reflection laws.

The fact that each of the large lenses lies at an image keeps their size to a minimum. The placement and powers of the three large lenses are chosen to give a two to one decrease in angular subtense so as to give a corresponding reduction in test plane diameter.

FIGURE 4 shows a second embodiment of the present invention wherein the intermediate lens 31 is somewhat weaker in power and is shifted in position so that it forms an image of the condenser lens 32 onto the projection lens 33 at a one to one magnification. These changes subtense the output beam to the same subtense as the input beam, resulting in twice the size of the test plane as produced by the system shown in FIGURE 3.

FIGURE 5 shows a third embodiment of the present invention wherein a variable lens system displaces the intermediate lens 27. The second lens group is the prime variable member and operates at a two to one magnification in the position that fills the penetration window and produces the minimum test plane diameter. The second lens group also operates at a one to one magnification at the other extreme of its travel. Since the distance from object to image of a lens is a minimum in the one to one position, if the power of the second lens is chosen to be correct for the two to one position, it will not be correct for the one to one position. The third embodiment of the present invention solves this problem by splitting the power of the second element into two lenses 33 and 35 and moving the two lens with a two to one differential motion to retain proper imaging characteristics.

The two extreme operating positions are shown in FIGURES 5 and 6.

As shown in FIGURE 1,various beam widths along with resultant intensity levels can be reflected from the mirror

23 onto the test area 11. The intensity level of the system of the present invention can thus be varied from maximum to zero for any diameter beam by turning off individual lamps or reducing their power levels. Moreover, the variable lens system, which functions to vary the beam diameter, also varies the intensity level inversely as the square.

As a result, a highly uniform well-collimated variable intensity beam can be projected from a single optical system onto the test area of a solar simulator without having to make costly changes in the mirrors, lens or other physical items. Moreover, it is now possible to effect the variations of test conditions at any time during testing.

It should be noted that various modifications can be made to the apparatus while still remaining within the purview of the following claims.