# FINAL REPORT

PART II OF TWO PARTS

# ILLUMINATION IN GROUP SHELTERS



Prepared by
Sanders & Thomas, Inc., Pottstown, Pa.
for the
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# ILLUMINATION IN GROUP SHELTERS

FINAL REPORT

Part II

Prepared by

Morell C. Smith

March 1963

Sanders and Thomas, Incorporated
Pottstown, Pennsylvania

Part I — Basic Report

Part II — Light Admitting Device Details

## ABSTRACT

A prototype light admitting device (LAD) was built and tested based on the arrangement suggested in Part I of this report. The test indicated that illumination of group shelters was feasible by this method during periods of sunlight. Illumination levels found by the test are given and various parameters of the use of LAD are discussed. Improvements in design based on experience with the prototype are also discussed.

## FOREWORD

This report concludes the study of Illumination for Group Shelters and is based on a suggestion in Part I of this report that light may be admitted to a group shelter by means of an inexpensive mirror arrangement which, while admitting sunlight, would not affect the attenuation capability of the shelter. Such an arrangement was designed, built, and evaluated. The material was prepared by Sanders and Thomas, Incorporated, Pottstown, Pennsylvania under contract number OCD-OS-62-80 for the Department of Defense, Office of Civil Defense.

## SUMMARY

## ILLUMINATION IN GROUP SHELTERS

*REQUIREMENT:*

To design, build, test, and evaluate a light admitting device (LAD) which could provide illumination in group shelters during periods of sunlight without affecting shelter attenuation.

*PROCEDURE:*

A prototype LAD was designed based on minimum cost consistent with a desirable 10 year life. Consideration was given to the following:

1. The greatest amount of illumination consistent with cost.

2. Simplicity of construction.

3. Ready availability of all materials.

4. Simple means of manipulation.

*FINDINGS:*

1. Light levels produced were approximately equivalent to four 100 watt incandescent lamps when solar intensity was 7550 foot-candles.

2. Since the reflected light was entirely diffused, glare was not a problem.

3. Light distribution was relatively constant along any of the radii tested both vertically and horizontally.

4. The tendency of the collecting mirror to flutter in a breeze does not affect light intensity on the diffuser nor the general illumination effect.

5. As a means of viewing, LAD proved quite satisfactory both when using it for direct viewing or when using the collecting mirror to increase the field of view.

6. For the most effective use the collecting mirror must be centered on the external opening of the LAD body.

7. The initial tilting motion of the collecting mirror from the stowed position proved excessively difficult in the original design.

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# CHAPTER 1

## INTRODUCTION

A suggestion in Part I of this report that it may be possible to inexpensively admit sunlight to a group shelter without disturbing the attenuation factor was acted upon by the Office of Civil Defense in that a request was made by that Office to build and evaluate such a device. Calculations indicated that light equivalent to a 100 watt lamp could be produced by a device of the suggested size under average solar illumination for the Eastern United States. The desirability of such a device would be (a) Should the normal source of illumination fail during a shelter stay, partial illumination would be available (b) The device may be used in order to permit servicing of the normal energy source or to conserve fuel and (c) Because of the size of the mirrors to be used, the device could provide a means of outward viewing to determine conditions in the immediate area of the shelter. It was desirable that it be made of materials readily available and be relatively simple to construct, install, and operate.

CHAPTER 2

# DESIGN

## A. SIZE

The solar beam to be projected into the shelter was chosen as 12 inches square as was mentioned in Part I. This was an arbitrary decision based on no more than the relationship between lumens and foot-candles and that this would represent a nominal size for all the components. In order to allow greater latitude of collection of sunlight, a 30 inch square collecting mirror was decided upon. The increased latitude became the prime consideration for the size of the collecting mirror rather than the fact that it may be possible to leave a larger mirror undisturbed for long periods of time as was originally suggested in Part I. (Operating tests indicated the criticalness of providing a solar beam perpendicular to the external opening of the LAD body for full effectiveness. Because the solar traverse changes in both altitude and azimuth at the same time, perpendicularity to the external opening of the LAD body requires relatively constant attention.) The 30 inch mirror is capable of providing a 12 inch wide solar beam at an angle of incidence as small as 25°.

## B. CONSTRUCTION

### 1. Body.

Both elbows of the LAD body were made alike. A three inch weather hood is used on the external end and a 12 inch extension on the internal end. The 12 inch extension will vary to suit the wall thickness of the shelter. The center section may be any suitable length. The 48 inch length in the prototype was chosen as a nominal unit length. Various quantities of this section may be added on to suit the particular shelter situation.

### 2. Controls.

Rope controls were decided upon as being the least expensive yet satisfactory method of control of the external mirror. The 3/16 inch nylon ropes used on the prototype appear to be a good choice both from the size and strength standpoint. They supply the two major criteria of being weatherproof and having a 10 year life. They are large enough to allow a firm grasp and are relatively friction-free when passing through the guide conduit.

The two bearing surfaces on the collecting mirror control, one for tilt, one for pivot, are somewhat inherently protected from weather by the design and if lubricated at installation should be workable for the intended life.

### 3. Dust Shield.

The dust shield on the collecting mirror will serve adequately for the nominal shelter stay period. It will not (nor was it intended to) provide adequate protection of the mirror surface for a long storage period. This aspect will be discussed further under Recommendations. It does function as intended in that with proper adjustment of the control rope, the dust shield will rise to the fully opened position approximately 1-1/2° for each 1° of tilt of

collecting mirror when starting from the vertical, or stowed, position. Thus the dust shield will not at any time shade the collecting mirror. The counterweights on the dust shield return the shield to its protective position when the collecting mirror is returned to vertical.

4. **Waterproofing.**

All joints in the LAD body are rubber gasketed to be waterproof. A double glass of the insulating type is provided on the external opening of the LAD body to prevent fogging. This glass also seals off outside (contaminated) air from being drawn into the shelter by the ventilation system. There are foam rubber plugs glued inside the control rope guide conduit through which the control ropes pass to seal off the conduit for the same reason.

5. **Diffuser.**

The diffuser was designed to provide an even distribution of reflected light from 85 degrees to the horizontal to 30 degrees from the horizontal when the solar beam is centered on it. The five degree center angle is to prevent reflected light impinging on the internal mirror and thus being lost. At an assumed mounting height of eight feet the nominal light circle from the diffuser at floor level would have a radius between 7/10 of a foot and 14 feet. This is approximately 600 square feet. Since the diffuser is of larger diameter than the projected solar beam by six inches, some misalignment of the beam may be tolerated without loss of total lumen output, but there is an increase in the radius of the light circle on the side of the small angle of incidence and a decrease on the opposite side.

6. **Materials.**

All materials used in the design were those readily available. Nothing was included that would be difficult to obtain or to machine or fabricate. All tools and equipment needed should be available in light machine shops or sheet metal shops. Gauges of metal, sizes of angles, tees, channels and tubing, etc., are those normally carried in stock by mill supply houses. Mirrors are nominal sizes though they must be cut to fit, sheet metal gauge is also nominal. The requirement to galvanize angles and tubing after fabrication represents the most difficult problem, though job-shop galvanizing facilities are not uncommon.

The prototype diffuser was made of laminated wood, lathe turned to match a full size template. Being of solid wood the diffuser is heavier than necessary but represented the least expensive means of producing the desired shape. It was painted with ordinary white house paint containing titanium dioxide.

7. **Weight.**

The weight of the entire prototype unit is approximately 150 pounds.

## C. COST

The initial prototype design was low bid for $440.00. This was for fabrication and assembly but did not include delivery charges. Design changes were incorporated during construction and further changes were made after the evaluation tests were run. All such changes were of a minor nature to either strengthen some particular member, simplify fabrication or improve controlability. The net effect was to improve LAD without changing the cost. Estimated cost of a quantity of 100 units would be $250.00 each, exclusive of delivery charges. The estimated cost of 200 units would be $225.00 each exclusive of delivery charges. Inasmuch as assembly is not particularly difficult, shipping LAD units in "knocked-down" condition for assembly at the point of use would further reduce the cost, though no figure is available for this report.

# CHAPTER 3

# EVALUATION

## A. OPERATION

### 1. Controls.

The operation of the unit by remote control was not difficult. The prototype design however did not provide a sufficient moment-arm to initiate the tilt motion. Once an angle of tilt of about 20 degrees was obtained the tilting motion could be easily controlled. A design change to improve this situation has been incorporated in the drawings. The prototype has also been modified to ease this situation. Horizontal control worked quite well and presented no problem. Without making an excessively heavy construction for the collecting mirror, some flutter due to wind is unavoidable. However, because of the size of the diffuser, this is not critical. The elasticity of the nylon control ropes also allows some minor fluctuations of the collecting mirror. Direction of the solar beam into the LAD body can be readily accomplished. However care must be taken to center the collecting mirror on the axis of the external opening of the LAD body in order to get full utilization of the collecting mirror. Because of the forces used in either adjusting or stabilizing the collecting mirror and with the effect of wind, the control rope guide conduit must be substantially fastened to the LAD body and the body in turn secured to the shelter. Also because of the large surface area of the collecting mirror and the application of the same forces mentioned above, the collecting mirror must be securely mounted.

If mirrors of reasonable flatness are used in the body, the height of the body may be 50 or more feet if necessary to clear surrounding buildings so that sunlight availability is not unduly restricted. Close alignment of the body sections and rather exact adjustment of the body mirrors would be necessary for such lengthy distances.

### 2. Positioning.

For short periods of the day within an hour or two plus or minus noon the system may be operable with the collecting mirror normally facing any direction in the as-stowed position. That is, the collecting mirror, due to shelter configuration limitations, may face due North in the as-stowed position with the design limitation being that maximum rotation would face from due East to due West in the East-North-West arc. The size of the collecting mirror is such that if sun elevation is 50° or more above the horizon the angle of incidence will be such as to give maximum light admission. Angles of sun elevation below this level will permit use of the system, however full capability will not be realized. The ideal configuration is, of course, just the opposite of that presented above. That is, the collecting mirror arc is East-South-West. With an elevation of the collecting mirror such that no objects provide shadow on the mirror at any time of the day, full utilization may be realized for the entire time the sun is above the horizon. However, below approximately 10° from the horizontal, the foot-candle value of the sun will be so low as to not provide satisfactory light plus

the fact that the red spectrum will be so dominant as to provide no more than esthetic values.

**3. Internal Mirror.**

The internal reflecting mirror should be no more than five nor less than three feet from the diffuser. At large distances mirror variations in collecting mirror location are magnified and present difficulty in holding the beam on the diffuser. At less than three feet the internal mirror may blank out a large portion of the reflected light from the diffuser in the area directly beneath.

## B. TEST RESULTS

**1. Solar Intensity.**

Light values were better than anticipated. Values were measured with a calibrated Weston 614 color-corrected meter. Outside direct sunlight was measured at 7550 foot-candles perpendicular to the sun's rays. This was on March 29, 1963 at 10 AM and 40° 12′ north latitude.

**2. Diffuser Values.**

A bare 100 watt incandescent lamp was adjacent to the diffuser in the area in which the tests were run. Readings were taken at several radial distances from both the diffuser and the bare 100 watt lamp. All readings indicated a lumenous flux from the diffuser as being approximately four times that of the 100 watt lamp. The reflecting surface of the diffuser was a standard grade of titanium dioxide white house paint. Two coats had been applied but the coatings were thin enough to allow the bare wood to show through in some small areas.

The comparative values are as follows:

| Radial Distance Inches | Diffuser Avg. F.C. | 100 W Inc. Avg. F.C. |
|---|---|---|
| 30 | 63 | 16 |
| 60 | 16 | 4 |
| 96 | 8 | 2 |

**3. Comparison Photographs.**

The accompanying photographs, Figures (1) and (2) illustrate the illumination level with the diffuser and 100 watt lamp separately being the sole light source. Exposure time, lens opening, and film type were the same for both photographs.

A better coating on the diffuser should give slightly better results than those indicated above. (Since the test, the diffuser has been given a third coat of paint.)

**4. Overcast Conditions.**

Time did not permit testing under variable weather conditions. However according to the Illuminating Engineering Society Handbook, 1962 Edition, a southern exposure on an overcast day can provide as much as 1000 foot candles. This is approximately one seventh of the foot candle value for the day of the test. It would be reasonable to assume values of one seventh of those for the diffuser in the above table so that at 60 inches from the diffuser 1.1 foot candles would be available. This is sufficient to read newsprint by. (See Part I, Page 7.)

**5. Shadow Strips.**

Strips of tape were pasted to the collecting mirror at the center in an effort to better center the solar beam on the diffuser. It was hoped that a small piece of tape not materially affecting the value of the beam would show up as

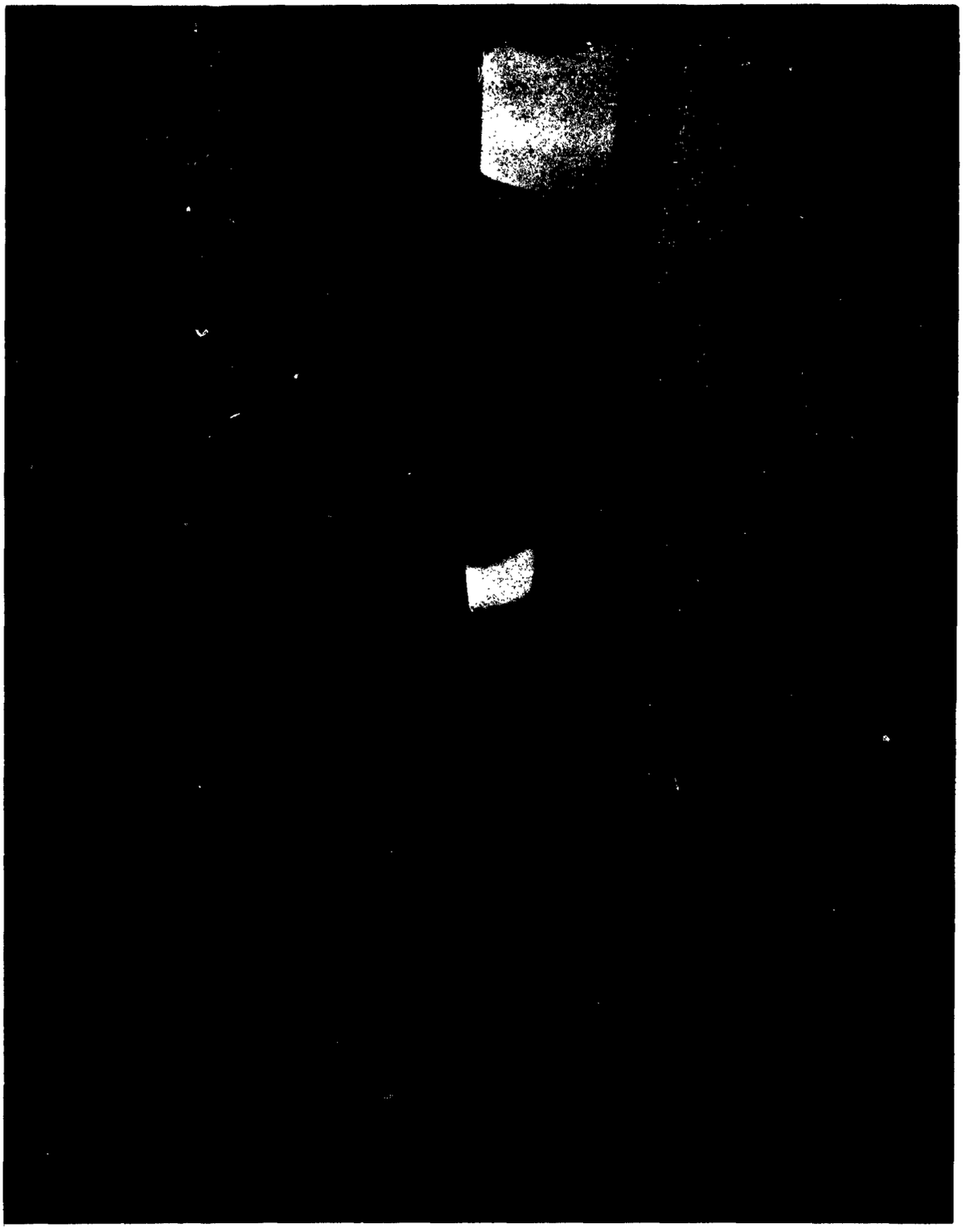


Figure 1. Diffuser Illumination. Solar Intensity 7550 Foot-Candles.

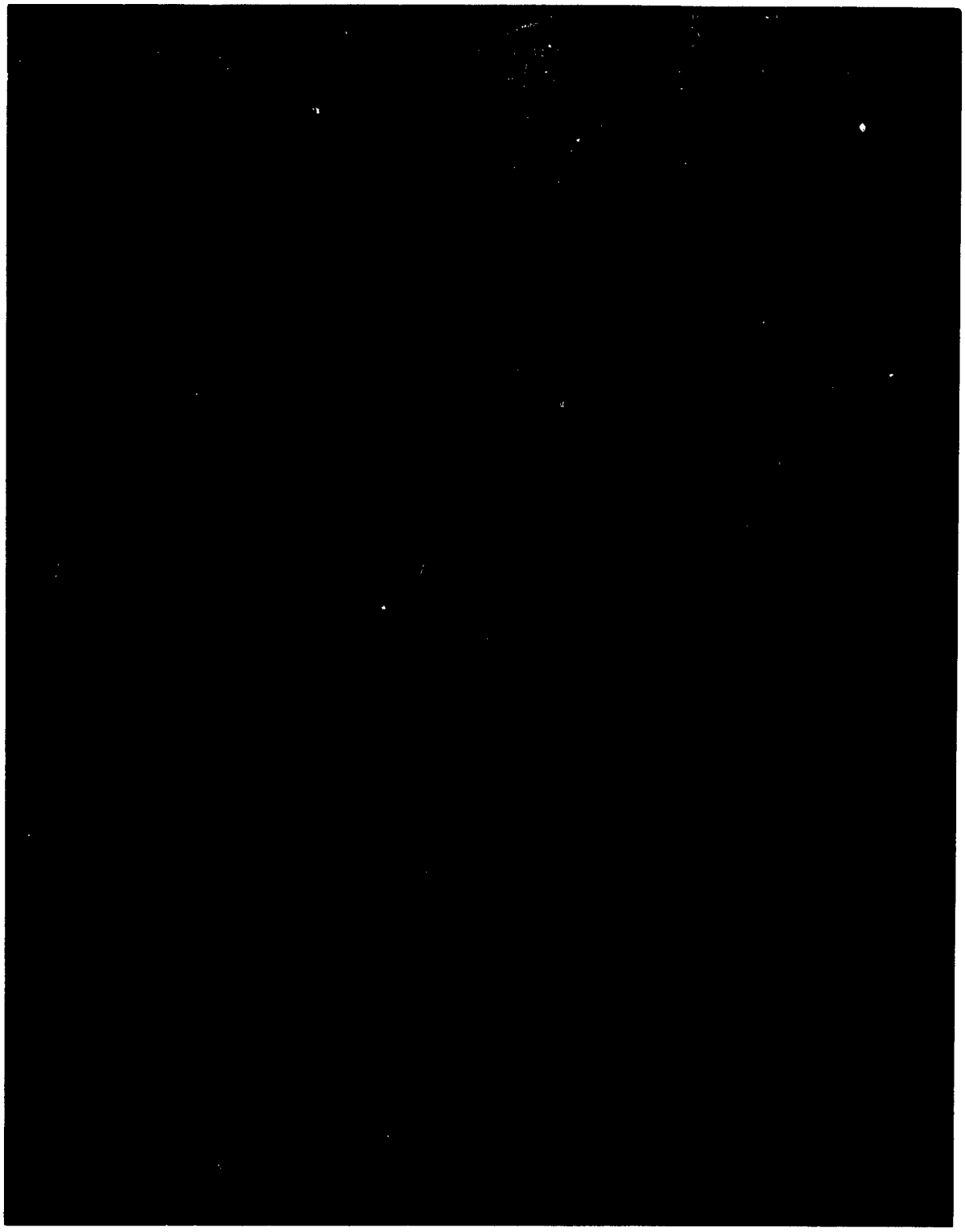


Figure 2. One Hundred Watt Lamp Illumination. Lamp Just Out of Top of Photograph.

a shadow on the diffuser. However, there was sufficient minor distortions in each mirror and in the external glass seal as to reduce resolution to a very low degree. Consequently it required a rather large piece of tape to produce a discernible shadow and the idea was abandoned. It is possible however, that other combinations of mirrors may provide more resolution and such an aid could be made useful.

**6. Outward Viewing.**

Outward viewing proved feasible. With the collecting mirror turned at 90° to the external opening, a direct view was possible and the thinness of the section of the mirror and frame (approximately one inch) allowed a relatively unrestricted view. By using the collecting mirror as an assisting device the 30 inch size permitted views in all directions except for the first 30° either side of the direct line of sight. That is, the possible field of view was 300°.

## C. TEN YEAR LIFE

As presented on the drawings the components should normally be expected to have a usable 10 year life. However, the present design does not include means for protection of the sealant glass in the LAD body nor the collecting mirror, either from weather or vandalism. Some configurations may not require protection from vandalism and so could suffice with lesser protection. Whether or not time could be taken in a case of emergency to remove the collecting mirror from a storage place and place it and the control ropes in position for use presents a debatable point. Such placement should only take 15 minutes for a ground level installation.

The design of a "fall-away" shield that would be actuated when the control ropes are first used would seem to be an acceptable solution. Such shielding could be of galvanized sheet metal and arranged so that in falling away it would allow unrestricted use of the LAD system but would be fastened to the system to prevent loss or falling from an elevated location.

## CHAPTER 4

## RECOMMENDATIONS

1. The LAD system should be further evaluated under more realistic conditions of placement and variable weather than was possible for this report.

2. Field testing should be done to determine actual rather than theoretical limitations of the light-collecting capability from various compass directions and sun altitudes.

3. A second mirror control assembly, reflecting the changes suggested by the prototype, should be built and tested.

4. A test of the LAD system should be made for its capability as a line-of-sight communication device between two shelters.

5. A non-use protective device for the external opening of the LAD body and for the collecting mirror should be designed and tested.

6. A smaller version of the present LAD system should be designed, built and tested for home shelter use. Such a design to be based on a "do-it-yourself" concept and requiring only common home workshop hand tools.

7. Offsetting the collecting mirror fulcrum slightly from the vertical would help in that improved viewing may be had from all installations because the mirror may achieve a more negative angle for viewing nearby surroundings. Under the test set-up, with a 50 foot elevation, the nearest ground sight was approximately 1/4 mile.

# APPENDIX

## A. SHIPPING CRATE

A shipping crate has been supplied with the prototype design. The crate has been designed for use as a support medium for the LAD system for demonstration purposes. Support devices for the collecting mirror control assembly, the LAD body, and in-shelter controls have been provided as attachments to this crate. The system may be demonstrated anywhere on a flat surface. Demonstration of the value of the diffuser however, would require its placement in a darkened area.

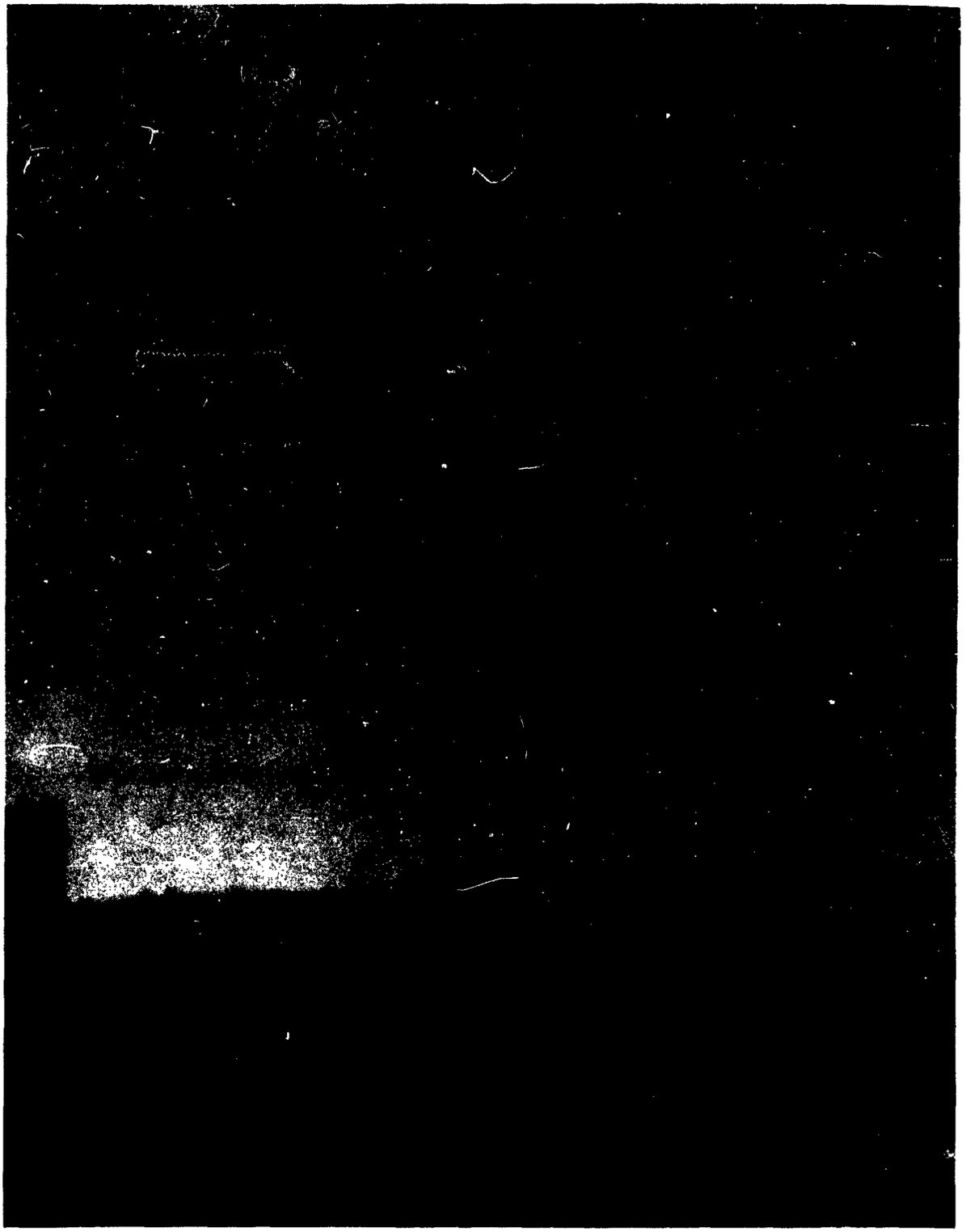
## B. PHOTOGRAPHS

The accompanying photographs show the LAD system complete and the test arrangement. (Pages A-2, A-3, A-4, and A-5)

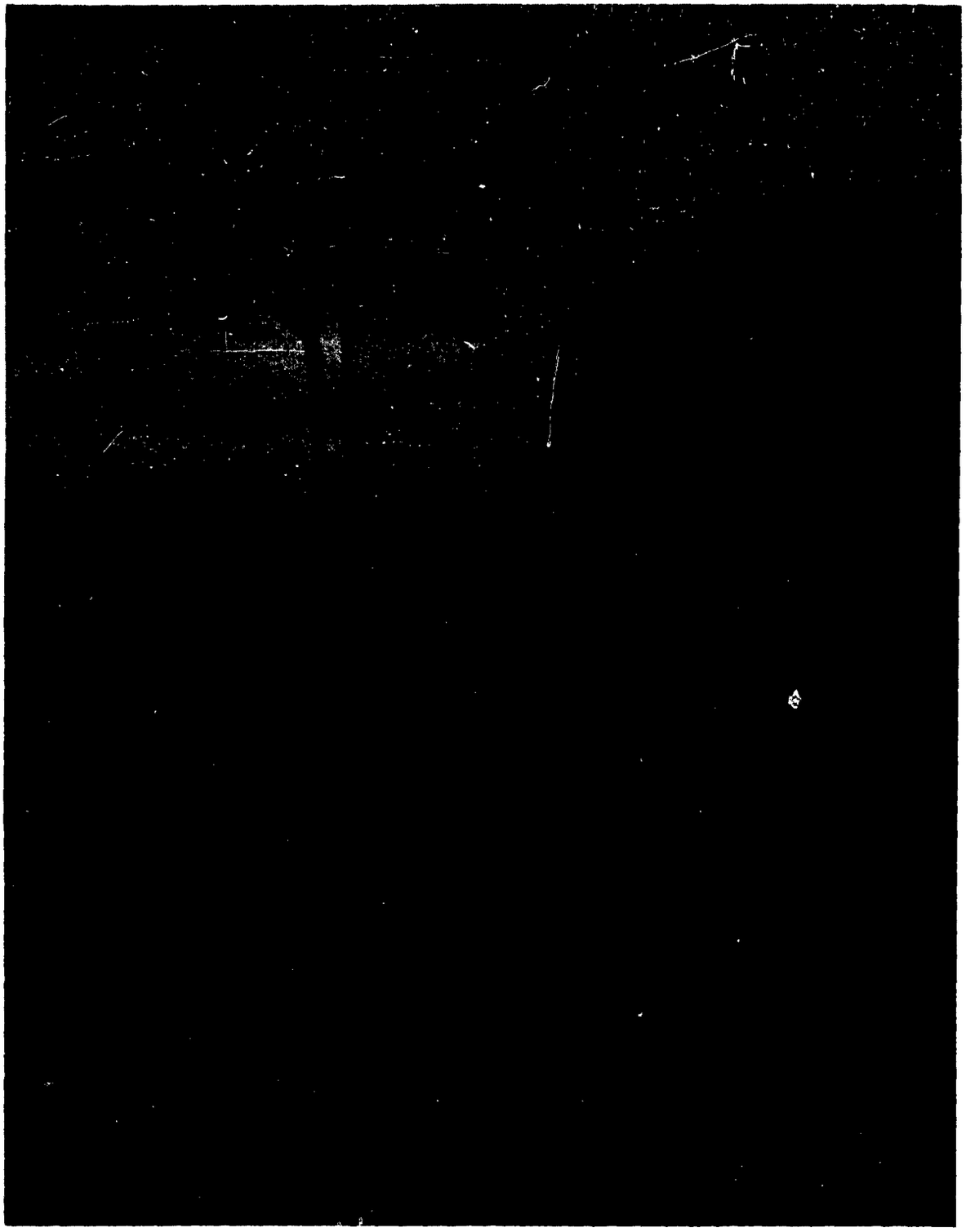
## C. ERRATUM

In Part I, Page 12, Column 2, "4000 to 8000 lumens" should read "4000 to 8000 foot-candles."

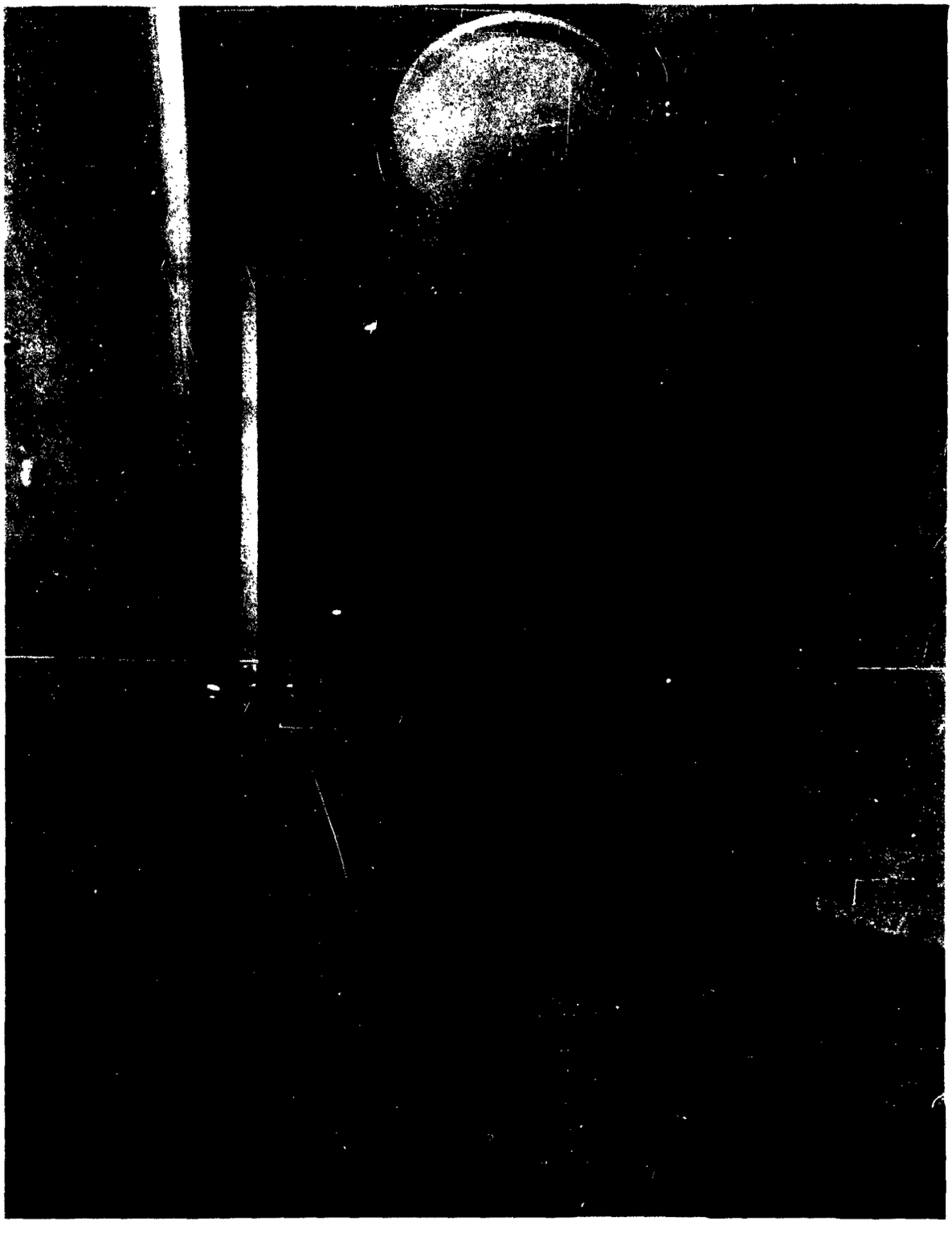
The Complete LAD System. The Collecting Mirror Tripod and Internal Mirror Stand are Those for Demonstration Purposes .



Edge View of the Collecting Mirror Showing the Operation of the Dust Shield. Also Indicated is the Small Amount of Interference Presented for Direct Viewing.



Collecting Mirror in Test Location Indicating the As-Stowed Position
with Dust Shield Lowered .



Flash Photograph Showing Internal Test Arrangement.