Title
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Publication Date
1979-09-01

UC-95D

LBL-9048 c.2
EEB-W-79-08

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UNIVERSITY OF CALIFORNIA

ENERGY & ENVIRONMENT DIVISION

To be presented at the Annual Illuminating Engineering Society Technical Conference, Atlantic City, NJ, September 16-20, 1979

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[redacted]

September 1979

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Prepared for the U. S. Department of Energy
under Contract W-7405-ENG-48

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The work described in this report was funded by the Office of Buildings and Community Systems, Assistant Secretary for Conservation and Solar Applications of the U.S. Department of Energy under contract No. W-7405-ENG-48.

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ABSTRACT

A Simplified procedure is described for calculating daylight illumination at any point within a room under clear sky conditions, which is consistent with the CIE recommended daylight factor method. The calculation procedure used here separates the light reaching the point being considered into three components; (1) light directly from the sky, (2) light after reflection from external, and (3) internal surfaces. Graphs and tables are developed for these components in order to evolve a calculation procedure which is simple to apply rather than lengthy direct computation from first principles. Finally, a validation case study is presented in order to demonstrate the accuracy of the proposed calculation procedure and to give readers a direct reference for future use.

KEY WORDS

Daylighting, natural illumination, lighting, energy conservation, energy use in buildings.

INTRODUCTION

Daylight has traditionally been an integral part of building design for the vast majority of buildings. Candles, kerosene lamps and gas lamps were used for illumination only at night and their lighting quality was very poor. Building forms tended to be narrow, with high ceilings and large windows, so that daylight could be used to the best advantage. With the invention of the fluorescent lamp and HVAC systems, deep bay building forms started to appear which had an increased reliance on artificial lighting rather than daylighting as a means of satisfying illumination during daylight hours. Today as energy has become a significant problem for building designers, daylighting after years of neglect is being "rediscovered" as an important tool for energy conservation in buildings.

Procedures for calculating illumination from natural sources first became available during the last half of the nineteenth century. Since then the literature on daylighting calculation procedures has become extensive.[1] The procedures presently available can be divided into two main bodies, those using the lumen method,[2] and those using the daylight factor method.[3]

The lumen method, which is primarily used in the United States, is based on a series of physical model measurements conducted in Texas in the early 1950's, whose results were used in developing a "coefficient of utilization" approach.[4] This method can consider both overcast and clear sky conditions; it assumes that the illumination contribution to the window is uniformly distributed across the surface of the window. This assumption results in this method being applicable only for a limited range of window configurations and accurate only for points that are situated along a line normal to the center of the window.

The daylight factor method, which is recommended by the CIE (Commission

Internationale de l'Eclairage), is used in Europe, particularly in Britain where the method was first developed. Design aids based upon the daylight factor method such as diagrams, graphs, tables and protractors have been developed to determine daylight factors at various stages of the design process. Unlike the lumen method, the daylight factor method is derived from first principles which enables it to accurately calculate daylight at any point within a room and be applicable to a wide range of window configurations. However, this method presently considers only uniform and overcast sky conditions. Various procedures for expanding the daylight factor method to include clear skies have been discussed in the literature.[5-8] Unfortunately, these procedures were either incomplete, too complex or involved long periods of expensive design time. Therefore, it became necessary to develop a simplified daylighting design procedure which will expand the daylight factor method to include clear skies.

A DAYLIGHT FACTOR PROCEDURE FOR CLEAR SKIES

The daylight factor method is based on the concept of the "daylight factor", which was developed in Britain in the 1920's.[9] Today, the daylight factor is defined as the ratio between the daylight illumination at a point in the interior and the simultaneous exterior illumination available on a horizontal surface from an unobstructed sky (excluding direct sunlight) expressed as a percentage. The light reaching the point being considered is separated into three paths (see Figure 1): light directly from the sky (Sky Component of SC); light after reflection from external surfaces (Externally Reflected Component or ERC); and light after reflection from internal surfaces (Internally Reflected Component or IRC). The total for these three components gives the daylight factor, which is simply expressed as:

$$\text{Daylight Factor} = SC + ERC + IRC$$

The Sky Component:

The sky component is the ratio between the daylight illumination at a point in the interior which is received directly from the sky and the simultaneous exterior illumination available on a horizontal surface from an unobstructed sky. The clear sky luminance distribution that will be used to calculate the sky component is consistent with the function presently being considered by the CIE Technical Committee TC-4.2,[10] which is given by the following formula:

$$L_\theta = L_z \frac{(1-e^{-0.32\sec\epsilon})(0.91+10e^{-3\delta}+0.45\cos^2\delta)}{0.274(0.91+10e^{-3z\theta}+0.45\cos^2 z\theta)}$$

where

L_θ = Luminance of sky position being considered
L_z = Luminance of the zenith
ϵ = Angular zenith distance of L_θ
δ = Angular distance of the sun from L_θ
$z\theta$ = Angular zenith distance of the sun

A diagrammatic technique called the Waldram diagram was used in the determination of the sky component, the same approach that was used in determining the sky component for uniform and overcast skies. Thus, the approach used here links itself with previously accepted techniques. Figure 2 illustrates the Waldram diagram grid which is a rectangular grid representing a half-hemisphere of the sky with equally scaled angles of azimuth and non-equally scaled angles of altitude.[11] The ordinate scale is non-equally spaced because light from different parts of the sky strikes the reference plane at different angles. Figure 3 subdivides the Waldram diagram grid into equal solid angles with the illumination for each solid angle determined by the above formula. Waldram diagrams were derived for every 10° of solar altitude (9 in total) in this manner. The solid curved lines in Figure 4 are called "droop lines" and represent the projection of horizontal edges parallel to the window-wall; the dashed curved lines represent the projection of horizontal edges at right angles, while vertical edges are not distorted. This diagram, which has been corrected for angle of incidence losses for a vertical single glazed window, is used to outline edges of window and/or obstructions so that the sky component can be determined.

The window illustrated in Figure 5 is plotted on a Waldram diagram grid with droop lines as shown in Figure 6. The angles for both horizontal and vertical edges are measured from a line that extends from the reference point normal to the plane of the window-wall. Vertical edges are plotted as a vertical line at the appropriate azimuth angle while horizontal edges are plotted by following the appropriate droop line.

With the window outline completed the sky component can now be determined. This is accomplished by overlaying the window outline (Figure 6) on the Waldram diagram that includes the sky illumination for the appropriate solar altitude (Figure 3). The window outline is positioned in relation to an angle that is formed between the orientation of the window-wall and the solar azimuth (see Figure 7). The window illustrated in Figure 5 is positioned 90^{o} west of the sun or -90^{o} from the sun which is always assumed to be 0^{o} on the azimuth scale. Figure 8 illustrates the coordinate system used to determine the position of the window. The values contained within the window outline in Figure 7 are then summed to provide the sky component. Thus the sky component for this window would be 6.4%.

Although the Waldram diagram can be applied to a wide variety of circumstances, their construction does tend to be tedious. Therefore, it became necessary to develop a procedure for more rapid estimation of the sky component. This was done by obtaining sky components for various window configurations from the Waldram diagram and plotting them on a graph (see Figure 9). Graphs for every 45^{o} in orientation of window-wall to solar azimuth (8 graphs for every 10° of solar altitude) were derived in this manner;[12] however, only one graph is presented here.

In order to use these graphs it is necessary to know; (a) the effective height H of the window above the reference plane, (b) the effective widths left W_l and right W_r of the window on each side of a line drawn from the reference point normal to the window-wall, and (c) the distance D from the reference point to the window-wall. The simple case of the vertically-glazed window in Figure 5 would be determined as follows. The height H of the window above the reference plane is 8 feet, the width of the window on the right W_r and left W_l of the center line are 6 and 12 feet respectively, and the distance D from the reference point to the window is 10 feet. Therefore, the value of H/D is 8/10 = 0.8, W_r/D is 6/10 = 0.6 and W_l/D is 12/10 = 1.2.

With the various window ratios calculated the sky component can now be determined by referring to Figure 9. Here the sky component for the portion of window to the right and to the left of the center line must be determined separately and then summed. The dash lines indicate how this graph is to be read; the sky component for the window portion to the right and left are found to be 2.0% and 4.4% respectively. Thus the sky component for the entire window is 6.4%, the same as was previously determined from the Waldram diagram.

The Externally Reflected Component:

The externally reflected component is the ratio between the daylight illumination at a point in the interior which is received directly from external reflecting surfaces and the simultaneous exterior illumination available on a horizontal surfaces from an unobstructed sky. Presently the determination of this component for clear skies is limited to the Waldram diagram approach. Work is in progress to extend the simplified approach to include the externally reflected component. The present procedure may be used with no loss in accuracy when there are no external obstructions visible from the reference point.

The Internally Reflected Component:

The internally reflected component is the ratio between the daylight illumination at a point in the interior which is received after being inter-reflected off interior surfaces and the simultaneous exterior illumination available on a horizontal surface from an unobstructed sky. Presently there are two approaches for calculating the internally reflected component, the split flux method[13] and the more accurate finite difference method.[14] The approach that will be used here is presently limited to the split flux method, the simpler of the two methods. However, this author is in the process of developing a computer program that will solve the simultaneous equations involved in the finite difference method for various window, room and photometric combinations, the results of which, when completed and tabulated will supersede the split flux method.

The split flux method divides the light entering the room into two parts (see Figure 10), light received directly from the sky and that received directly from the ground. The light from the sky on entering the room is considered to be modified by the average reflectance of the floor and those parts of the walls below the mid-height of the window. The light from the ground is considered to be modified by the average reflectance of the ceiling and those parts of the walls above the mid-height of the window.

The formula for the internally reflected component is given as:

$$\text{Average IRC} = \frac{T \times W}{A(1-R)} \left(f_s \cdot R_{fw} + f_g \cdot R_{cw}\right) \times 100\%$$

where

- T = Transmittance of glass
- W = Area of window
- A = Total area of ceiling, floor and walls including area of window
- R = Average reflectance of the ceiling, floor and all walls, including window
- R_{fw} = Average reflectance of the floor and those parts of the walls, below the plane of the mid-height of the window (excluding the window-wall)
- R_{cw} = Average reflectance of the ceiling and those parts of the walls, above the plane of the mid-height of the window (excluding the window-wall)
- f_s = Window factor due to the light incident on the window from sky
- f_g = Window factor due to the light incident on the window from ground

Room utilization factors are now introduced, U_{fw} for the lower and U_{cw} for the upper portions of the room.

$$U_{fw} = \frac{R_{fw}}{1-R} \qquad U_{cw} = \frac{R_{cw}}{1-R}$$

Then the internally reflected component formula can be rewritten as follows:

$$\text{Average IRC} = \frac{T \times W}{A} (f_s \cdot U_{fw} + f_g \cdot U_{cw})$$

Table 1 has been developed for determining the room utilization factors. This table was designed primarily for rooms of 400 ft^2 with a ceiling reflectance of 70%, but by means of a conversion factor other values can be considered. Conditions between these values are assumed to be linear, thus the necessity to interpolate becomes a simple operation. The information required before entering this table is as follows; (a) ratio of window area to floor area or percentage of floor area, (b) average reflectance of the floor, and (c) average reflectance of the walls.

Room utilization factors are obtained from Table 1 simply by intersecting the window area to floor area relationship and wall reflectance (under the appropriate floor reflectance column). For example, a 400 ft^2 room with a ceiling reflectance of 70%, floor reflectance of 40%, wall reflectance of 60% and with the window illustrated in Figure 5 (ratio of window to floor of 1:2.9) would have a U_{fw} of 1.07 and a U_{cw} of 1.43.

The window factors for both the sky f_s and ground f_g are the only remaining unknowns to be determined before the above formula can be entered. The window factor for the sky has been predetermined and can be found by looking at the top right hand corner of Figure 9, while the window factor for the ground is calculated as follows:

$$f_g = \frac{(E_{sun} + E_{sky}) \times R_g \times G_{cf}}{E_{sky}}$$

where

E_{sun} = Illumination from the sun (from Figure 37 in the Recommended Practice of Daylighting)

E_{sky} = Illumination from the sky (from Figure 36B, C, or D in the Recommended Practice of Daylighting)

R_g = Reflectance of ground surface

G_{cf} = Ground configuration factor (for a horizontal surface this value is always 0.5)

The Total Daylight Factor:

The total daylight factor is the sum of the sky component (SC), the externally reflected component (ERC) if present and the internally reflected component (IRC). However, corrections may need to be applied to allow for various types of glazing material, obstructions caused by the window framing and dust or dirt on the glazing. When these corrections are applied to the daylight factor, the resultant product is termed the corrected daylight factor.

Unlike the case of the overcast sky,[15] there have not been any daylight factor standards developed for the clear sky. Therefore the daylight factor needs to be converted into daylight illumination in order to be useful. This is accomplished by determining the exterior illumination incident on a horizontal surface from Figures 36B, C, or D in the Recommended Practice of Daylighting; this number is then multiplied by the daylight factor in order to get the interior daylight illumination.

VALIDATION OF PROPOSED PROCEDURE

Numerous analyses for validation purposes have been completed to date. The following case study is presented in order to demonstrate the accuracy of the proposed calculation procedure and to give readers a direct reference for future use.

The methods presently available for validating daylighting calculation procedures can be divided into either of three approaches; physical model measurements under a natural or artificial sky, full-size room measurements under a natural sky, or some other calculation procedure. The latter approach was chosen, however an attempt will shortly be made at validation using physical model measurements under an artificial sky. From the several calculation procedures considered for validation purposes the Lumen II computer program was selected. The Lumen II program is well documented, has undergone extensive testing, and its daylighting features have been compared favorably to a series of physical model measurements.[16]

Figure 11 illustrates the 20'x20'x10' room with 6'x16' window 2.5' high that was used in this case study. Within this room a 2.5'x2.5' grid (49 reference points) 2.5' high was selected for analyses. External and internal conditions were then established as criteria for the Daylight Factor Procedure and Lumen II Daylighting analyses.

The external conditions for this case study assumed the following parameters.

Date: June 21
Time: 8:20
Area Condition: Rural
Climate Condition: Temperate
Sky Condition: Clear
Solar Altitude: 40°
Solar Azimuth: 90°
Window Orientation: -90° in azimuth from sun
Illumination from sky on ground: 1374 footcandles (Lumen II value)
Illumination from sun on ground: 5192 footcandles (Lumen II value)
Ground Reflectance: 20%
Obstructions: None

The internal conditions for this case study assumed the following parameters.

Room Length: 20 feet, Discretization of 1 (Lumen II parameter)
Room Width: 20 feet, Discretization of 1 (Lumen II parameter)
Room Height: 10 feet, Discretization of 1 (Lumen II parameter)
Sill Height: 2.5 feet
Ceiling Reflectance: 70%
Wall Reflectance: 60%
Floor Reflectance; 40%
Glazing Type: Clear, 85% Transmittance

Daylight Factor Procedure Analysis:

The sky component for the 49 reference points illustrated in Figure 11 were determined from Figure 9, and are presented in Table 2.

The externally reflected component was omitted because no obstructions are present.

The internally reflected component's room utilization factor U_{fw} and U_{cw} were determined from Table 1 to be 1.10 and 1.47 respectively. The window factor for the sky f_s is 0.50 (from top right hand corner of Figure 9), while the window factor for the ground f_g was calculated as follows:

$$f_g = \frac{(E_{sun} + E_{sky}) \times R_g \times G_{cf}}{E_{sky}}$$

$$= \frac{(5192 + 1374) \times .20 \times 0.5}{1374} = .48$$

With these values known the average internally reflected component was determined as follows:

$$\text{Average IRC} = \frac{T \times W}{A} (f_s \cdot U_{fw} + f_g \cdot U_{cw}) \times 100\%$$

$$= \frac{.85 \text{x} 96}{1600} (.5 \times 1.10 + .48 \times 1.47) \times 100\% = 6.4\%$$

The daylight factor is determined by adding the internally reflected component of 6.4% to the 49 sky component values presented in Table 2. Daylight factors for the 49 reference points are presented in Table 3. Finally, the daylight factors are multiplied by the horizontal illumination available from an unobstructed sky (1374 footcandles) in order to determine the daylight illumination incident on the reference points. The daylight illumination for the 49 reference points are presented in Table 4.

Lumen II Daylighting Anaysis:

A Lumen II daylighting analysis was performed utilizing the same parameters assumed in the previous analysis. The daylight illumination for the 49 reference points are presented in Table 5.

Comparison of Analyses:

The percent difference between the Daylight Factor Procedure and Lumen II were calculated and are presented in Table 6. From Table 6 it can be observed that except for 4 reference points near the rear of the room, the Daylight Factor Procedure results are within ± 5% of Lumen II results. In addition, the difference between the averages is 1.1 footcandles, the ratio of the averages is 1.01, and the standard deviations for the Daylight Factor Procedure and Lumen II are 85.02 and 78.30 respectively. These results suggest an ideal correlation between the proposed procedure and Lumen II.

GENERAL COMMENTS

An accurate and simple to apply procedure for calculating daylight from clear skies has been presented which links itself with internationally recommended procedures. However, it should be emphasized that much work remains to be completed. With this in mind, work has begun on including the externally reflected component (for obstructions as well as for external shading devices), refinement of the internally reflected component calculation, developing design aids such as protractors as well as a programmable hand calculator approach. With these additions, the above procedure can be further simplified.

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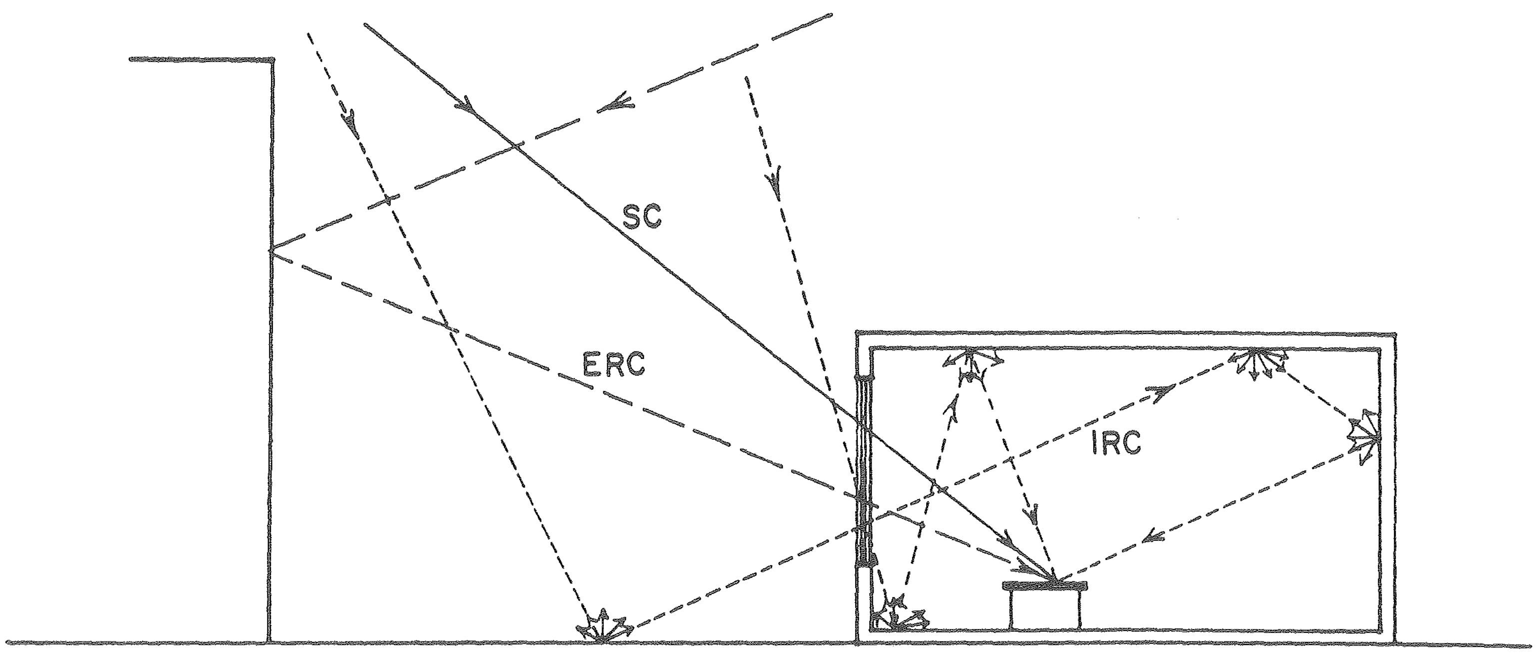

Figure 1. Components of the daylight factor.

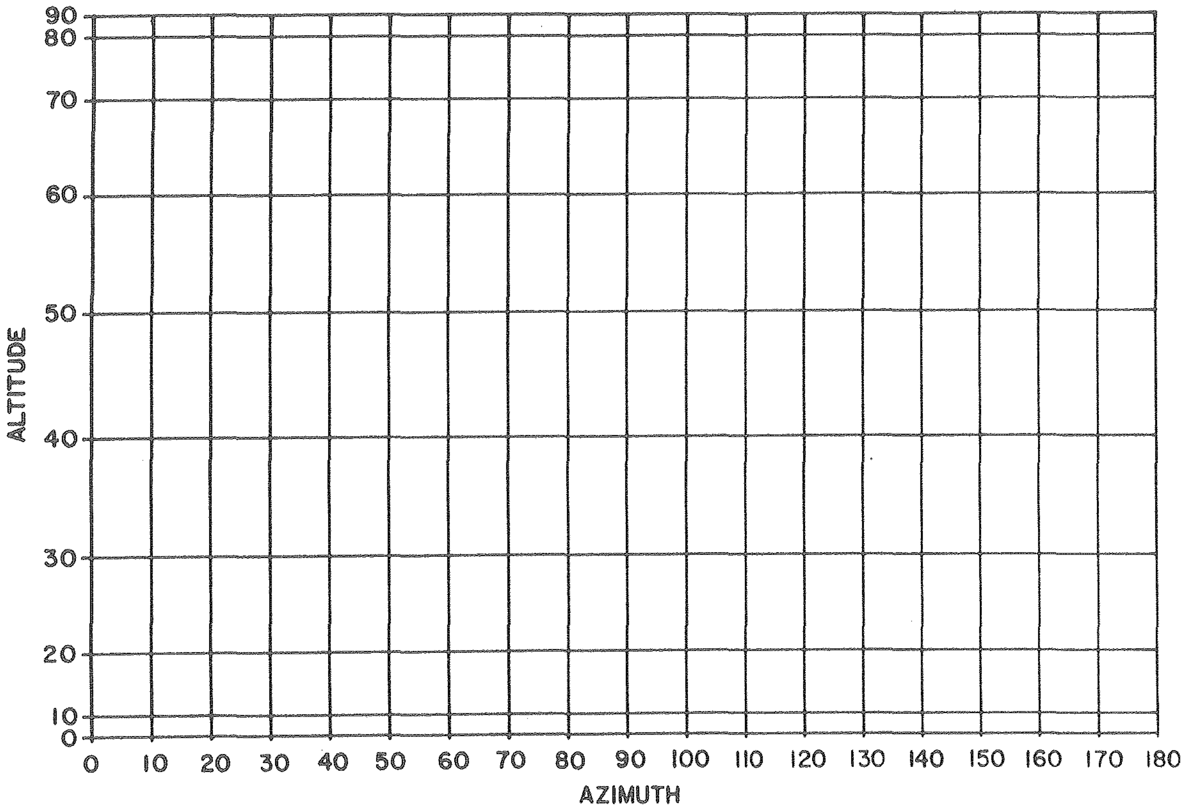

Figure 2. The Waldram diagram grid.

0.18	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.08
0.22	0.21	0.20	0.19	0.17	0.16	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08
0.28	0.26	0.24	0.22	0.19	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08
0.34	0.32	0.28	0.24	0.21	0.18	0.15	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.08
0.42	0.38	0.33	0.27	0.22	0.19	0.16	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.08
0.52	0.46	0.37	0.30	0.24	0.20	0.16	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.08
0.64	0.53	0.41	0.32	0.25	0.20	0.17	0.14	0.12	0.11	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08
0.78	0.60	0.44	0.34	0.26	0.21	0.17	0.14	0.13	0.11	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09
0.85	0.64	0.47	0.35	0.27	0.21	0.18	0.15	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.09	0.09
0.82	0.64	0.48	0.36	0.28	0.22	0.18	0.15	0.13	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.76	0.63	0.48	0.37	0.29	0.23	0.19	0.16	0.14	0.13	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11
0.70	0.61	0.48	0.38	0.30	0.24	0.20	0.17	0.15	0.14	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.13
0.66	0.59	0.49	0.39	0.32	0.26	0.22	0.19	0.17	0.15	0.15	0.14	0.14	0.14	0.15	0.15	0.15	0.15
0.63	0.57	0.48	0.40	0.32	0.27	0.23	0.20	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17

ALTITUDE: 90 80 70 60 50 40 30 20 10 0

AZIMUTH: 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

Figure 3. Waldram diagram for clear sky horizontal illumination - 40°.

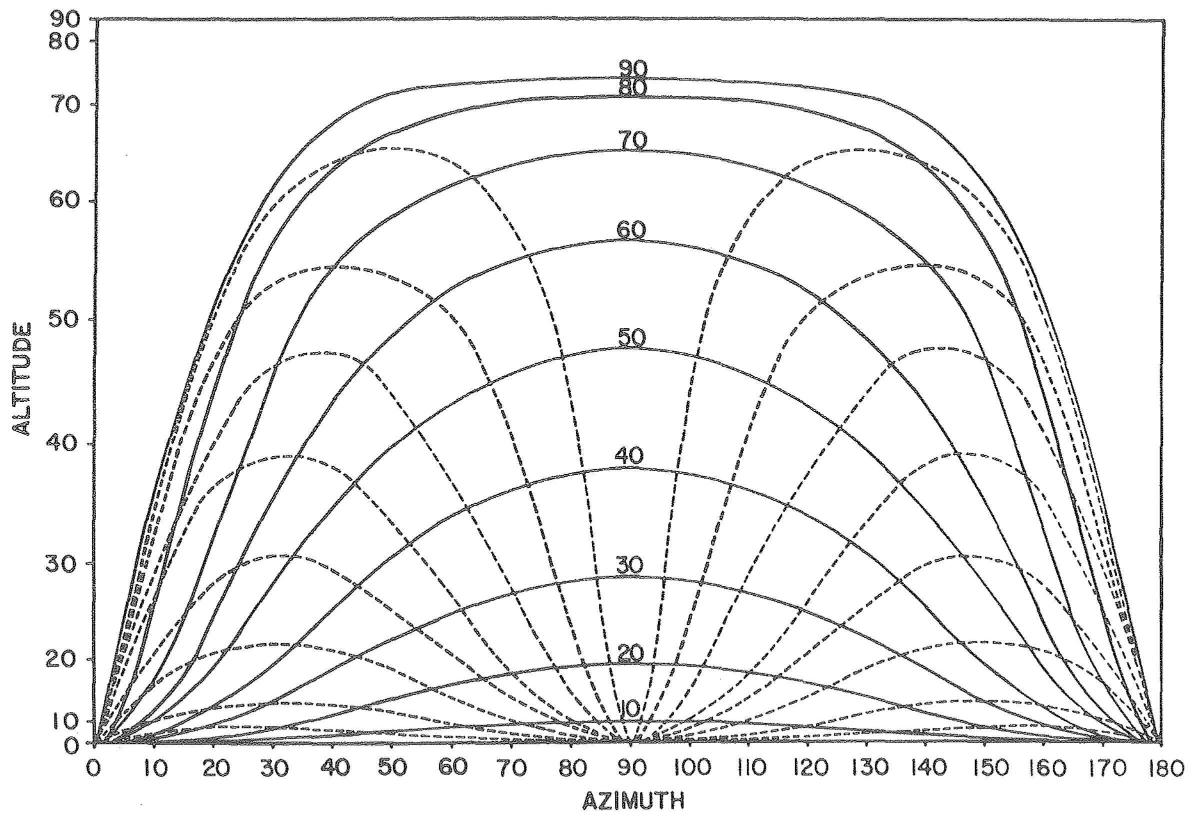

Figure 4. Waldram diagram with droop lines corrected for glazing losses.

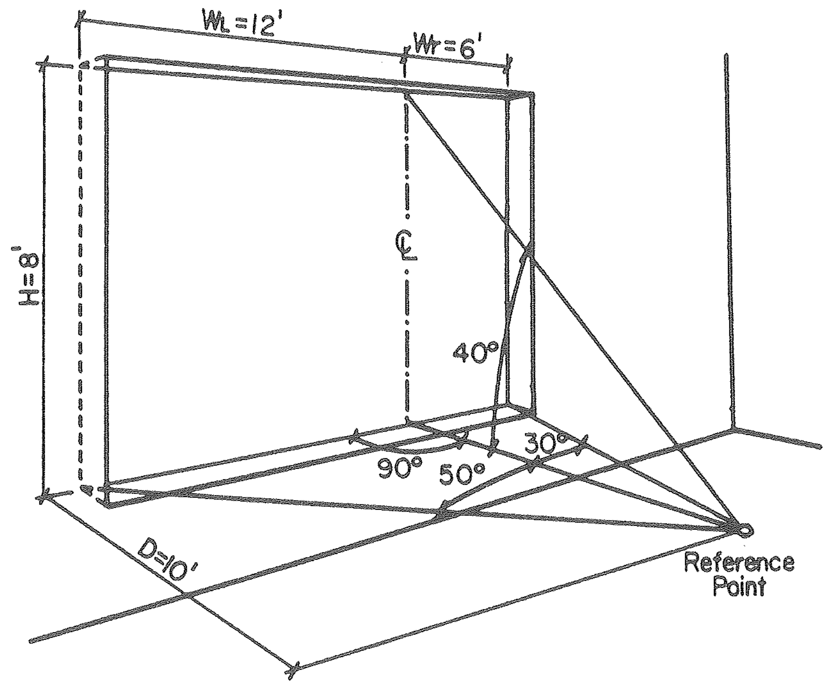

Figure 5. Vertically-glazed window.

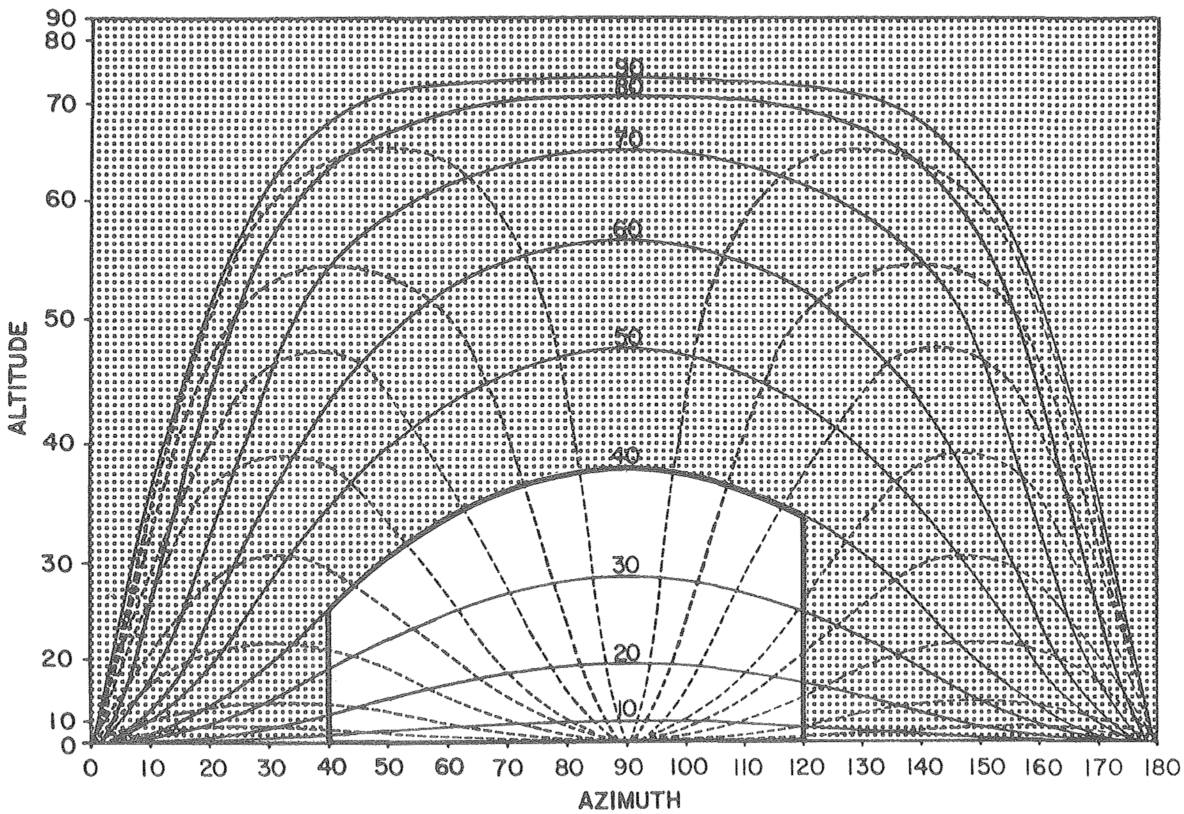

Figure 6. Window outline on Waldram diagram with droop lines.

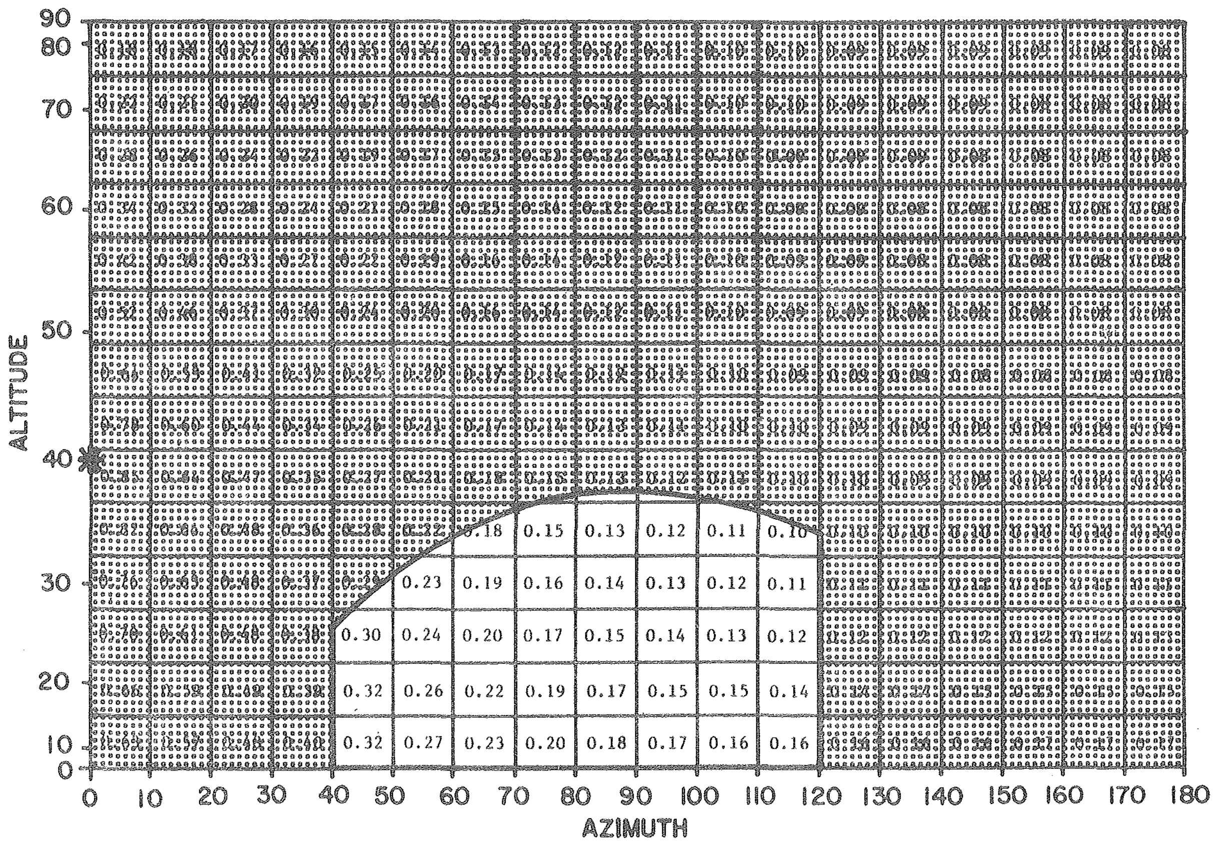

Figure 7. Window outline overlaid on the Waldram diagram that includes sky illumination.

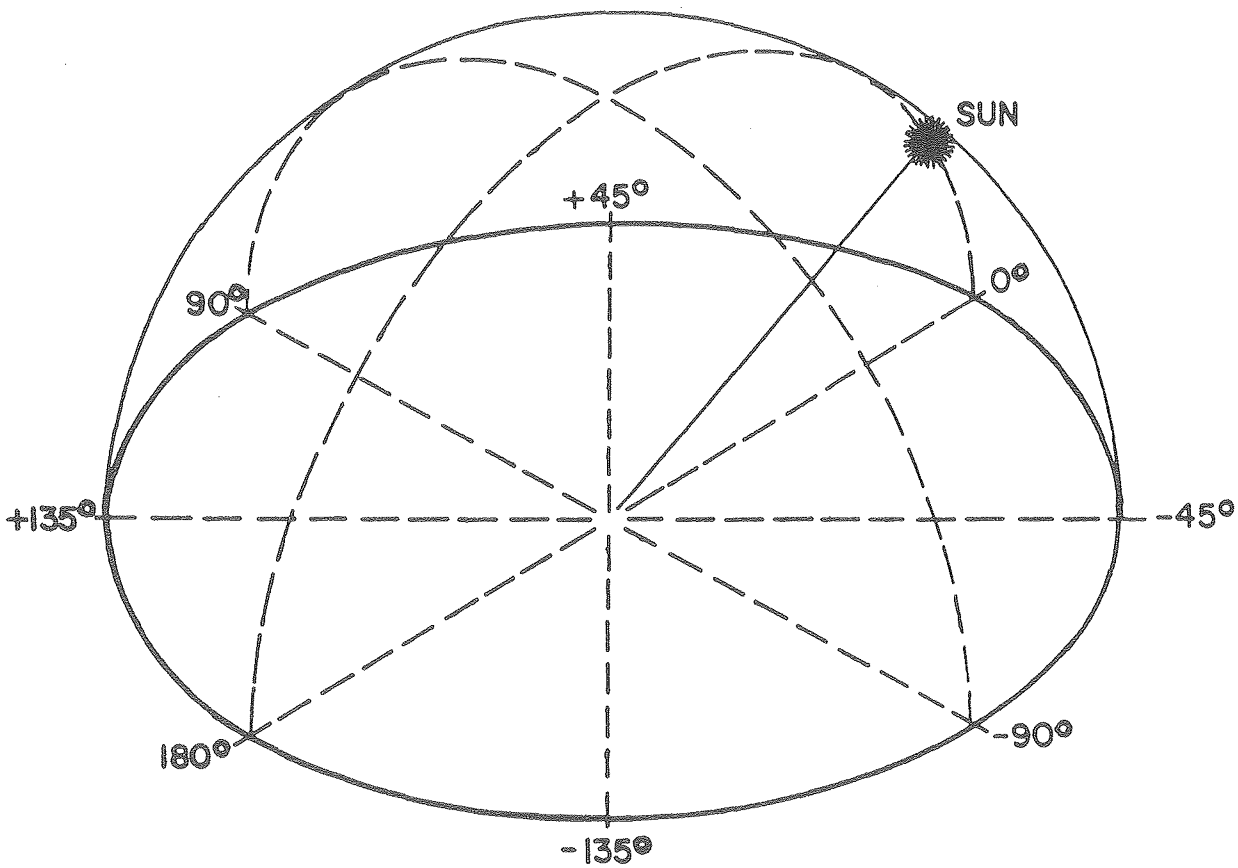

Figure 8. Coordinate system used to determine position of window-wall.

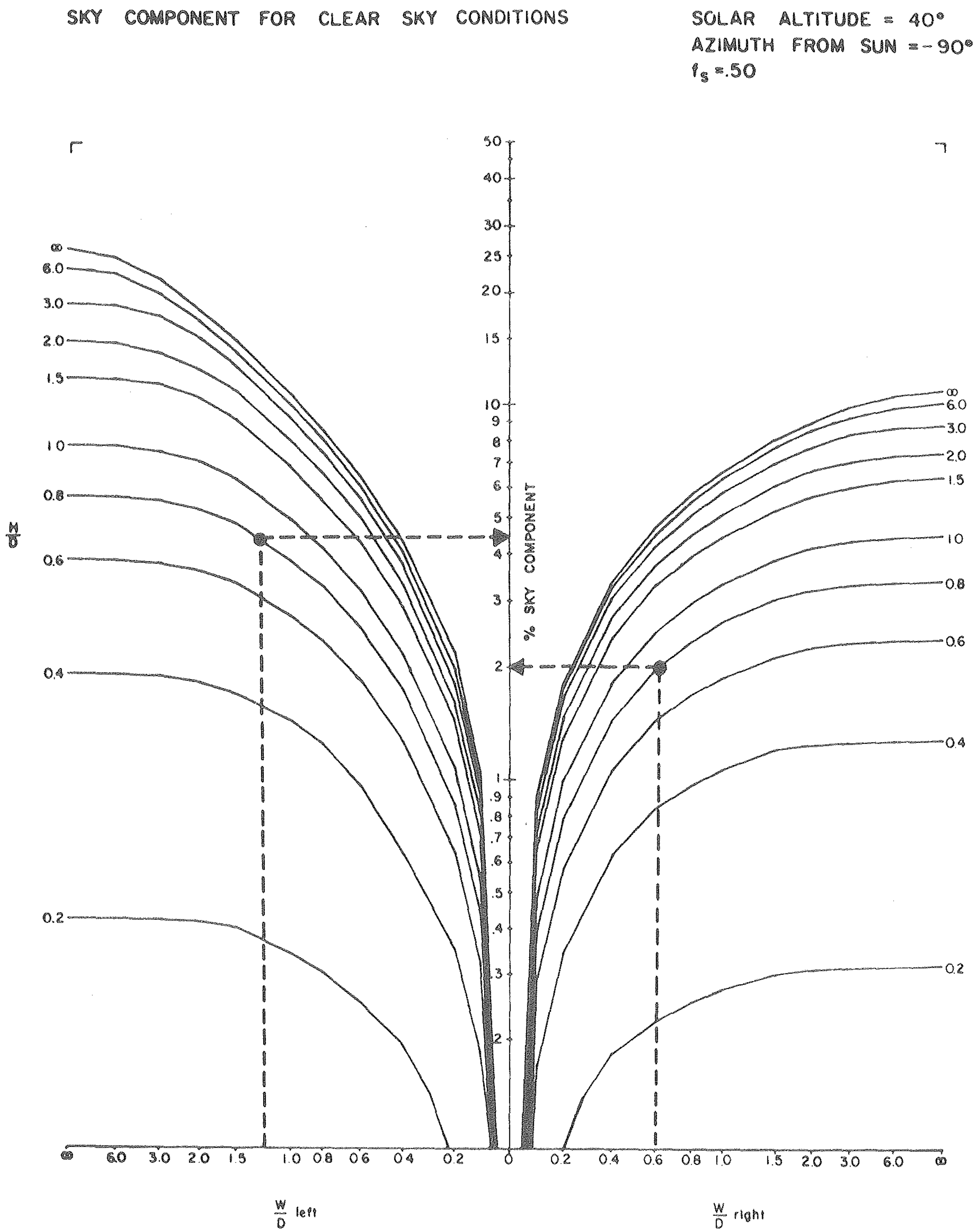

Figure 9. Graph for determining sky component.

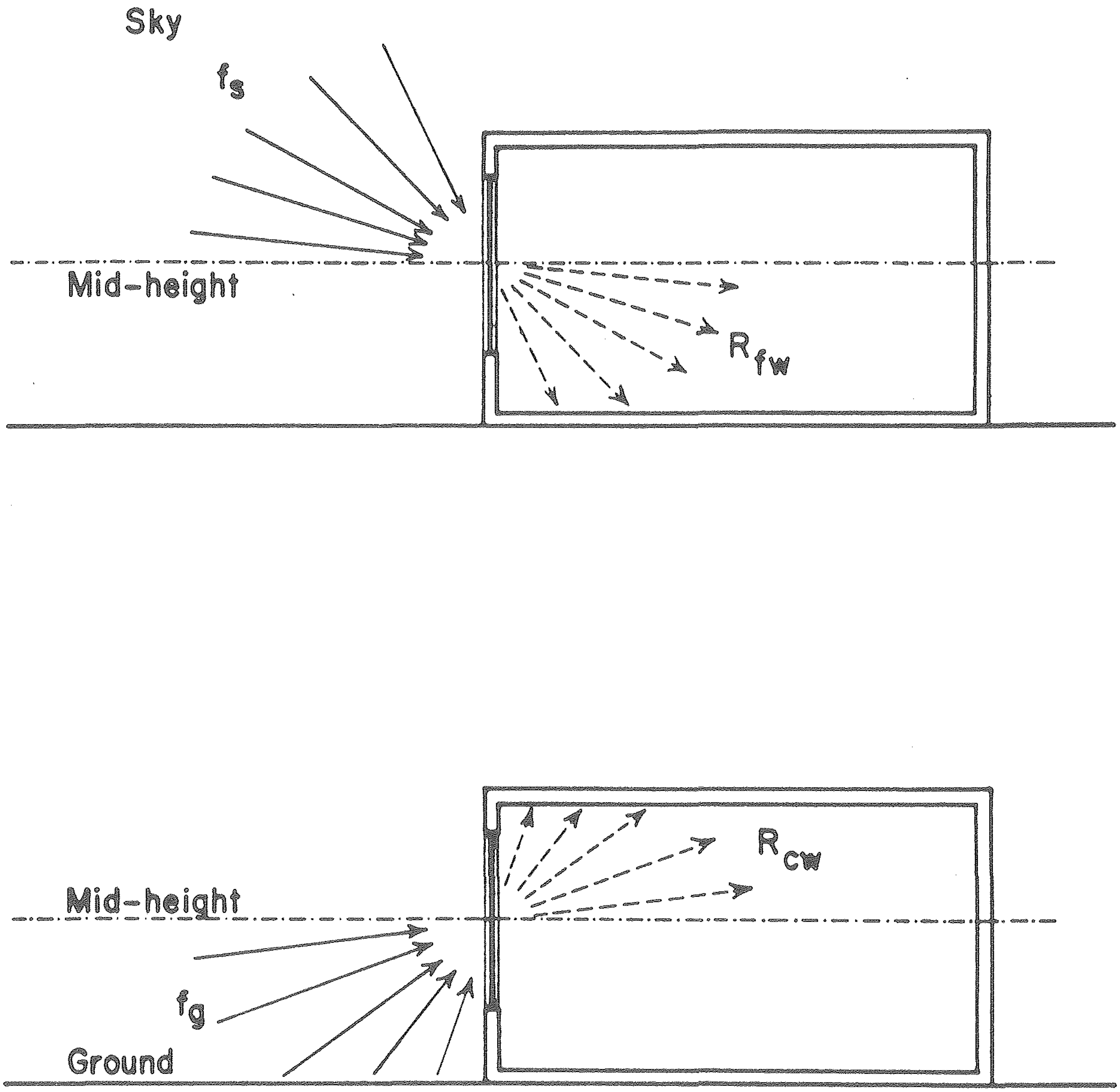

Figure 10. Conceptual illustration of the split flux method.

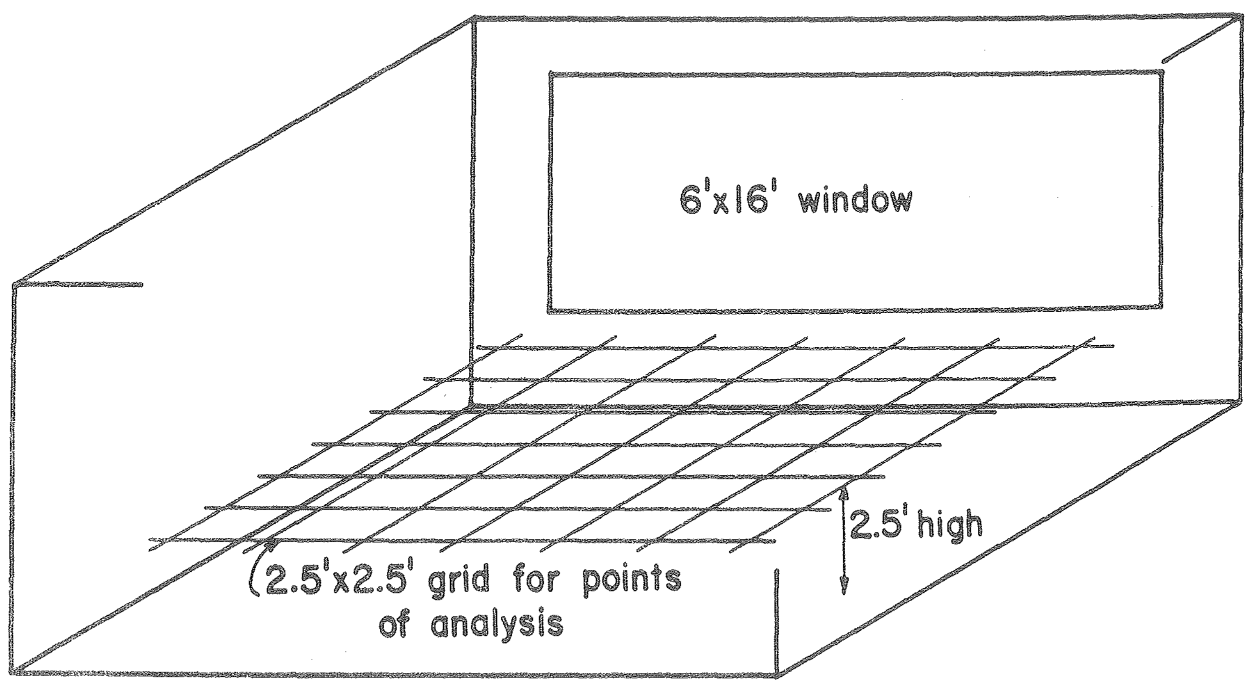

Figure 11. Typical room arrangement.

Table 1.

ROOM UTILIZATION FACTORS FOR A 400 ft^2 ROOM *

Ratio of window area: floor area	Window area as percentage of floor area	U_{fw} U_{cw}	Floor Reflectance					
			20%			40%		
			Wall Reflectance					
			40%	60%	80%	40%	60%	80%
1:10	10	U_{fw}	.52	.83	1.29	.75	1.15	1.77
		U_{cw}	1.04	1.37	1.87	1.14	1.53	2.15
1:6.7	15	U_{fw}	.51	.81	1.24	.75	1.13	1.71
		U_{cw}	1.02	1.35	1.84	1.12	1.51	2.10
1:5	20	U_{fw}	.51	.80	1.22	.74	1.11	1.67
		U_{cw}	1.01	1.34	1.80	1.11	1.49	2.05
1:4	25	U_{fw}	.51	.79	1.19	.74	1.10	1.63
		U_{cw}	1.01	1.32	1.77	1.10	1.47	2.01
1:3.3	30	U_{fw}	.50	.78	1.17	.74	1.09	1.60
		U_{cw}	1.00	1.31	1.73	1.10	1.45	1.97
1:2.9	35	U_{fw}	.50	.77	1.15	.73	1.07	1.56
		U_{cw}	1.00	1.29	1.70	1.09	1.43	1.92
1:2.5	40	U_{fw}	.49	.75	1.10	.73	1.05	1.51
		U_{cw}	.98	1.27	1.68	1.07	1.41	1.89
1:2.2	45	U_{fw}	.48	.72	1.05	.72	1.03	1.46
		U_{cw}	.96	1.26	1.65	1.05	1.39	1.86
1:2	50	U_{fw}	.47	.70	1.00	.72	1.01	1.41
		U_{cw}	.94	1.24	1.63	1.03	1.37	1.83

* Assuming a ceiling reflectance = 70%

Table 2.

****
DAYLIGHT FACTOR PROCEDURE ANALYSIS
****

SKY COMPONENT

WORKING PLANE HEIGHT: 2.50

ABS. Y COOR.	ABSOLUTE X-COORDINATE(S) 2.5	5.0	7.5	10.0	12.5	15.0	17.5
17.5 *	1.2	1.2	1.1	1.1	1.1	1.0	.9
15.0 *	1.8	1.7	1.6	1.6	1.5	1.4	1.1
12.5 *	2.4	2.5	2.5	2.5	2.3	2.0	1.6
10.0 *	3.4	3.8	3.9	3.8	3.4	2.9	2.2
7.5 *	5.6	6.3	6.4	6.4	5.8	4.7	3.3
5.0 *	9.4	11.2	11.5	11.6	10.4	8.0	5.3
2.5 *	17.8	21.7	22.5	22.3	20.5	16.2	8.6

Table 3.

****
DAYLIGHT FACTOR PROCEDURE ANALYSIS
****

DAYLIGHT FACTOR

WORKING PLANE HEIGHT: 2.50

ABS. Y COOR.	ABSOLUTE X-COORDINATE(S) 2.5	5.0	7.5	10.0	12.5	15.0	17.5
17.5 *	7.6	7.6	7.5	7.5	7.5	7.4	7.3
15.0 *	8.2	8.1	8.0	8.0	7.9	7.8	7.5
12.5 *	8.8	8.9	8.9	8.9	8.7	8.4	8.0
10.0 *	9.8	10.2	10.3	10.2	9.8	9.3	8.6
7.5 *	12.0	12.7	12.8	12.8	12.2	11.1	9.7
5.0 *	15.8	17.6	17.9	18.0	16.8	14.4	11.7
2.5 *	24.2	28.1	28.9	28.7	26.9	22.6	15.0

Table 4.

****
DAYLIGHT FACTOR PROCEDURE ANALYSIS
****

ILLUMINATION

WORKING PLANE HEIGHT: 2.50

AVERAGE: 170.1 MINIMUM: 100.3 MAXIMUM: 397.1

STANDARD DEVIATION: 85.02

ABS. Y COOR.	ABSOLUTE X-COORDINATE(S) 2.5	5.0	7.5	10.0	12.5	15.0	17.5
17.5	104.4	104.4	103.1	103.1	103.1	101.7	100.3
15.0	112.7	111.3	109.9	109.9	108.5	107.2	103.1
12.5	120.9	122.3	122.3	122.3	119.5	115.4	109.9
10.0	134.7	140.1	141.5	140.1	134.7	127.8	118.2
7.5	164.9	174.5	175.9	175.9	167.7	152.5	133.3
5.0	217.1	241.8	245.9	247.3	230.8	197.9	160.8
2.5	332.5	386.1	397.1	394.3	369.6	310.5	206.1

Table 5.

****
LUMEN II DAYLIGHTING ANALYSIS
****

ILLUMINATION

WORKING PLANE HEIGHT: 2.50

AVERAGE: 168.964 MINIMUM: 105.271 MAXIMUM: 379.272

STANDARD DEVIATION: 78.30

ABS. Y COOR.	ABSOLUTE X-COORDINATE(S) 2.5	5.0	7.5	10.0	12.5	15.0	17.5
17.5 *	111.3	111.1	107.8	108.8	107.6	105.8	105.3
15.0 *	118.7	117.1	114.4	115.4	113.5	111.6	107.8
12.5 *	127.2	127.7	123.0	124.6	122.0	117.3	112.6
10.0 *	141.6	144.5	141.6	141.2	136.6	128.9	120.7
7.5 *	166.1	173.9	172.9	171.9	161.8	148.3	132.3
5.0 *	215.9	235.3	239.2	236.6	220.0	189.7	154.3
2.5 *	322.2	371.2	379.3	376.0	353.2	297.2	196.6

Table 6.

****
PERCENT DIFFERENCE BETWEEN DAYLIGHT FACTOR PROCEDURE AND LUMEN II
****

$$\text{PERCENT DIFFERENCE} = \frac{\text{DAYLIGHT FACTOR} - \text{LUMEN II}}{\text{LUMEN II}} \times 100\%$$

WORKING PLANE HEIGHT: 2.50

ABS. Y COOR.	ABSOLUTE X-COORDINATE(S) 2.5	5.0	7.5	10.0	12.5	15.0	17.5
17.5 *	-6.2	-6.0	-4.4	-5.2	-4.2	-3.9	-4.7
15.0 *	-5.1	-5.0	-3.9	-4.8	-4.4	-3.9	-4.4
12.5 *	-5.0	-4.2	-0.6	-1.8	-2.0	-1.6	-2.4
10.0 *	-4.9	-3.0	-0.1	-1.1	-1.4	-0.9	-2.1
7.5 *	-0.7	+0.3	+1.7	+2.3	+3.6	+2.8	+0.8
5.0 *	+0.6	+2.5	+2.8	+4.5	+4.9	+4.3	+4.2
2.5 *	+3.2	+4.0	+4.7	+4.9	+4.6	+4.5	+4.8

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