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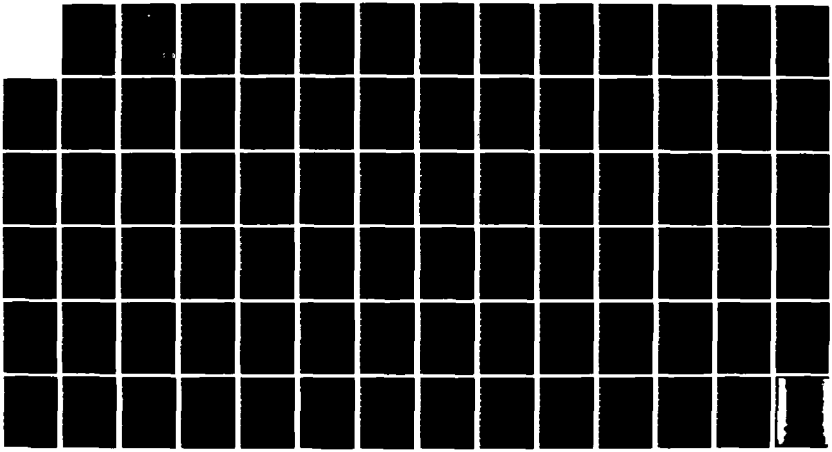

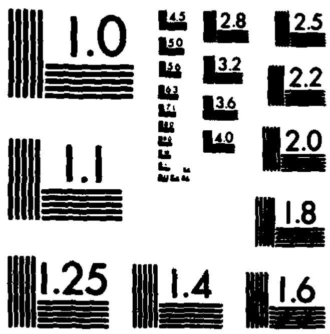


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

# THE QUANTIFICATION OF DAYLIGHTING

Thomas J. Ingram
2nd Lt USAF

LSSR 52-83





DEPARTMENT OF THE AIR FORCE
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Thesis Chairman: Timothy L. Skvarenina,
Major, USAF

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It is the policy of the Air Force to consider solar design applications in its new construction where there is a potential for significant savings of fossil fuel-derived energy. The required analysis, however, is often either not performed properly, or not performed at all. There is a requirement for a simplified preliminary analysis of solar applications so that such analyses may be more reliably accomplished. One aspect of passive solar design is daylighting, used to supplement electric light when conditions are appropriate. A computer program is developed to aid in preliminary daylighting analysis by automating two accepted deisgn procedures: the Zonal Cavity Method for interior lighting design; and the Libby-Owens-Ford method for predicting interior daylighting. After a trial run, it is shown that the appropriate use of passive daylighting can save approximately 23% to 33% of kilowatt-hour lighting costs for a design light level of 70 footcandles. The author concludes that daylighting can offer significant potential savings in lighting costs.

LSSR 52-83

# THE QUANTIFICATION OF DAYLIGHTING

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering Management

By

Thomas J. Ingram, BS
Second Lieutenant, USAF

December 1983

This thesis, written by

2LT Thomas J. Ingram

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING MANAGEMENT

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LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

The purpose of this project has been to develop a procedure by which the contribution of daylighting to the illumination of a room may be predicted, and to describe that contribution in terms of the electric lighting that is not required when daylight is sufficient to provide a given level of illumination. This procedure could be used by the Air Force to determine the cost effectiveness of unique passive solar daylighting applications. Such applications could potentially reduce the cost of meeting the energy demands of the Air Force.

## Background

In 1979, the Congress of the United States passed legislation (Section 2688 (a) to Title 10 of the United States Code, November 1979) requiring that all new military construction include solar energy applications, where such applications are found to be cost effective. Among the solar applications to be considered is unique passive daylighting, which is defined as using window areas greater than 15% of the affected wall area to provide workplace illumination. Where increasing the window size is appropriate, savings would result as the level of daylighting permits electric lights to be turned off.

The experience within the Air Force, however, indicates that the preliminary analysis to determine the cost effectiveness of passive daylighting is not being performed adequately. Specifically, many of the individuals responsible for doing the required analysis are either not aware of accepted methods, or they consider those procedures too time consuming. The task of simplifying the analysis procedure was offered as a topic for graduate research at the Air Force Institute of Technology by Headquarters Air Force/LEEEU. This thesis is the result of that research.

## Definitions

Unique passive solar daylighting is defined as an application in which in which glazing is more than 15% of the affected wall area. Using up to 15% of the wall area for windows is generally considered to be normal (7:1). A unique solar application can be expected to add to the initial cost of a structure, and must therefore be analyzed and proved cost effective in accordance with Congressional guidelines (6:1).

The amount of light at a given location is usually described in terms of footcandles. For the purposes of this report, one footcandle may be considered to be the amount of light that falls on a one-square-foot surface from a candle one foot away (5:7).

## Problem Statement

It is the policy of the Air Force to consider passive solar applications in construction where there is a potential for significant savings of fossil fuel-derived energy. What is lacking, however, is a simple and direct approach to analyzing daylighting and quantifying the savings that may be possible at a given location. Research into the specific criteria involved in the evaluation of passive solar daylighting applications is needed.

## Research Question

How may the designers of Air Force construction projects, in accomplishing the required preliminary analysis of unique solar daylighting applications, quickly and reliably estimate the value of daylighting at a given location?

## Procedure

Current procedures for predicting interior daylight illumination is investigated, and a simple computerized method of estimating potential savings in electric lighting costs is developed.

## Scope and Limitations

This project is limited to consideration of passive solar daylighting applications, as distinct from passive solar heating and cooling applications. A thorough cost analysis must consider both types of applications, because increasing glass area is a technique for increasing direct heat gain as well as daylight availability. Predicting the cost effectiveness of solar heating and cooling, however, is by itself a significant topic and is left for other research.

The computer program developed during the course of this project has been written with conventional rectangular structures in mind. Such daylighting techniques as skylights and clerestories are not considered.

Only the quantity of available daylight is taken into account. Such aspects of light quality as contrast and glare are ignored.

Calculations may only be performed for locations between 24 and 52 degrees latitude, which includes all of the continental United States. The rooms considered in this program must face south.

CHAPTER 2

# LITERATURE REVIEW

Literature in the field of interior lighting and daylighting will be briefly discussed in this chapter. Specifically, previous work that is relevant to developing simplified estimating procedures is reviewed. Also included is recent Air Force guidance details approved methods for the analysis of passive solar applications.

## Viability of Daylighting

As Evans (3:142) observes, "daylighting is part of the total building cost-benefit picture...and must be considered in conjunction with other lighting costs and benefits" in order to make a reliable estimate of cost effectiveness. Evans takes particular care to establish that windows are not necessarily the "energy losers" that many people believe them to be. Solar gains during the air-conditioning season and conduction losses during the heating season are the obvious disadvantages associated with windows, but these must be balanced against solar heat gain in the winter and the reduced heat load that results from not turning lights on in the summer. Multipane windows offer greatly decreased thermal transmittance as compared to monolithic glass windows. According to a booklet published by the Libby-Owens-Ford Company (5:3), "the proper use of daylighting for interiors can reduce the electrical consumption of a building by three times the kilowatt cost of heat gain and loss through the windows.

The American Institute of Architects Level 3A Seminar on Daylighting reinforces Evans's observations concerning the broader cost-benefit picture (1:5.1), and includes several simplified methods for estimating the various energy requirements of a building. The seminar package includes a worksheet for calculating the electric energy savings that would result if appropriate lights were turned off around the perimeter of a building. The method makes use of the "Sun Angle Calculator," a design aid available from the Libby-Owens-Ford Company, and local weather information to determine average annual savings.

## LOF Publications

In addition to the above-mentioned "Sun Angle Calculator," the Libby-Owens-Ford Company has also published a booklet called How to Predict Interior Daylight Illumination . Both of these items are easy to use, and the fact of their incorporation into the AIA methods suggests that they have been well received by design professionals. Air Force Engineering Technical Letter 82-5 specifically identifies these LOF publications as acceptable for Air Force purposes (6:5). How to Predict Interior Daylight Illumination provides graphs and tables, from which values may be obtained for illumination, coefficients of utilization, surface reflectance, and glass transmittance.

## CEL-1

An extensive computer program, the Conservation of Electric Lighting Program Version 1.0 (CEL-1), is presently available for aiding the illumination engineer in designing energy efficient rooms. In particular, CEL-1 calculates the most efficient luminaire locations given the user's design criteria. The user may provide such details as the placement of furniture, walls and partitions, and the use of dimmers. The level of detail possible with CEL-1 suggests that its most profitable use might be somewhat later in the design process than the procedure developed for this project.

## AFIT Material

The Air Force Institute of Technology School of Civil Engineering distributes a guide called the "Introduction to Lighting Design" in conjunction with its electrical engineering classes. The guide contains a procedure, the Zonal Cavity Method, for calculating the number of lighting fixtures required to provide a given footcandle level in a rectangular room (2:2). This procedure forms the basis for determining what electric lighting is required in the preliminary analysis design room considered in this project. The Method is one way of determining a room's Coefficient of Utilization (CU), that coefficient being the percentage of generated light that actually reaches the workplane. The Zonal Cavity Method considers aspects of room geometry, such as fixture-to-workplane distance and fixture-to ceiling distance, from which guide numbers are calculated. The guide numbers are used to locate the appropriate CU on a chart, such as the Photometric Data Chart in the Illuminating Engineering Society's IES Lighting Handbook .

## Air Force Guidance

Engineering Technical Letter (ETL) 82-5, entitled "Solar Applications," and dated 10 November 1982 has been distributed to the Air Force Major Commands by Headquarters Air Force. This document outlines current initiatives in the implementation of passive solar technology. For purposes of calculating daylight illumination, ETL 82-5 states that 20 feet is the maximum room depth to be considered (6:6).

ETL 82-6, entitled "Normal Passive Solar

Applications," and dated 30 December 1982, provides details of solar design considerations that must be considered in all Air Force building design. Of specific interest is the guidance on orientation: maximum solar exposure is achieved by situating a rectangular building with the long dimension along the east-west axis, and all buildings should be sited within 45 degrees of this orientation unless significant factors indicate otherwise (8:2). Rooms with southern exposure may get much of their heat and light from the sun. Spaces that are less temperature- and light-sensitive, such as corridors, closets, and mechanical rooms, should be placed along the northern side to act as a "buffer between the heated spaces and the colder north face" (8:3).

There must be available daylight for at least 6 hours per day at all times of the year, and ETL 82-6 specifies that those hours should be between 0900 and 1500 for analysis purposes.

# CHAPTER 3

# METHODOLOGY

The methodology employed in this project has been to identify the variables and equations used in existing lighting and daylighting prediction procedures, and to then develop a computerized routine for the quantification of electricity savings possible with the use of daylighting. Such a routine would be useful as part of an economic analysis of the cost effectiveness of daylighting applications.

## Choice of Methods

Because of their simplicity and the ease with which they could be adapted to a computer program, the Libby-Owens-Ford methods and the AFIT School of Civil Engineering methods were chosen to form the basis of the daylighting quantification procedure. Further, both methods have been identified as acceptable for Air Force use in making daylighting and electric lighting calculations.

## Automating the Procedure

While the LOF and AFIT methods are relatively simple to use, they can also become tedious as the number of iterations increases. For example, the LOF procedure for estimating daylight at a particular location involves finding the angle of the sun at the specific hour, reading direct and reflected light values from a series of charts, and performing several mathematical calculations using coefficients corresponding to the design conditions. In order to estimate yearly savings, these calculations would have to be repeated for each daylight hour on a representative selection of days. Further, the calculations would have to be done for both cloudy and clear conditions. As the number calculations increases, the desirability of using the LOF method to manually figure yearly savings decreases.

By storing the required tables and equations in a computer, what are essentially the same calculations can be performed for each hour, season, and sky condition. The principal effort of this project has been directed at automating the LOF procedure, and calculating the possible savings when the electric lighting system chosen by the AFIT procedure can be turned off.

## Equipment

The computer equipment used to develop this project is the Tandy Corporation TRS-80 Color Computer and disk system. A microcomputer was chosen because such systems are increasingly available to private individuals and to professionals at their places of work. Many of these systems use a version of the BASIC computer language licensed from the Microsoft Corporation, as does the TRS-80. In that no version of BASIC is likely to be very different from any other, the potential user of this program should have no difficulty in finding a microcomputer on which the routines may be run. The principal changes that one might expect would be in the input/output statements, as each manufacturer is likely to address storage and printing devices in a different way.

It is necessary to have data available concerning light fixtures and lamps, such as may be found in the IES Lighting Handbook .

## The Program

The program for quantifying potential daylighting savings is divided into five parts, as follows: calculating required solar altitudes and azimuths for a given latitude; setting illumination data into arrays for later use; calculating available light for winter, spring, and autumn skies; calculating available light for summer and cloudy skies; and determining energy savings based on calculations using the previously stored available light and room data. Each part is a separate program, the separations being made on the basis of the logical grouping of procedures and the limitations of available computer memory. Their interrelationship is depicted in Figure 1.

The first program, PART1, calculates solar angles and azimuths for a given latitude. The required latitude having been entered, the program searches through data statements until that value has been bracketed by latitudes for which solar altitude angles and azimuths are available. The altitude and azimuth data was obtained from the LOF "Sun Angle Calculator." For input latitudes not equal to one of the index latitudes, altitudes and azimuths are obtained by linear interpolation. The altitude and azimuth calculations are then written to a file for later use.

The second program, PART2, is designed to set information into arrays and to write it to files for later use. This information has been read from the charts in the LOF booklet, How to Predict Interior Daylight Illumunation , and consists of data for sky illuminations, direct illuminations, and coefficients of utilization.

PART3 is the third program, which calculates the available illumination under summer and cloudy skies. The solar altitude angles and azimuths found in PART1 are compared to the indexes of the available light tables stored in PART2. The resulting values for available light are saved in a file.

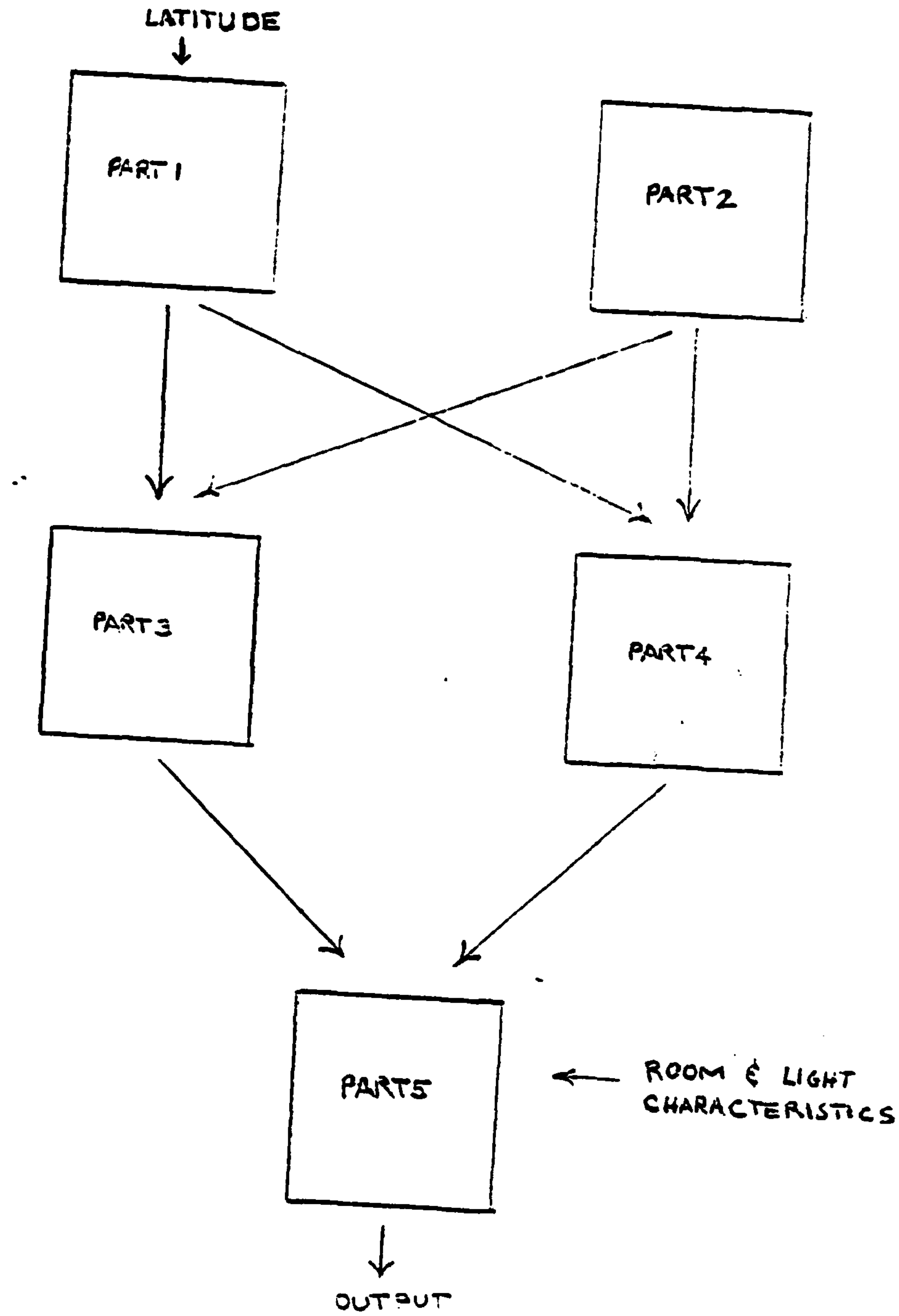


Figure 1

Program Relationships

PART4 performs the same function as PART3, but finds and saves the available light for winter and spring/fall skies. Because sun positions are symmetric with respect to the summer and winter solstices, it is sufficient to use the one chart for both seasons.

PART5 is the program in which the electric lighting and daylighting calculations are made. The program consists of two routines: finding a prototype electric lighting system using the Zonal Cavity Method; and finding the amount of time during the course of a year that daylight is sufficient to allow turning off the electric lights.

Output of interest to the user is printed during the course of the run to record the user's inputs and the program's assumptions. The user may elect to have more information printed, specifically the footcandle levels for daylight under both clear and cloudy skies at three reference points in the prototype room. As this information is printed for each hour for seven months (the fall and spring months being symmetrical about the solstices, as previously noted) and for three glass areas, the user might wish to stop the extended printout as soon as he was satisfied that the values obtained were realistic.

CHAPTER 4

# ANALYSIS

This chapter describes a test case of the program developed for this thesis. The progress of the program during the test run is followed and the results are discussed. Recommendations are made with respect to further research.

## Location

The program user describes the geographic location he wishes to analyze in two ways: by choosing the location latitude; and by using actual or assumed weather data to indicate the occurrence of clear, partly cloudy, and cloudy skies. For the purposes of this example, a latitude of 39 degrees north is assumed. Sky conditions are taken to be clear 20% of the time over the course of a year, partly cloudy 50%, and cloudy 30%.

Also included in Appendix D are the outputs for two assumed locations near the northern and southern borders of the continental United States. The northern location was chosen at 49 degrees north latitude, and the southern location at 30 degrees north latitude.

## Prototype Room

The prototype room used in this test run is depicted in Figure 2. Clear thermopane glass is used to maximize light transmission, and also to minimize heat transfer even though heating and cooling considerations are not a part of this analysis.

The lights are placed in three rows parallel to the plane of the window. The lights are directly over the three desktop-level points in the room (MAX, MID, and MIN) at which the illumination levels are predicted. Thus, if daylight provides the required amount of light at a certain distance into the room, all the lights at that distance may be turned off.

The design light level is 70 footcandles, which is suitable for such office tasks as reading manuscripts, typing, and filing.

On clear days, direct sunlight falls on the surface of the window. It is assumed that there is a macadam street or parking lot outside the window, and that 18% of the daylight that falls on it is reflected to the window (5:11).

## Running the Program

Upon giving the command to run PART1, the user is asked to enter the latitude of the location to be analyzed.

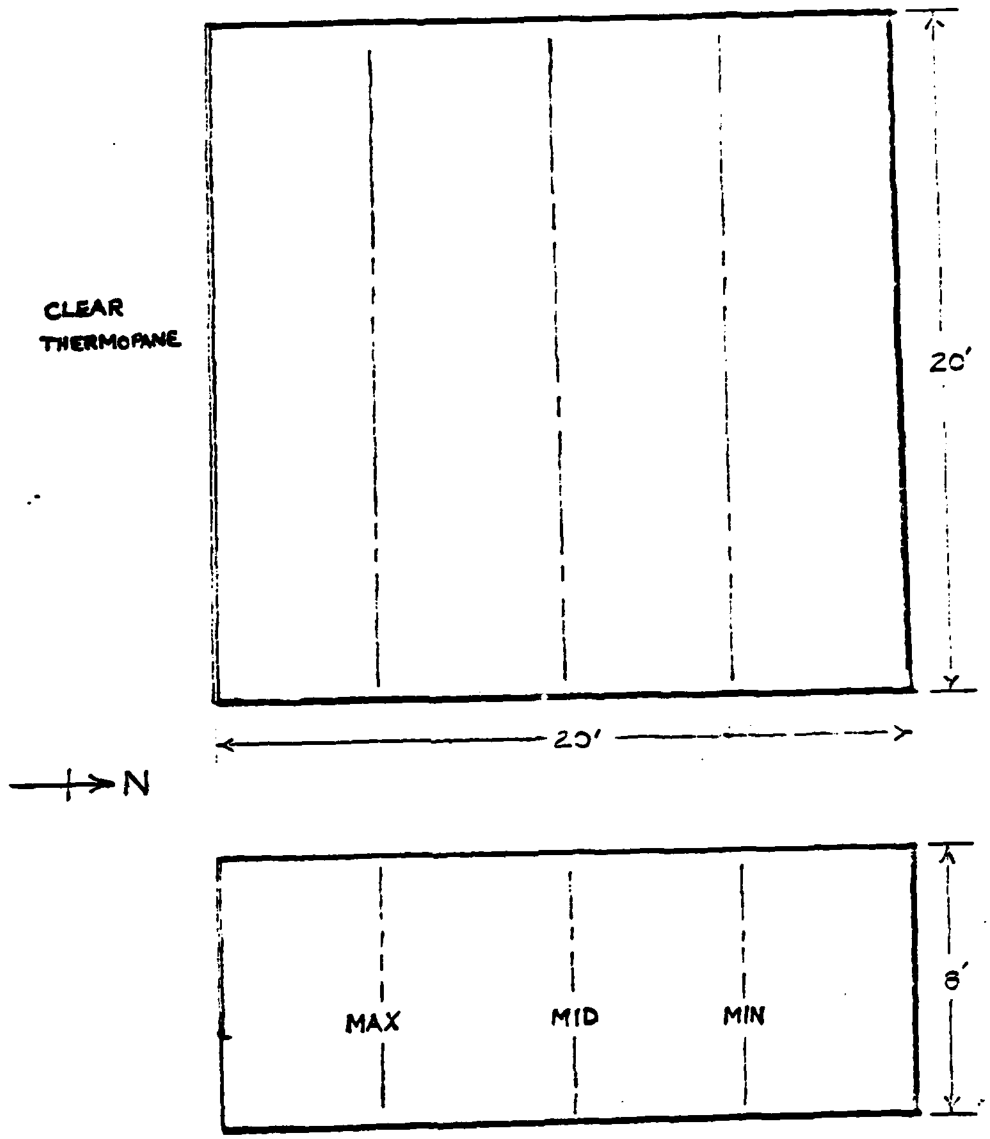


Figure 2

Prototype Room

In this example, the value 39 is entered. The program proceeds to read data statements containing the solar altitude angles and azimuths for each latitude until the input latitude is bracketed by the stored latitudes (in this case, 36 and 40). Solar altitudes and azimuths are then estimated for the input latitude by linear interpolation between the bracket latitudes. These interpolated values are stored for later use in a file called "ANGLES/DAT".

Executing program PART2 causes several tables, stored as matrices, to be saved in files on disk. The tables include sky illumination data for clear summer, winter, and spring-fall skies; direct sunlight illumination values; overcast sky illuminations; and coefficients of utilization.

PART3 and PART4 accomplish similar functions. Both use the solar altitude angles and azimuths found in PART1, and compare those angles to the indexes of the tables stored in PART2. PART3 finds and saves available light information for summer and cloudy skies; PART4 finds and saves available light information for winter and spring/fall skies. Spring and fall values are obtained from the same chart because the sun positions in the two seasons are symmetrical with respect to the summer and winter solstices.

The program PART5 consists of two sections. The first section involves choosing an artificial lighting system. The second part analyzes daylight in the same room, and calculates the kilowatt-hour savings possible based on the electric lighting system characteristics.

## Choosing Electric Lighting

The first user inputs required in PART5 are room dimensions. The user may choose from three room lengths: 20, 30, or 40 feet. The ceiling height may be chosen at 8, 10, or 12 feet. In this example, a 20 foot length and an 8 foot ceiling height were entered. The room depth is set at 20 feet, the upper limit imposed by Air Force guidance on daylight analysis.

The next user inputs involve the choice of a particular electric lighting system. This example assumes fluorescent light fixtures mounted in a suspended ceiling, and thus the fixture-to-ceiling height is 0. Given these room characteristics, the program is able to proceed with the Zonal Cavity Method for interior light design. The Room Cavity Ratio (RCR) is calculated and printed so that the user may find the coefficient of utilization (CU) for his choice of fixture in the IES Handbook . For the example, given an RCR of 2.75, a two lamp unit with a flat prismatic lens was chosen and the CU was found to be .64 (2:C76).

Also chosen from the IES Handbook tables is the lamp to be installed in the fixture. A 36-inch, 32.4 watt (including ballast) Cool White lamp was chosen for the example. A Lamp Lumen Depreciation factor (LLD) of .81 was noted for the lamp (2:D83). The Luminaire Dirt Depreciation factor (LDD) of .9 was obtained from the IES Handbook tables ,for clean conditions (2:B59). Multiplying the LLD by the LDD gives the Maintenance Factor (.73 in this case), which is entered into the program.

Given the required footcandle level, the program calculates the number of fixtures required to provide that level. The user is given the opportunity to choose a whole number of fixtures that could be symmetrically installed. For the example, 13 fixtures were required and 15 were chosen for the final design. The user is also given the opportunity to go back and change either room dimensions or fixture and lamp characteristics.

## Daylight Analysis

The electric light design having been accomplished, the daylighting analysis begins. The program reads in the files containing the total available light that were previously obtained, and calculates glass areas as percentages (15%, 30%, and 60%) of the wall area. The user supplies the program with the percentage of light that is reflected to the window from the ground (obtained from IES Handbook tables), and the percentage of light that passes through the chosen window (obtained from manufacturer's data). The reflectance entered for the example was 18%, and the glass transmittance was 77%.

The user may choose to have all the footcandle levels calculated for the room printed out, or may choose to save time by printing only the final results. The example was run twice: the short output is included as Figure 3; the complete run, including the individual light levels, is included as Appendix C.

## Results

Figure 3 shows the output from the example run. The most significant observation to be made about this example is that daylight seems to be able to provide a substantial saving in terms of kilowatt-hours: a window that is 60% of the wall area could be expected to save 591 kilowatt-hours out of a total of 1769 kilowatt-hours per year, or better than 33% of electric lighting costs per year given the assumed weather. Whether daylighting would in fact be cost effective under the circumstances analyzed in this example would depend on the cost of installing the larger window, and on the cost of electricity. The cost-benefit analysis would have to be carried out for the projected life of the

```
LATITUDE = 39

LENGTH OF ROOM:  20

WIDTH OF ROOM ASSUMED TO BE 20 FEET

CEILING HEIGHT= 8

FLOOR TO WORKPLANE HEIGHT ASSUMED TO BE 2.5 FEET

FIXTURE TO CEILING HEIGHT= 0
ROOM CAVITY RATIO= 2.75
CEILING CAVITY RATIO= 0
FLOOR CAVITY RATIO= 1.25

COEFFICIENT OF UTILIZATION: .64
MAINTENANCE FACTOR: .73
LAMPS PER LUMINAIRE: 2
LUMENS PER LAMP: 2300
WATTS PER LAMP: 32.4

DESIGN FOOTCANDLE LEVEL:          70

THE ACTUAL FOOTCANDLE LEVEL FOR 15 FIXTURES IS: 80.592
GROUND REFLECTANCE: .18
GLASS TRANSMITTANCE: .77


ELECTRIC USE WITHOUT DAYLIGHTING: 1769.04 KW-HRS/YR


THE FOLLOWING ARE LUMINAIRE ROW-HOURS WHEN LIGHTS ARE OFF--
GLASS AREA        HRS OFF(SUN)     HRS OFF(CLD)

 15%               2808             108
 30%               2952             864
 60%               3024             1944


GLASS AREA        KW-HRS OFF(SUN) KW-HRS OFF(CLD)

 15%               909.792001       34.992
 30%               956.448          279.936
 60%               979.776001       629.856
```

Figure 3

Output for Example Run

```
CLEAR= 20 %, PTLY CLDY= 50 %, CLDY= 30 %

TOTAL EXPECTED KW-HRS SAVINGS: 246.6936
FOR GLASS = 15 % OF WALL AREA


TOTAL EXPECTED KW-HRS SAVINGS: 393.0768
FOR GLASS = 30 % OF WALL AREA


TOTAL EXPECTED KW-HRS SAVINGS: 591.364801
FOR GLASS = 60 % OF WALL AREA
```

Figure 3 (cont'd)

Output for Example Run

building.

The results for test runs at other latitudes (Appendix D) support the observation that daylighting has a significant impact on kilowatt-hour usage at a 70 footcandle design light level, at each latitude providing a possible 23% and 33% savings in kilowatt-hour lighting use for 30%- and 60%- of-wall-area windows, respectively. Of course, even greater savings could be realized if the design footcandle level was lower.

## Recommendations for Further Research

The quantity of light at a given location is not the only consideration of the lighting designer. Also important are aspects of the quality of the light being provided, such as contrast, glare, and veiling reflections. The proper use of daylighting to address light quality can result in greater task visibility, while footcandle requirements can be reduced by 50% or more (4:6). Further research might find ways of incorporating quality aspects into the routine, so that without affecting task visibility, the threshold at which daylight becomes sufficient to replace electric light could be safely lowered.

Further research might also develop a program that combines solar lighting and heating applications, and which would consider installation and energy costs in determining if an integrated solar energy system is cost effective for a given situation.

APPENDIX A

VARIABLE LIST

# VARIABLES USED

| | |
|---|---|
| L | LATITUDE, LENGTH OF ROOM |
| LA(2) | INDEX LATITUDES |
| SA(2,7,7) | SOLAR ALTITUDE(ITERATION,MONTH,HOUR) |
| AA(7,7) | CALCULATED SOLAR ALTITUDE(MONTH,HOUR) |
| SZ(2,7,7) | AZIMUTH (ITERATION,MONTH,HOUR) |
| AZ(7,7) | CALCULATED AZIMUTH(MONTH,HOUR) |
| AT(11) | SOLAR ANGLE INDEX |
| AW(11) | SOLAR ANGLE INDEX |
| AF(14) | SOLAR ANGLE INDEX |
| CS(11,5) | ILLUMINATION ARRAY(ALT.,AZ.) |
| CW(11,5) | ILLUMINATION ARRAY |
| CA(14,5) | ILLUMINATION ARRAY |
| BA(5) | AZIMUTH INDEX |
| DS(19,4) | ILLUMINATION ARRAY(ALT.,AZ.) |
| DA(19) | ALTITUDE INDEX |
| OS(19,2) | OVERCAST ILLUMINATION ARRAY(ALT.,SURFACE) |
| CU(4,3,3) | COEFFICIENTS OF UTILIZATION |
| TL(7,2,7,2) | TOTAL LIGHT(MONTH,SKY,HR,SURF.) |
| E1-E4 | LIGHT VALUE READ FROM TABLE |
| TC | ELECTRIC USE WITHOUT DAYLIGHT, KW-HRS |
| I1-I7 | FOOTCANDLE VALUES, CLR SKIES |
| J1-J7 | FOOTCANDLE VALUES, CLDY SKIES |
| WB | WATT-HRS PER BANK |
| S1-S3 | WEATHER %'S |

| | |
|---|---|
| S4 | HRS OFF, CLEAR |
| S5 | HRS OFF, CLDY |
| S6,S7 | HRS OFF, PTLY CLDY |
| S8 | HRS OFF, TOTAL |
| S10 | KW-HRS SAVINGS, TOTAL |

# APPENDIX B

# PROGRAM LISTINGS

```
100 ' PROGRAM: PART1
110 '
120 ' PROGRAM STORES HOURLY SOLAR ANGLES AND AZIMUTHS FOR
130 ' LATITUDES 24 TO 52  (BY 4) AND INTERPOLATES TO FIND
VALUES
140 ' FOR ANY GIVEN LATITUDE BETWEEN 24 AND 52.
150 '
160 DIM LA(2),SA(2,7,7),AA(7,7),SZ(2,7,7),AZ(7,7)
170 INPUT "LATITUDE";L
180 PRINT #-2,"LATITUDE =";L
190 PRINT#-2
200 '
210 '  READ IN STORED ANGLE DATA
220 READ LA(1)
230 FOR M=1 TO 7
240 FOR H=1 TO 7
250 READ SA(1,M,H):NEXT H
260 FOR J=1 TO 7
270 READ SZ(1,M,J):NEXT J
280 NEXT M
290 FOR I=1TO7
300 LA(2)=LA(1)
310 READ LA(1)
320 FOR M=1TO7
330 FOR H=1TO7
340 SA(2,M,H)=SA(1,M,H)
350 READ SA(1,M,H)
360 '   BRACKET GIVEN LATITUDE BETWEEN AVAILABLE LATITUDES-
370 IF LA(1)>=L AND LA(2)<L THEN 420
380 GOTO 460
390 '
400 '
410 '  INTERPOLATION STEPS-SOLAR ANGLES
420 AA(M,H)=((LA(1)-L)/4)*(SA(1,M,H)-SA(2,M,H))-SA(1,M,H)
430 AA(M,H)=AA(M,H)*-1
440 '  ROUND RESULT TO NEAREST 5 DEGREES
450 AA(M,H)=INT(AA(M,H)/5+.5)*5
460 NEXT H
470 '
480 FOR J=1TO7
490 SZ(2,M,J)=SZ(1,M,J)
500 READ SZ(1,M,J)
510 IF LA(1)>=L AND LA(2)<L THEN 540
520 GOTO 570
```

```
530 '  INTERPOLATION TO FIND AZIMUTHS FOR GIVEN LAT.
540 AZ(M,J)=((LA(1)-L)/4)*(SZ(1,M,J)-SZ(2,M,J))-SZ(1,M,J)
550 AZ(M,J)=AZ(M,J)*-1
560 '
570 NEXT J
580 NEXT M
590 NEXT I
600 '
610 ' WRITE CALCULATED ANGLES AND AZIMUTHS TO FILE:
ANGLES/DAT
620 OPEN "O",#1,"ANGLES/DAT"
630 FOR A=1TO7
640
WRITE#1,AA(A,1),AA(A,2),AA(A,3),AA(A,4),AA(A,5),AA(A,6),AA(A
,7)
650 NEXT A
660 FOR B=1TO7
670
WRITE#1,AZ(B,1),AZ(B,2),AZ(B,3),AZ(B,4),AZ(B,5),AZ(B,6),AZ(B
,7)
680 NEXT B
690 CLOSE #1
700 '
710 '  DATA-
720 DATA 24,26,34,40,43,40,34,26
730 DATA    46,33,18,0,18,33,46
740 DATA    28,37,44,46,44,37,28
750 DATA    48,35,20,0,20,35,48
760 DATA    34,45,53,56,53,45,34
770 DATA    56,42,24,0,24,42,56
780 DATA    40,53,62,67,62,53,40
790 DATA    68,55,33,0,33,55,68
800 DATA    46,59,72,78,72,59,46
810 DATA    82,71,51,0,51,71,82
820 DATA    48,62,76,86,76,62,48
830 DATA    90,87,76,0,76,87,90
840 DATA    49,63,77,87,77,63,49
850 DATA    90,90,89,0,89,90,90
860 DATA 28,22,31,37,39,37,31,22
870 DATA    45,32,17,0,17,32,45
880 DATA    25,34,40,42,40,34,25
890 DATA    47,34,18,0,18,34,47
900 DATA    32,42,48,52,48,42,32
910 DATA    55,40,22,0,22,40,55
920 DATA    39,50,59,62,59,50,39
930 DATA    65,51,29,0,29,51,65
940 DATA    45,58,69,74,69,58,45
950 DATA    78,66,42,0,42,66,78
960 DATA    49,62,75,82,75,62,49
970 DATA    89,80,62,0,62,80,89
980 DATA    50,63,76,85,76,63,50
990 DATA    90,87,73,0,73,87,90
```

```
1000 DATA 32,20,27,33,35,33,27,20
1010 DATA    43,31,16,0,16,31,43
1020 DATA    22,31,36,38,36,31,22
1030 DATA    46,33,17,0,17,33,46
1040 DATA    30,38,45,47,45,38,30
1050 DATA    52,38,21,0,21,38,52
1060 DATA    37,48,55,58,55,48,37
1070 DATA    62,47,27,0,27,47,62
1080 DATA    45,56,66,70,66,56,45
1090 DATA    74,60,37,0,37,60,74
1100 DATA    48,61,72,78,72,61,48
1110 DATA    85,73,51,0,51,73,85
1120 DATA    50,62,74,82,74,62,50
1130 DATA    89,79,59,0,59,79,89
1140 DATA 36,17,24,29,31,29,24,17
1150 DATA    42,30,16,0,16,30,42
1160 DATA    20,27,33,34,33,27,20
1170 DATA    44,31,16,0,16,31,44
1180 DATA    27,36,42,44,42,36,27
1190 DATA    51,37,19,0,19,37,51
1200 DATA    35,45,52,54,52,45,35
1210 DATA    59,44,24,0,24,44,59
1220 DATA    43,54,63,66,63,54,43
1230 DATA    70,55,32,0,32,55,70
1240 DATA    48,60,70,74,70,60,48
1250 DATA    80,66,42,0,42,66,80
1260 DATA    50,62,72,77,72,62,50
1270 DATA    84,71,48,0,48,71,84
1280 DATA 40,15,21,25,27,25,21,15
1290 DATA    42,30,15,0,15,30,42
1300 DATA    17,24,29,31,29,24,17
1310 DATA    44,31,16,0,16,31,44
1320 DATA    25,33,38,40,38,33,25
1330 DATA    50,35,19,0,19,35,50
1340 DATA    33,42,48,51,48,42,33
1350 DATA    57,42,23,0,23,42,57
1360 DATA    42,52,59,62,59,52,42
1370 DATA    68,52,29,0,29,52,68
1380 DATA    47,58,67,71,67,58,47
1390 DATA    76,61,37,0,37,61,76
1400 DATA    49,60,70,74,70,60,49
1410 DATA    80,66,42,0,42,66,80
1420 DATA 44,11,17,21,23,21,17,11
1430 DATA    41,29,15,0,15,29,41
1440 DATA    14,20,25,26,25,20,14
1450 DATA    43,30,15,0,15,30,43
1460 DATA    22,29,34,36,34,29,22
1470 DATA    48,34,18,0,18,34,48
1480 DATA    31,39,44,47,44,39,31
1490 DATA    55,39,21,0,21,39,55
1500 DATA    40,49,55,58,55,49,40
1510 DATA    64,47,26,0,26,47,64
```

```
1520 DATA     46,56,63,67,63,56,46
1530 DATA     72,55,32,0,32,55,72
1540 DATA     48,58,66,70,66,58,48
1550 DATA     75,59,35,0,35,59,75
1560 DATA 48,8,14,17,18,17,14,8
1570 DATA     41,28,14,0,14,28,41
1580 DATA     12,17,21,22,21,17,12
1590 DATA     43,29,15,0,15,29,43
1600 DATA     20,26,30,32,30,26,20
1610 DATA     47,33,17,0,17,33,47
1620 DATA     28,36,41,43,41,36,28
1630 DATA     53,38,20,0,20,38,53
1640 DATA     37,46,52,54,52,46,37
1650 DATA     61,45,24,0,24,45,61
1660 DATA     45,53,60,63,60,53,45
1670 DATA     68,51,28,0,28,51,68
1680 DATA     47,56,63,66,63,56,47
1690 DATA     71,54,31,0,31,54,71
1700 DATA 52,5,10,13,14,13,10,5
1710 DATA     41,28,14,0,14,28,41
1720 DATA     8,13,17,18,17,13,8
1730 DATA     42,29,15,0,15,29,42
1740 DATA     16,23,26,27,26,23,16
1750 DATA     46,32,16,0,16,32,46
1760 DATA     26,33,37,38,37,33,26
1770 DATA     52,36,19,0,19,36,52
1780 DATA     36,43,48,50,48,43,36
1790 DATA     59,42,22,0,22,42,59
1800 DATA     43,51,57,58,57,51,43
1810 DATA     65,47,26,0,26,47,65
1820 DATA     46,54,59,62,59,54,46
1830 DATA     67,50,27,0,27,50,67
```

```
100 '  PROGRAM: PART2
110 '
120 ' PROGRAM READS IN DATA FOR SEASONAL AND OVERCAST SKY
130 ' ILLUMINATIONS, AND COEFFICIENTS OF UTILIZATION.
140 ' DATA IS SAVED IN FILES FOR REFERENCE BY LATER
PROGRAMS.
150 DIM
AT(11),AW(11),AF(14),CS(11,5),CW(11,5),CA(14,5),BA(5)
160 '
170 '  READS IN CLEAR SUMMER SKY ILLUMINATIONS.
180 '  AT(A) IS THE SOLAR ANGLE INDEX; BA(C) IS THE AZIMUTH
INDEX
190 '  CS(A,B) IS THE ILLUMINATION ARRAY.
200 '
210 I=35
220 FOR A=1TO11
230 AT(A)=I+5
240 I=I+5
250 FOR B=1TO5
260 READ CS(A,B)
270 NEXT B:NEXT A
280 FOR C=1TO5
290 READ BA(C):NEXT C
300 DATA 1480,1330,950,700,1350
310 DATA 1490,1320,950,710,1450
320 DATA 1480,1300,950,730,1500
330 DATA 1450,1270,940,750,1580
340 DATA 1420,1210,930,750,1600
350 DATA 1380,1080,920,750,1600
360 DATA 1300,1050,900,750,1600
370 DATA 1250,1020,900,750,1600
380 DATA 1200,990,900,750,1600
390 DATA 1150,960,900,750,1600
400 DATA 1100,930,900,750,1600
410 DATA 0,45,70,90,100
420 '
430 '
440 '  READS IN CLEAR WINTER SKY ILLUMINATIONS.
450 '  AW(A) IS THE SOLAR ANGLE INDEX; CW(A,B) IS ILLUM.
ARRAY
460 '
470 Y=0
480 FOR A=1TO11
490 AW(A)=Y
500 Y=Y+5
510 FOR B=1TO5
520 READ CW(A,B)
530 NEXT B:NEXT A
540 DATA 0,0,0,0,0
550 DATA 600,400,200,150,280
560 DATA 830,670,380,250,440
```

```
570 DATA 970,800,490,330,580
580 DATA 1040,880,570,390,670
590 DATA 1100,910,620,430,770
600 DATA 1120,940,660,470,850
610 DATA 1130,950,680,500,920
620 DATA 1130,940,690,520,980
630 DATA 1120,930,700,530,1030
640 DATA 1120,920,700,530,1050
650 '
660 '
670 '  READS IN CLEAR FALL/SPRING SKY ILLUMINATIONS.
680 '  AF(A) IS THE SOLAR ANGLE INDEX; CA(A,B) IS ILLUM.
ARRAY
690 '
700 V=10
710 FOR A=1TO14
720 AF(A)=V+5
730 FOR B=1TO5
740 READ CA(A,B)
750 NEXTB:NEXTA
760 DATA 1040,830,590.380,630
770 DATA 1140,960,670,460,760
780 DATA 1200,1040,740,510,880
790 DATA 1250,1090,780,560,1000
800 DATA 1280,1120,810,590,1100
810 DATA 1300,1130,830,610,1180
820 DATA 1300,1130,830,620,1250
830 DATA 1290,1110,820,610,1310
840 DATA 1270,1080,800,600,1360
850 DATA 1250,1050,780,590,1400
860 DATA 1230,1020,760,580,1440
870 DATA 1210,990,730,560,1470
880 DATA 1180,960,700,540,1500
890 DATA 1150,920,670,510,1500
900 '
910 '
920 '  READS IN ILLUMINATIONS FROM DIRECT SUNSHINE.
930 '  DA(A) IS THE SOLAR ANGLE INDEX; DS(A,B) IS ILLUM.
ARRAY
940 '
950 DIM DS(19,4),DA(19),OS(19,2),CU(4,3,3)
960 U=0
970 FOR A=1TO19
980 DA(A)=U
990 U=U+5
1000 FOR B=1TO4
1010 READ DS(A,B)
1020 NEXT B:NEXT A
1030 DATA 0,0,0,0
1040 DATA 1750,1250,300,175
1050 DATA 3000,2250,700,500
1060 DATA 4200,2900,1000,1000
```

```
1070 DATA 5000,3500,1250,750
1080 DATA 5500,3750,1400,2600
1090 DATA 5700,4000,1500,3500
1100 DATA 5800,4100,1600,4100
1110 DATA 5700,4100,1600,5000
1120 DATA 5500,3900,1500,5500
1130 DATA 5200,3600,1400,6000
1140 DATA 4700,3300,1250,6500
1150 DATA 4200,2900,1000,7000
1160 DATA 3500,2500,800,7500
1170 DATA 3000,2000,600,7750
1180 DATA 2300,1500,500,8250
1190 DATA 1500,1000,250,8400
1200 DATA 800,500,100,8600
1210 DATA 0,0,0,8800
1220 '
1230 '
1240 ' READS IN O'CAST ILLUMINATIONS
1250 '  INDEX SAME AS DIRECT ILLUM,NOT READ IN AGAIN;
OS(A,B) IS
1260 '  THE OVERCAST ILLUMINATION ARRAY
1270 FOR A=1TO19
1280 FOR B=1TO2
1290 READ OS(A,B)
1300 NEXT B:NEXTA
1310 DATA 0,0,50,180,150,350
1320 DATA 200,540,280,700,350,850
1330 DATA 400,1050,480,1200,550,1300
1340 DATA 650,1580,700,1750,800,1950
1350 DATA 900,2150,1000,2350,1100,2700
1360 DATA 1200,3200,1300,3300
1370 DATA 1400,3400,1500,3400
1380 '
1390 '  READS IN COEFFICIENTS OF UTILIZATION
1400 '  STORED IN ARRAY CU(A,B,C)
1410 FOR A=1TO4
1420 FOR B=1TO3
1430 FOR C=1TO3
1440 READ CU(A,B,C)
1450 NEXT C:NEXTB:NEXTA
1460 DATA .0276,.0159,.0087
1470 DATA .0191,.0101,.0063
1480 DATA .0143,.0081,.005
1490 DATA .125,.0908,.0908
1500 DATA .121,.107,.0951
1510 DATA .111,.111,.111
1520 DATA .0206,.0153,.0106
1530 DATA .0143,.01,.0079
1540 DATA .011,.0083,.0067
1550 DATA .145,.110,.105
1560 DATA .129,.116,.112
1570 DATA .111,.111,.111
```

```
1580 '
1590 '
1600 '  SAVE DATA TO FILES-
1610 '
1620 OPEN "O",#1,"WINTER/DAT"
1630 FOR A=1TO11
1640 PRINT#1,AW(A)
1650 FOR B=1TO5:WRITE#1,CW(A,B):NEXT B
1660 NEXT A
1670 FOR C=1TO5:WRITE#1,BA(C):NEXT C
1680 FOR A=1TO19
1690 PRINT#1,DA(A)
1700 FOR B=1TO4:WRITE#1,DS(A,B):NEXT B
1710 NEXT A
1720 CLOSE #1
1730 '
1740 OPEN"O",#1,"FALLSPR/DAT"
1750 FOR A=1TO14
1760 WRITE#1,AF(A)
1770 FOR B=1TO5:WRITE#1,CA(A,B):NEXT B
1780 NEXT A
1790 CLOSE#1
1800 '
1810 OPEN"O",#1,"SUMMER/DAT"
1820 FOR A=1TO11
1830 WRITE#1,AT(A)
1840 FOR B=1TO5:WRITE#1,CS(A,B):NEXT B
1850 NEXT A
1860 FOR C=1TO5:WRITE#1,BA(C):NEXT C
1870 FOR A=1TO19
1880 WRITE#1,DA(A)
1890 FOR B=1TO4:WRITE#1,DS(A,B):NEXT B
1900 NEXT A
1910 CLOSE#1
1920 '
1930 OPEN"O",#1,"OCAST/DAT"
1940 FOR A=1TO19
1950 WRITE#1,DA(A)
1960 FOR B=1TO2:WRITE#1,OS(A,B):NEXT B
1970 NEXT A
1980 CLOSE#1
1990 '
2000 OPEN"O",#1,"CUTBLS/DAT"
2010 FOR A=1TO4:FOR B=1TO3
2020 FOR C=1TO3:WRITE#1,CU(A,B,C):NEXT C
2030 NEXT B:NEXT A
2040 CLOSE#1
```

```
100 'PROGRAM:PART3- SUMMER AND CLDY SKIES
110 ' THIS PROGRAM CALCULATES THE AVAILABLE ILLUMINATION
USING
120 ' THE STORED ANGLES FROM PART1 AND THE STORED TABLES
FROM
130 ' PART2. STORES RESULTS FOR CLEAR SUMMER AND O'CAST
SKIES.
140 '
150 DIM AA(7,7),AZ(7,7)
160 DIM
TL(7,2,7,2),AT(11),CS(11,5),BA(5),DA(19),DS(19,4),OS(19,2)
170 '
180 OPEN"I",#1,"ANGLES/DAT"
190 FOR A=1TO7:FOR B=1TO7
200 INPUT#1,AA(A,B)
210 NEXT B:NEXT A
220 FOR A=1TO7:FOR B=1TO7
230 INPUT#1,AZ(A,B)
240 NEXT B:NEXT A
250 CLOSE#1
260 '
270 '
280 ' INPUT AVAIL. LIGHT FILES FOR SUMMER AND O'CAST SKIES
290 '
300 OPEN"I",#1,"SUMMER/DAT"
310 FOR A=1TO11
320 INPUT#1,AT(A)
330 FOR B=1TO5:INPUT#1,CS(A,B):NEXT B
340 NEXT A
350 FOR C=1TO5:INPUT#1,BA(C):NEXT C
360 FOR A=1TO19
370 INPUT#1,DA(A)
380 FOR B=1TO4:INPUT#1,DS(A,B):NEXT B
390 NEXT A
400 CLOSE#1
410 '
420 '
430 OPEN"I",#1,"OCAST/DAT"
440 FOR A=1TO19
450 INPUT#1,DA(A)
460 FOR B=1TO2
470 INPUT#1,OS(A,B):NEXT B
480 NEXT A
490 CLOSE#1
500 '
510 '
520 ' FIND AND SAVE AVAILABLE LIGHT, CLEAR SUMMER SKY
530 FOR M=6TO7
540 FOR H=1TO7
550 FOR B=1 TO 11
560 IF AA(M,H)=AT(B)THEN K=B
```

```
570 NEXT B
580 FOR C=1TO4
590 IF AZ(M,H)>BA(C)AND AZ(M,H)<BA(C+1)THEN 610
600 GOTO640
610 E1=(AZ(M,H)-BA(C+1))*(CS(K,C)-CS(K,C+1))
620 E1=E1/(BA(C)-BA(C+1))+CS(K,C+1)
630 E2=CS(K,5)
640 NEXT C
650 '
660 FOR A=1TO19:E3=0
670 IF AA(M,H)<>DA(A)THEN 700
680 E4=DS(A,4)
690 Q=A
700 NEXT A
710 IF AZ(M,H)>75 THEN 780
720 IF AZ(M,H)<=75 AND AZ(M,H)>45 THEN 760
730 E3=(AZ(M,H)-45)*(DS(Q,1)-DS(Q,2))
740 E3=E3/-45 +DS(Q,2)
750 GOTO 780
760 E3=(AZ(M,H)-75)*(DS(Q,2)-DS(Q,3))
770 E3=E3/-30+DS(Q,3)
780 '
790 '
800 TL(M,1,H,1)=E1+E3
810 TL(M,1,H,2)=E2+E4
820 NEXT H
830 NEXT M
840 '
850 '
860 OPEN"O",#1,"TLSMR/DAT"
870 FOR M=6TO7:FOR H=1TO7
880 FOR W=1TO2:WRITE#1,TL(M,1,H,W):NEXT W
890 NEXT H:NEXT M
900 CLOSE#1
910 '
920 '
930 ' FIND AND SAVE AVAILABLE LIGHT, O'CAST SKY
940 '
950 FOR M=1TO7
960 FOR H=1TO7
970 K=0
980 FOR B=1TO19
990 IF AA(M,H)=DA(B)THEN K=B
1000 NEXT B
1010 TL(M,2,H,1)=OS(K,1)
1020 TL(M,2,H,2)=OS(K,2)
1030 NEXT H
1040 NEXT M
1050 '
1060 '
1070 OPEN"O",#1,"TLCLD/DAT"
1080 FOR M=1TO7
```

```
1090 FOR H=1TO7
1100 FOR W=1TO2
1110 WRITE#1,TL(M,2,H,W)
1120 NEXT W
1130 NEXT H
1140 NEXT M
1150 CLOSE#1
```

```
100 'PROGRAM: PART4-WINTER AND SPRING/FALL
110 DIM TL(7,2,7,2)
120 DIM AF(14),CA(14,5)
130 DIM
AA(7,7),AZ(7,7),BA(5),DS(20,5),DA(19),AW(11),CW(11,5)
140 '
150 '
160 'READ FILES
170 '
180 OPEN"I",#1,"ANGLES/DAT"
190 FOR A=1TO7:FOR B=1TO7
200 INPUT#1,AA(A,B)
210 NEXT B:NEXT A
220 FOR A=1TO7:FOR B=1TO7
230 INPUT#1,AZ(A,B)
240 NEXT B:NEXT A
250 CLOSE#1
260 OPEN "I",#1,"WINTER/DAT"
270 FOR A=1TO11
280 INPUT#1,AW(A)
290 FOR B=1TO5:INPUT#1,CW(A,B):NEXT B
300 NEXT A
310 FOR C=1TO5:INPUT#1,BA(C):NEXT C
320 FOR A=1TO19
330 INPUT#1,DA(A)
340 FOR B=1TO4:INPUT#1,DS(A,B):NEXT B
350 NEXT A
360 CLOSE#1
370 OPEN"I",#1,"FALLSPR"
380 FOR A=1TO14
390 INPUT#1,AF(A)
400 FOR B=1TO5:INPUT#1,CA(A,B):NEXT B
410 NEXT A
420 CLOSE#1
430 '
440 '
450 'FIND ILLUMINATIONS-WINTER
460 '
470 FOR M=1TO2
480 FOR H=1TO7
490 FOR B=1TO11
500 IF AA(M,H)=AW(B)THEN K=B:NEXT B
510 FOR C=1TO4
520 IF AZ(M,H)>BA(C) AND AZ(M,H)<BA(C+1) THEN540
530 GOTO 570
540 E1=(AZ(M,H)-BA(C+1))*(CW(K,C)-CW(K,C+1))
550 E1=E1/(BA(C)-BA(C+1))+CW(K,C+1)
560 E2=CW(K,5)
570 NEXT C:NEXT B
```

```
580 '
590 FOR A=1TO19
600 IF AA(M,H)<>DA(A) THEN 670
610 E4=DS(A,4)
620 IF AZ(M,H)>75THEN670
630 IF AZ(M,H)<=75 AND AZ(M,H)>45THEN660
640 E3=(AZ(M,H)-45)*(DS(A,1)- DS(A,2))/(-45)+DS(A,2)
650 GOTO670
660 E3=(AZ(M,H)-75)*(DS(A,2)- DS(A,3))/(-30)+DS(A,3)
670 NEXT A
680 '
690 TL(M,1,H,1)=E1+E3
700 TL(M,1,H,2)=E2+E4
710 NEXT H
720 NEXT M
730 '
740 'SAVE TOTAL WINTER ILLUMS.
750 OPEN "O",#1,"TLWTR/DAT"
760 FOR M=1TO2:FOR H=1TO7
770 FOR W=1TO2:WRITE#1,TL(M,1,H,W):NEXT W
780 NEXT H:NEXT M
790 CLOSE#1
800 '
810 '
820 '
830 'FIND SPRING/FALL ILLUMS.-
840 '
850 FOR M=3TO5
860 FOR H=1TO7
870 FOR B=1TO14
880 IF AA(M,H)=AF(B)THEN K=B:NEXT B
890 FOR C=1TO4
900 IF AZ(M,H)>BA(C) AND AZ(M,H)<BA(C+1) THEN 950
910 GOTO950
920 E1=(AZ(M,H)-BA(C+1))*(CA(K,C)-CA(K,C+1))
930 E1=E1/(BA(C)-BA(C+1))+CA(K,C+1)
940 E2=CA(K,5)
950 NEXT C
960 '
970 FOR A=1 TO 19
980 IF AA(M,H)<>DA(A) THEN 1050
990 E4=DS(A,4)
1000 IF AZ(M,H)>75THEN1050
1010 IF AZ(M,H)<=75 AND AZ(M,H)>45THEN1040
1020 E3=(AZ(M,H)-45)*(DS(A,1)- DS(A,2))/(-45)+DS(A,2)
1030 GOTO1050
1040 E3=(AZ(M,H)-75)*(DS(A,2)- DS(A,3))/(-30)+DS(A,3)
1050 NEXT A
1060 '
1070 TL(M,1,H,1)=E1+E3
1080 TL(M,1,H,2)=E2+E4
1090 NEXT H:NEXT M
```

```
1100 '
1110 'SAVE SPRING/FALL ILLUMS.
1120 OPEN"O",#1,"TLSF/DAT"
1130 FOR M=3TO5:FOR H=1TO7
1140 FOR W=1TO2:WRITE#1,TL(M,1,H,W):NEXT W
1150 NEXT H:NEXT M
1160 CLOSE#1
```

```
100 '    THE QUANTIFICATION OF DAYLIGHTING
110 '
120 ' PROGRAM TO CALCULATE A TENTATIVE ARTIFICIAL LIGHT
SYSTEM;
130 ' CALCULATE THE AMOUNT OF INTERIOR ILLUMINATION
POSSIBLE BY
140 ' USING PASSIVE DAYLIGHTING TECHNIQUES; AND CALCULATE
THE
150 ' NUMBER OF HOURS DURING WHICH DAYLIGHT IS SUFFICIENT
TO TURN
160 ' OFF SOME OR ALL OF THE ELECTRIC LIGHTING.
170 '
180 '
190 '
200 ' ARTIFICIAL LIGHT ANALYSIS
210 '
220 ' ROOM DIMENSIONS-
230 PRINT"CHOOSE LENGTH OF ROOM: 20, 30, OR 40 FEET"
240 INPUT L
250 PRINT#-2,"LENGTH OF ROOM:",L
260 PRINT#-2
270 PRINT#-2,"WIDTH OF ROOM ASSUMED TO BE 20 FEET"
280 PRINT#-2
290 W=20
300 PRINT
310 PRINT"CHOOSE CEILING HEIGHT: 8, 10, OR 12 FEET"
320 INPUT "CEILING HEIGHT";H1
330 PRINT #-2,"CEILING HEIGHT=";H1
340 PRINT#-2
350 PRINT
360 PRINT
370 PRINT#-2,"FLOOR TO WORKPLANE HEIGHT ASSUMED TO BE 2.5
FEET"
380 PRINT#-2
390 H2=2.5
400 PRINT
410 PRINT
420 INPUT "FIXTURE TO CEILING HEIGHT";H3
430 PRINT#-2,"FIXTURE TO CEILING HEIGHT=";H3
440 '
450 '
460 ' OTHER ROOM CHARACTERISTICS-
470 '
480 H4=H1-H2-H3
490 R1=(5*H4*(L+W))/(L*W)
500 PRINT#-2,"ROOM CAVITY RATIO=";R1
510 C1=(5*H3*(L+W))/(L*W)
520 PRINT
530 PRINT
540 PRINT#-2,"CEILING CAVITY RATIO=";C1
```

```
550 F1=(5*H2*(L+W))/(L*W)
560 PRINT
570 PRINT
580 PRINT#-2,"FLOOR CAVITY RATIO=";F1
590 PRINT#-2
600 PRINT"FROM IES HANDBOOK, FIND THE FOLLOWING:"
610 INPUT"CU FOR ROOM SPECIFIED";U1
620 PRINT#-2,"COEFFICIENT OF UTILIZATION:";U1
630 '
640 '
650 ' LUMINAIRE CHARACTERISTICS-
660 '
670 INPUT"INPUT THE LLD X LDD OR MAINTENANCE FACTOR";M1
680 PRINT#-2,"MAINTENANCE FACTOR:";M1
690 INPUT"INPUT LAMPS PER LUMINAIRE";F2
700 PRINT#-2,"LAMPS PER LUMINAIRE:";F2
710 INPUT"HOW MANY LUMENS PER LAMP";B1
720 PRINT#-2,"LUMENS PER LAMP:";B1
730 INPUT"WATTS PER LAMP(INCL BALLAST)";WL
740 PRINT#-2,"WATTS PER LAMP:";WL
750 PRINT#-2
760 '
770 '
780 INPUT"WHAT IS DESIRED FOOTCANDLE LEVEL";F3
790 PRINT#-2,"DESIGN FOOTCANDLE LEVEL:",F3
800 PRINT#-2
810 F5=(F3*(L*W))/(U1*B1*M1*F2)
820 PRINT
830 PRINT
840 PRINT"NO. OF FIXTURES REQ'D TO PROVIDE"
850 PRINT"DESIRED FOOTCANDLE LEVEL FOR ROOM IS:";F5
860 PRINT
870 PRINT
880 INPUT"HOW MANY FIXTURES DO YOU INTEND TO USE";A1
890 A2=(A1/F5)*F3
900 PRINT
910 PRINT
920 PRINT"THE ACTUAL FOOTCANDLE LEVEL FOR YOUR NO. OF
FIXTURES IS ";A2
930 PRINT#-2,"THE ACTUAL FOOTCANDLE LEVEL FOR";A1;"FIXTURES
IS:";A2
940 PRINT
950 PRINT
960 INPUT"DO YOU WISH TO TRY ANOTHER CU (1=YES, 0=NO)";Z
970 IF Z=1 THEN 610
980 PRINT
990 INPUT"DO YOU WISH TO TRY ANOTHER ROOM";Z2
1000 IF Z2=1 THEN 240
1010 TC=WL*A1*F2*7*260
1020 '
1030 '
1040 '   DAYLIGHTING ANALYSIS
```

```
1050 '
1060 '
1070 DIM TL(7,2,7,2),CU(4,3,3),AG(3),SO(3,2),C(3),K(3)
1080 DIM D(3,3),E(3,3)
1090 '
1100 OPEN"I",#1,"CUTBLS/DAT"
1110 FOR A=1TO4:FOR B=1TO3
1120 FOR C=1TO3:INPUT#1,CU(A,B,C):NEXT C
1130 NEXT B:NEXT A
1140 CLOSE #1
1150 '
1160 OPEN"I",#1,"TLSMR/DAT"
1170 FOR M=6TO7:FOR H=1TO7
1180 FOR W=1TO2:INPUT#1,TL(M,1,H,W):NEXT W
1190 NEXT H:NEXT M
1200 CLOSE#1
1210 '
1220 OPEN"I",#1,"TLCLD/DAT"
1230 FOR M=1TO7
1240 FOR H=1TO7
1250 FOR W=1TO2
1260 INPUT#1,TL(M,2,H,W)
1270 NEXT W
1280 NEXT H
1290 NEXT M
1300 CLOSE#1
1310 '
1320 OPEN"I",#1,"TLWTR/DAT"
1330 FOR M=1TO2:FOR H=1TO7
1340 FOR W=1TO2:INPUT#1,TL(M,1,H,W):NEXT W
1350 NEXT H:NEXT M
1360 '
1370 CLOSE#1
1380 OPEN"I",#1,"TLSF/DAT"
1390 FOR M=3TO5:FOR H=1TO7
1400 FOR W=1TO2:INPUT#1,TL(M,1,H,W)
1410 NEXT H:NEXT M
1420 '
1430 CLOSE#1
1440 '
1450 ' GLASS AREAS-
1460 AG(1)=.15*L*H1
1470 AG(2)=.3*L*H1
1480 AG(3)=.6*L*H1
1490 '
1500 '  SITE CHARACTERISTICS-
1510 INPUT"GROUND REFLECTANCE RATIO";R
1520 INPUT"TRANSMITTANCE OF GLASS";T
1530 '
1540 PRINT #-2,"GROUND REFLECTANCE:";R
1550 PRINT #-2,"GLASS TRANSMITTANCE:";T
1560 '
```

```
1570 PRINT"DO YOU WISH TEST OUTPUT GIVING ALL LIGHT VALUES
? (1=YES,0=NO)"
1580 INPUT OP
1590 '
1600 L10=20:H10=8
1610 FOR A=1TO3
1620 IF L= L10 THEN X=A
1630 IF H1=H10 THEN Y=A
1640 L10=L10+10
1650 H10=H10+2
1660 NEXT A
1670 '
1680 IF OP<>1THEN 1710
1690 PRINT#-2," ","MAX","MID","MIN"
1700 '
1710 FOR M=1TO7
1720 IF OP<>1THEN 1740
1730 PRINT#-2,"MONTH:";M
1740 FOR H=1TO7
1750 IF OP<>1THEN 1780
1760 PRINT#-2
1770 PRINT#-2," HOUR:";H
1780 I1=TL(M,1,H,1)
1790 I2=TL(M,1,H,2)
1800 I3=I2*.5*R
1810 IF OP<>1THEN 1830
1820 ' FOR EACH INTERIOR LOCATION
1830 FOR A=1TO3
1840 '
1850 ' COEFFICIENTS OF UTILIZATION CHOSEN
1860 C(A)=CU(3,X,A)
1870 K(A)=CU(4,Y,A)
1880 IF OP<>1THEN 1900
1890 ' FOR EACH GLASS AREA
1900 FOR B=1TO3
1910 I5=I1*AG(B)*T*C(A)*K(A)
1920 I6=I3*AG(B)*T*C(A)*K(A)
1930 I7=I5+I6
1940 D(A,B)=I7
1950 IF OP<>1THEN 1960
1960 IF I7>=F3 THEN SO(B,1)=SO(B,1)+1
1970 IF M>1 AND M<7 AND I7>=F3 THEN SO(B,1)=SO(B,1)+1
1980 NEXT B:NEXT A
1990 IF OP<>1THEN 2080
2000 PRINT#-2
2010 FOR B=1TO3
2020 PRINT#-2," ",D(1,B),D(2,B),D(3,B)
2030 NEXT B
2040 PRINT #-2
2050 '
2060 ' CLOUDY SKIES
2070 '
```

```
2080 J1=TL(M,2,H,1)
2090 J2=TL(M,2,H,2)
2100 J3=J2*.5*R
2110 '
2120 IF OP<>1THEN 2130
2130 FOR A=1TO3
2140 C(A)=CU(1,X,A)
2150 K(A)=CU(2,Y,A)
2160 IF OP<>1THEN 2170
2170 FOR B=1TO3
2180 J5=J1*AG(B)*T*C(A)*K(A)
2190 J6=J3*AG(B)*T*C(A)*K(A)
2200 J7=J5+J6
2210 E(A,B)=J7
2220 IF OP<>1THEN 2230
2230 IF J7>=F3 THEN SO(B,2)=SO(B,2)+1
2240 IF M>1 AND M<7 AND J7>=F3 THEN SO(B,2)=SO(B,2)+1
2250 NEXT B:NEXT A
2260 IF OP<>1THEN 2300
2270 FOR B=1TO3
2280 PRINT#-2," ",E(1,B),E(2,B),E(3,B)
2290 NEXT B
2300 NEXT H:NEXT M
2310 '
2320 ' *OUTPUT*
2330 PRINT #-2:PRINT#-2
2340 WD=WL*F2*A1*1820/1000
2350 PRINT #-2,"ELECTRIC USE WITHOUT DAYLIGHTING:";WD;"KW-
HRS/YR"
2360 '
2370 ' FOR EACH GLASS AREA; FOR CLEAR AND CLOUDY SKIES
2380 PRINT#-2:PRINT#-2
2390 PRINT#-2,"THE FOLLOWING ARE LUMINAIRE ROW-HOURS WHEN
LIGHTS ARE OFF--"
2400 PRINT#-2,"GLASS AREA","HRS OFF(SUN)","HRS OFF(CLD)"
2410 PRINT#-2
2420 PRINT#-2," 15%",SO(1,1)*12,SO(1,2)*12
2430 PRINT#-2," 30%",SO(2,1)*12,SO(2,2)*12
2440 PRINT#-2," 60%",SO(3,1)*12,SO(3,2)*12
2450 PRINT#-2:PRINT#-2
2460 WB=WL*F2*A1/3:' WATTS PER BANK
2470 PRINT#-2,"GLASS AREA","KW-HRS OFF(SUN)","KW-HRS
OFF(CLD)"
2480 PRINT#-2
2490 PRINT#-2," 15%",SO(1,1)*WB*12/1000,SO(1,2)*WB*12/1000
2500 PRINT#-2," 30%",SO(2,1)*WB*12/1000,SO(2,2)*WB*12/1000
2510 PRINT#-2," 60%",SO(3,1)*WB*12/1000,SO(3,2)*WB*12/1000
2520 PRINT#-2:PRINT#-2
2530 '
2540 PRINT"ASSUME THREE POSSIBLE SKY CONDITIONS- CLEAR,
PARTLY CLOUDY, CLOUDY"
2550 INPUT"% CLEAR";S1
```

```
2560 INPUT"% CLOUDY";S3
2570 S2=100-S1-S3
2580 PRINT#-2,"CLEAR=";S1;"%, PTLY CLDY=";S2;"%,
CLDY=";S3;"%"
2590 Y=15
2600 FOR X=1TO3
2610 S4=(S1*18.20)*(S0(X,1)/1820)
2620 S5=(S3*18.20)*(SO(X,2)/1820)
2630 S6=(S2/2)*18.20*(SO(X,1)/1820)
2640 S7=(S2/2)*18.20*(SO(X,2)/1820)
2650 S8=S4+S5+S6+S7
2660 S9=S8*WB*12
2670 PRINT#-2
2680 PRINT#-2,"TOTAL EXPECTED KW-HRS SAVINGS:";S9/1000
2690 PRINT#-2,"FOR GLASS =";Y;"% OF WALL AREA"
2700 Y=Y*2
2710 PRINT#-2
2720 NEXT X
```

# APPENDIX C

## COMPLETE OUTPUT: EXAMPLE RUN

LATITUDE = 39

LATITUDE = 39

LENGTH OF ROOM: 20

WIDTH OF ROOM ASSUMED TO BE 20 FEET

CEILING HEIGHT= 8

FLOOR TO WORKPLANE HEIGHT ASSUMED TO BE 2.5 FEET

FIXTURE TO CEILING HEIGHT= 0
ROOM CAVITY RATIO= 2.75
CEILING CAVITY RATIO= 0
FLOOR CAVITY RATIO= 1.25

COEFFICIENT OF UTILIZATION: .64
MAINTENANCE FACTOR: .73
LAMPS PER LUMINAIRE: 2
LUMENS PER LAMP: 2300
WATTS PER LAMP: 32.4

DESIGN FOOTCANDLE LEVEL: 70

THE ACTUAL FOOTCANDLE LEVEL FOR 15 FIXTURES IS: 80.592
GROUND REFLECTANCE: .18
GLASS TRANSMITTANCE: .77

| | MAX | MID | MIN |
|---|---|---|---|
| MONTH: 1 | | | |
| HOUR: 1 | | | |
| | 166.498541 | 123.661538 | 85.6740067 |
| | 332.997083 | 247.323076 | 171.348013 |
| | 665.994165 | 494.646152 | 342.696027 |
| | 14.0745706 | 8.10817651 | 4.43654941 |
| | 28.1491411 | 16.216353 | 8.87309883 |
| | 56.2982822 | 32.4327061 | 17.7461977 |
| HOUR: 2 | | | |
| | 213.865113 | 158.841565 | 110.047097 |
| | 427.730226 | 317.683129 | 220.094194 |
| | 855.460453 | 635.366259 | 440.188388 |
| | 19.4190575 | 11.1870657 | 6.12122466 |
| | 38.8381151 | 22.3741315 | 12.2424493 |
| | 77.6762301 | 44.748263 | 24.4848986 |
| HOUR: 3 | | | |
| | 263.927171 | 196.023579 | 135.807185 |
| | 527.854343 | 392.047157 | 271.61437 |
| | 1055.70869 | 784.094315 | 543.228741 |
| | 24.1464374 | 13.9104476 | 7.61137701 |
| | 48.2928748 | 27.8208953 | 15.222754 |
| | 96.5857496 | 55.6417906 | 30.4455081 |
| HOUR: 4 | | | |
| | 300.861584 | 223.455449 | 154.812272 |
| | 601.723169 | 446.910897 | 309.624543 |
| | 1203.44634 | 893.821794 | 619.249086 |
| | 27.9962797 | 16.1282916 | 8.82491426 |
| | 55.9925595 | 32.2565832 | 17.6498285 |
| | 111.985119 | 64.5131663 | 35.2996571 |

HOUR: 5

| | | |
|---|---|---|
| 263.927171 | 196.023579 | 135.807185 |
| 527.854343 | 392.047157 | 271.61437 |
| 1055.70869 | 784.094315 | 543.228741 |
| 24.1464374 | 13.9104476 | 7.61137701 |
| 48.2928748 | 27.8208953 | 15.222754 |
| 96.5857496 | 55.6417906 | 30.4455081 |

HOUR: 6

| | | |
|---|---|---|
| 213.865113 | 158.841565 | 110.047097 |
| 427.730226 | 317.683129 | 220.094194 |
| 855.460453 | 635.366259 | 440.188388 |
| 19.4190575 | 11.1870657 | 6.12122466 |
| 38.8381151 | 22.3741315 | 12.2424493 |
| 77.6762301 | 44.748263 | 24.4848986 |

HOUR: 7

| | | |
|---|---|---|
| 166.498541 | 123.661538 | 85.6740067 |
| 332.997083 | 247.323076 | 171.348013 |
| 665.994165 | 494.646152 | 342.696027 |
| 14.0745706 | 8.10817651. | 4.43654941 |
| 28.1491411 | 16.216353 | 8.87309883 |
| 56.2982822 | 32.4327061 | 17.7461977 |

MONTH: 2

HOUR: 1

| | | |
|---|---|---|
| 192.042046 | 142.63317 | 98.817752 |
| 384.084093 | 285.266341 | 197.635504 |
| 768.168185 | 570.532682 | 395.271008 |
| 19.4190575 | 11.1870657 | 6.12122466 |
| 38.8381151 | 22.3741315 | 12.2424493 |
| 77.6762301 | 44.748263 | 24.4848986 |

HOUR: 2

| | | |
|---|---|---|
| 235.235097 | 174.713446 | 121.043303 |
| 470.470195 | 349.426892 | 242.086605 |
| 940.94039 | 698.853785 | 484.17321 |
| 24.1464374 | 13.9104476 | 7.61137701 |
| 48.2928748 | 27.8208953 | 15.222754 |
| 96.5857496 | 55.6417906 | 30.4455081 |

HOUR: 3

| | | |
|---|---|---|
| 276.485764 | 205.351077 | 142.269374 |
| 552.971528 | 410.702154 | 284.538747 |
| 1105.94306 | 821.404309 | 569.077495 |
| 27.9962797 | 16.1282916 | 8.82491426 |
| 55.9925595 | 32.2565832 | 17.6498285 |
| 111.985119 | 64.5131663 | 35.2996571 |

HOUR: 4

| | | |
|---|---|---|
| 302.027391 | 224.321314 | 155.412153 |
| 604.054781 | 448.642629 | 310.824305 |
| 1208.10956 | 897.285258 | 621.64861 |
| 27.9962797 | 16.1282916 | 8.82491426 |
| 55.9925595 | 32.2565832 | 17.6498285 |
| 111.985119 | 64.5131663 | 35.2996571 |

HOUR: 5

| | | |
|---|---|---|
| 276.485764 | 205.351077 | 142.269374 |
| 552.971528 | 410.702154 | 284.538747 |
| 1105.94306 | 821.404309 | 569.077495 |
| 27.9962797 | 16.1282916 | 8.82491426 |
| 55.9925595 | 32.2565832 | 17.6498285 |
| 111.985119 | 64.5131663 | 35.2996571 |

HOUR: 6

| | | |
|---|---|---|
| 235.235097 | 174.713446 | 121.043303 |
| 470.470195 | 349.426892 | 242.086605 |
| 940.94039 | 698.853785 | 484.17321 |
| 24.1464374 | 13.9104476 | 7.61137701 |
| 48.2928748 | 27.8208953 | 15.222754 |
| 96.5857496 | 55.6417906 | 30.4455081 |

HOUR: 7

| | | |
|---|---|---|
| 192.042046 | 142.63317 | 98.817752 |
| 384.084093 | 285.266341 | 197.635504 |
| 768.168185 | 570.532682 | 395.271008 |
| 19.4190575 | 11.1870657 | 6.12122466 |
| 38.8381151 | 22.3741315 | 12.2424493 |
| 77.6762301 | 44.748263 | 24.4848986 |

MONTH: 3

HOUR: 1

| | | |
|---|---|---|
| 178.419298 | 132.515304 | 91.8079881 |
| 356.838596 | 265.030607 | 183.615976 |
| 713.677191 | 530.061215 | 367.231953 |
| 24.1464374 | 13.9104476 | 7.61137701 |
| 48.2928748 | 27.8208953 | 15.222754 |
| 96.5857496 | 55.6417906 | 30.4455081 |

HOUR: 2

| | | |
|---|---|---|
| 138.178324 | 102.62759 | 71.1014674 |
| 276.356647 | 205.25518 | 142.202935 |
| 552.713294 | 410.510359 | 284.40587 |
| 33.2898129 | 19.177827 | 10.493528 |
| 66.5796258 | 38.355654 | 20.987056 |
| 133.159252 | 76.711308 | 41.9741119 |

HOUR: 3

| | | |
|---|---|---|
| 225.752298 | 167.670397 | 116.163804 |
| 451.504597 | 335.340793 | 232.327608 |
| 903.009194 | 670.681586 | 464.655216 |
| 37.7624238 | 21.7544398 | 11.9033727 |
| 75.5248476 | 43.5088796 | 23.8067454 |
| 151.049695 | 87.0177592 | 47.6134909 |

HOUR: 4

| | | |
|---|---|---|
| 201.562876 | 149.704466 | 103.71682 |
| 403.125751 | 299.408932 | 207.433639 |
| 806.251503 | 598.817863 | 414.867278 |
| 37.7624238 | 21.7544398 | 11.9033727 |
| 75.5248476 | 43.5088796 | 23.8067454 |
| 151.049695 | 87.0177592 | 47.6134909 |

HOUR: 5

| | | |
|---|---|---|
| 249.650623 | 185.420123 | 128.461 |
| 499.301245 | 370.840245 | 256.922 |
| 998.60249 | 741.68049 | 513.844 |
| 37.7624238 | 21.7544398 | 11.9033727 |
| 75.5248476 | 43.5088796 | 23.8067454 |
| 151.049695 | 87.0177592 | 47.6134909 |

HOUR: 6

| | | |
|---|---|---|
| 239.593607 | 177.950592 | 123.286031 |
| 479.187214 | 355.901183 | 246.572061 |
| 958.374428 | 711.802366 | 493.144123 |
| 33.2898129 | 19.177827 | 10.493528 |
| 66.5796258 | 38.355654 | 20.987056 |
| 133.159252 | 76.711308 | 41.9741119 |

HOUR: 7

| | | |
|---|---|---|
| 278.197147 | 206.622153 | 143.149988 |
| 556.394294 | 413.244306 | 286.299976 |
| 1112.78859 | 826.488611 | 572.599953 |
| 24.1464374 | 13.9104476 | 7.61137701 |
| 48.2928748 | 27.8208953 | 15.222754 |
| 96.5857496 | 55.6417906 | 30.4455081 |

MONTH: 4

HOUR: 1

| | | |
|---|---|---|
| 239.593607 | 177.950592 | 123.286031 |
| 479.187214 | 355.901183 | 246.572061 |
| 958.374428 | 711.802366 | 493.144123 |
| 33.2898129 | 19.177827 | 10.493528 |
| 66.5796258 | 38.355654 | 20.987056 |
| 133.159252 | 76.711308 | 41.9741119 |

HOUR: 2

| | | |
|---|---|---|
| 249.650623 | 185.420123 | 128.461 |
| 499.301245 | 370.840245 | 256.922 |
| 998.60249 | 741.68049 | 513.844 |
| 44.8506629 | 25.8378819 | 14.137709 |
| 89.7013258 | 51.6757637 | 28.2754179 |
| 179.402652 | 103.351527 | 56.5508358 |

HOUR: 3

| | | |
|---|---|---|
| 239.593607 | 177.950592 | 123.286031 |
| 479.187214 | 355.901183 | 246.572061 |
| 958.374428 | 711.802366 | 493.144123 |
| 48.5476438 | 27.9676644 | 15.3030616 |
| 97.0952876 | 55.9353287 | 30.6061233 |
| 194.190575 | 111.870657 | 61.2122466 |

HOUR: 4

| | | |
|---|---|---|
| 225.752298 | 167.670397 | 116.163804 |
| 451.504597 | 335.340793 | 232.327608 |
| 903.009194 | 670.681586 | 464.655216 |
| | | |
| 48.5476438 | 27.9676644 | 15.3030616 |
| 97.0952876 | 55.9353287 | 30.6061233 |
| 194.190575 | 111.870657 | 61.2122466 |

HOUR: 5

| | | |
|---|---|---|
| 201.562876 | 149.704466 | 103.71682 |
| 403.125751 | 299.408932 | 207.433639 |
| 806.251503 | 598.817863 | 414.867278 |
| | | |
| 48.5476438 | 27.9676644 | 15.3030616 |
| 97.0952876 | 55.9353287 | 30.6061233 |
| 194.190575 | 111.870657 | 61.2122466 |

HOUR: 6

| | | |
|---|---|---|
| 178.419298 | 132.515304 | 91.8079881 |
| 356.838596 | 265.030607 | 183.615976 |
| 713.677191 | 530.061215 | 367.231953 |
| | | |
| 44.8506629 | 25.8378819 | 14.137709 |
| 89.7013258 | 51.6757637 | 28.2754179 |
| 179.402652 | 103.351527 | 56.5508358 |

HOUR: 7

| | | |
|---|---|---|
| 138.178324 | 102.62759 | 71.1014674 |
| 276.356647 | 205.25518 | 142.202935 |
| 552.713294 | 410.510359 | 284.40587 |
| | | |
| 33.2898129 | 19.177827 | 10.493528 |
| 66.5796258 | 38.355654 | 20.987056 |
| 133.159252 | 76.711308 | 41.9741119 |

MONTH: 5

HOUR: 1

| | | |
|---|---|---|
| 166.569908 | 123.714543 | 85.7107292 |
| 333.139816 | 247.429086 | 171.421458 |
| 666.279631 | 494.858173 | 342.842917 |
| | | |
| 37.7624238 | 21.7544398 | 11.9033727 |
| 75.5248476 | 43.5088796 | 23.8067454 |
| 151.049695 | 87.0177592 | 47.6134909 |

HOUR: 2

| | | |
|---|---|---|
| 201.562876 | 149.704466 | 103.71682 |
| 403.125751 | 299.408932 | 207.433639 |
| 806.251503 | 598.817863 | 414.867278 |
| | | |
| 55.2282525 | 31.8162759 | 17.4089057 |
| 110.456505 | 63.6325519 | 34.8178114 |
| 220.91301 | 127.265104 | 69.6356227 |

HOUR: 3

| | | |
|---|---|---|
| 205.891806 | 152.919642 | 105.944327 |
| 411.783612 | 305.839285 | 211.888655 |
| 823.567224 | 611.678569 | 423.777309 |
| | | |
| 61.9088612 | 35.6648874 | 19.5147497 |
| 123.817722 | 71.3297749 | 39.0294995 |
| 247.635445 | 142.65955 | 78.058999 |

HOUR: 4

| | | |
|---|---|---|
| 260.721791 | 193.642884 | 134.157815 |
| 521.443582 | 387.285767 | 268.315629 |
| 1042.88716 | 774.571534 | 536.631259 |
| | | |
| 68.58947 | 39.513499 | 21.6205938 |
| 137.17894 | 79.026998 | 43.2411876 |
| 274.35788 | 158.053996 | 86.4823751 |

HOUR: 5

| | | |
|---|---|---|
| 222.137032 | 164.985271 | 114.303521 |
| 444.274063 | 329.970542 | 228.607042 |
| 888.548127 | 659.941085 | 457.214085 |
| | | |
| 61.9088612 | 35.6648874 | 19.5147497 |
| 123.817722 | 71.3297749 | 39.0294995 |
| 247.635445 | 142.65955 | 78.058999 |

HOUR: 6

| | | |
|---|---|---|
| 281.849975 | 209.335176 | 145.029599 |
| 563.69995 | 418.670351 | 290.059197 |
| 1127.3999 | 837.340702 | 580.118395 |
| | | |
| 55.2282525 | 31.8162759 | 17.4089057 |
| 110.456505 | 63.6325519 | 34.8178114 |
| 220.91301 | 127.265104 | 69.6356227 |

HOUR: 7

| | | |
|---|---|---|
| 257.068963 | 190.929861 | 132.278204 |
| 514.137926 | 381.859721 | 264.556408 |
| 1028.27585 | 763.719443 | 529.112816 |

| | | |
|---|---|---|
| 37.7624238 | 21.7544398 | 11.9033727 |
| 75.5248476 | 43.5088796 | 23.8067454 |
| 151.049695 | 87.0177592 | 47.6134909 |

MONTH: 6

HOUR: 1

| | | |
|---|---|---|
| 63.025373 | 46.8101071 | 32.4305317 |
| 126.050746 | 93.6202142 | 64.8610634 |
| 252.101492 | 187.240428 | 129.722127 |

| | | |
|---|---|---|
| 44.8506629 | 25.8378819 | 14.137709 |
| 89.7013258 | 51.6757637 | 28.2754179 |
| 179.402652 | 103.351527 | 56.5508358 |

HOUR: 2

| | | |
|---|---|---|
| 152.051089 | 112.931149 | 78.2398808 |
| 304.102178 | 225.862298 | 156.479762 |
| 608.204357 | 451.724595 | 312.959523 |

| | | |
|---|---|---|
| 61.9088612 | 35.6648874 | 19.5147497 |
| 123.817722 | 71.3297749 | 39.0294995 |
| 247.635445 | 142.65955 | 78.058999 |

HOUR: 3

| | | |
|---|---|---|
| 172.363725 | 128.017718 | 88.692014 |
| 344.727451 | 256.035437 | 177.384028 |
| 689.454901 | 512.070873 | 354.768056 |

| | | |
|---|---|---|
| 76.0343856 | 43.8024178 | 23.9673607 |
| 152.068771 | 87.6048355 | 47.9347213 |
| 304.137542 | 175.209671 | 95.8694426 |

HOUR: 4

| | | |
|---|---|---|
| 208.281638 | 154.694615 | 107.174047 |
| 416.563276 | 309.38923 | 214.348094 |
| 833.126553 | 618.778459 | 428.696187 |

| | | |
|---|---|---|
| 76.0343856 | 43.8024178 | 23.9673607 |
| 152.068771 | 87.6048355 | 47.9347213 |
| 304.137542 | 175.209671 | 95.8694426 |

HOUR: 5

| | | |
|---|---|---|
| 172.363725 | 128.017718 | 88.692014 |
| 344.727451 | 256.035437 | 177.384028 |
| 689.454901 | 512.070873 | 354.768056 |
| 76.0343856 | 43.8024178 | 23.9673607 |
| 152.068771 | 87.6048355 | 47.9347213 |
| 304.137542 | 175.209671 | 95.8694426 |

HOUR: 6

| | | |
|---|---|---|
| 152.051089 | 112.931149 | 78.2398808 |
| 304.102178 | 225.862298 | 156.479762 |
| 608.204357 | 451.724595 | 312.959523 |
| 61.9088612 | 35.6648874 | 19.5147497 |
| 123.817722 | 71.3297749 | 39.0294995 |
| 247.635445 | 142.65955 | 78.058999 |

HOUR: 7

| | | |
|---|---|---|
| 63.025373 | 46.8101071 | 32.4305317 |
| 126.050746 | 93.6202142 | 64.8610634 |
| 252.101492 | 187.240428 | 129.722127 |
| 44.8506629 | 25.8378819 | 14.137709 |
| 89.7013258 | 51.6757637 | 28.2754179 |
| 179.402652 | 103.351527 | 56.5508358 |

MONTH: 7

HOUR: 1

| | | |
|---|---|---|
| 63.5535775 | 47.2024144 | 32.7023263 |
| 127.107155 | 94.4048289 | 65.4046526 |
| 254.21431 | 188.809658 | 130.809305 |
| 48.5476438 | 27.9676644 | 15.3030616 |
| 97.0952876 | 55.9353287 | 30.6061233 |
| 194.190575 | 111.870657 | 61.2122466 |

HOUR: 2

| | | |
|---|---|---|
| 136.303549 | 101.23516 | 70.1367777 |
| 272.607098 | 202.470321 | 140.273555 |
| 545.214197 | 404.940641 | 280.547111 |
| 61.9088612 | 35.6648874 | 19.5147497 |
| 123.817722 | 71.3297749 | 39.0294995 |
| 247.635445 | 142.65955 | 78.058999 |

HOUR: 3

| | | |
|---|---|---|
| 166.201338 | 123.4408 | 85.521077 |
| 332.402677 | 246.8816 | 171.042154 |
| 664.805353 | 493.763199 | 342.084308 |
| | | |
| 76.0343856 | 43.8024178 | 23.9673607 |
| 152.068771 | 87.6048355 | 47.9347213 |
| 304.137542 | 175.209671 | 95.8694426 |

HOUR: 4

| | | |
|---|---|---|
| 179.37124 | 133.222329 | 92.2978225 |
| 358.74248 | 266.444658 | 184.595645 |
| 717.48496 | 532.889315 | 369.19129 |
| | | |
| 84.2436081 | 48.5316438 | 26.5550504 |
| 168.487216 | 97.0632876 | 53.1101008 |
| 336.974433 | 194.126575 | 106.220202 |

HOUR: 5

| | | |
|---|---|---|
| 166.201338 | 123.4408 | 85.521077 |
| 332.402677 | 246.8816 | 171.042154 |
| 664.805353 | 493.763199 | 342.084308 |
| | | |
| 76.0343856 | 43.8024178 | 23.9673607 |
| 152.068771 | 87.6048355 | 47.9347213 |
| 304.137542 | 175.209671 | 95.8694426 |

HOUR: 6

| | | |
|---|---|---|
| 136.303549 | 101.23516 | 70.1367777 |
| 272.607098 | 202.470321 | 140.273555 |
| 545.214197 | 404.940641 | 280.547111 |
| | | |
| 61.9088612 | 35.6648874 | 19.5147497 |
| 123.817722 | 71.3297749 | 39.0294995 |
| 247.635445 | 142.65955 | 78.058999 |

HOUR: 7

| | | |
|---|---|---|
| 63.5535775 | 47.2024144 | 32.7023263 |
| 127.107155 | 94.4048289 | 65.4046526 |
| 254.21431 | 188.809658 | 130.809305 |
| | | |
| 48.5476438 | 27.9676644 | 15.3030616 |
| 97.0952876 | 55.9353287 | 30.6061233 |
| 194.190575 | 111.870657 | 61.2122466 |

ELECTRIC USE WITHOUT DAYLIGHTING: 1769.04 KW-HRS/YR

THE FOLLOWING ARE LUMINAIRE ROW-HOURS WHEN LIGHTS ARE OFF--

| GLASS AREA | HRS OFF(SUN) | HRS OFF(CLD) |
|---|---|---|
| 15% | 2808 | 108 |
| 30% | 2952 | 864 |
| 60% | 3024 | 1944 |

| GLASS AREA | KW-HRS OFF(SUN) | KW-HRS OFF(CLD) |
|---|---|---|
| 15% | 909.792001 | 34.992 |
| 30% | 956.448 | 279.936 |
| 60% | 979.776001 | 629.856 |

CLEAR= 20 %, PTLY CLDY= 50 %, CLDY= 30 %

TOTAL EXPECTED KW-HRS SAVINGS: 246.6936
FOR GLASS = 15 % OF WALL AREA

TOTAL EXPECTED KW-HRS SAVINGS: 393.0768
FOR GLASS = 30 % OF WALL AREA

TOTAL EXPECTED KW-HRS SAVINGS: 591.364801
FOR GLASS = 60 % OF WALL AREA

## APPENDIX D

## OUTPUT: 30 AND 49 DEGREES NORTH LATITUDE

LATITUDE = 30

LENGTH OF ROOM: 30

WIDTH OF ROOM ASSUMED TO BE 20 FEET

CEILING HEIGHT= 10

FLOOR TO WORKPLANE HEIGHT ASSUMED TO BE 2.5 FEET

FIXTURE TO CEILING HEIGHT= 0
ROOM CAVITY RATIO= 3.125
CEILING CAVITY RATIO= 0
FLOOR CAVITY RATIO= 1.04166667

COEFFICIENT OF UTILIZATION: .55
MAINTENANCE FACTOR: .72
LAMPS PER LUMINAIRE: 2
LUMENS PER LAMP: 3200
WATTS PER LAMP: 40.7

DESIGN FOOTCANDLE LEVEL: 70

THE ACTUAL FOOTCANDLE LEVEL FOR 18 FIXTURES IS: 76.032
GROUND REFLECTANCE: .06
GLASS TRANSMITTANCE: .77

ELECTRIC USE WITHOUT DAYLIGHTING: 2666.664 KW-HRS/YR

THE FOLLOWING ARE LUMINAIRE RUN-HOURS WHEN LIGHTS ARE OFF--

| GLASS AREA | HRS OFF(SUN) | HRS OFF(CLD) |
|---|---|---|
| 15% | 2556 | 276 |
| 30% | 2880 | 1152 |
| 60% | 3024 | 2388 |

| GLASS AREA | KW-HRS OFF(SUN) | KW-HRS OFF(CLD) |
|---|---|---|
| 15% | 1248.3504 | 134.7984 |
| 30% | 1406.592 | 562.6368 |
| 60% | 1476.9216 | 1166.2992 |

CLEAR= 30 %, PTLY CLDY= 50 %, CLDY= 20 %

TOTAL EXPECTED KW-HRS SAVINGS: 372.74688
FOR GLASS = 15 % OF WALL AREA

TOTAL EXPECTED KW-HRS SAVINGS: 604.83456
FOR GLASS = 30 % OF WALL AREA

TOTAL EXPECTED KW-HRS SAVINGS: 894.065041
FOR GLASS = 60 % OF WALL AREA

LATITUDE = 49

LENGTH OF ROOM: 30

WIDTH OF ROOM ASSUMED TO BE 20 FEET

CEILING HEIGHT= 10

FLOOR TO WORKPLANE HEIGHT ASSUMED TO BE 2.5 FEET

FIXTURE TO CEILING HEIGHT= 0
ROOM CAVITY RATIO= 3.125
CEILING CAVITY RATIO= 0
FLOOR CAVITY RATIO= 1.04166667

COEFFICIENT OF UTILIZATION: .55
MAINTENANCE FACTOR: .72
LAMPS PER LUMINAIRE: 2
LUMENS PER LAMP: 3200
WATTS PER LAMP: 40.7

DESIGN FOOTCANDLE LEVEL: 70

THE ACTUAL FOOTCANDLE LEVEL FOR 18 FIXTURES IS: 76.032
GROUND REFLECTANCE: .3
GLASS TRANSMITTANCE: .77

ELECTRIC USE WITHOUT DAYLIGHTING: 2666.664 KW-HRS/YR

THE FOLLOWING ARE LUMINAIRE ROW-HOURS WHEN LIGHTS ARE OFF--

| GLASS AREA | HRS OFF(SUN) | HRS OFF(CLD) |
|---|---|---|
| 15% | 2832 | 252 |
| 30% | 3024 | 960 |
| 60% | 3024 | 2088 |

| GLASS AREA | KW-HRS OFF(SUN) | KW-HRS OFF(CLD) |
|---|---|---|
| 15% | 1383.1488 | 123.0768 |
| 30% | 1476.9216 | 468.864 |
| 60% | 1476.9216 | 1019.7792 |

CLEAR= 20 %, PTLY CLDY= 45 %, CLDY= 35 %

TOTAL EXPECTED KW-HRS SAVINGS: 381.97764
FOR GLASS = 15 % OF WALL AREA

TOTAL EXPECTED KW-HRS SAVINGS: 601.90416
FOR GLASS = 30 % OF WALL AREA

TOTAL EXPECTED KW-HRS SAVINGS: 918.6804
FOR GLASS = 60 % OF WALL AREA

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