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Lawrence Berkeley Laboratory
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APPLIED SCIENCE DIVISION

CONTROLITE 1.0:
PROGRAM DOCUMENTATION

Lighting Technologies

March 1984

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CONTROLITE 1.0: PROGRAM DOCUMENTATION*

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March 1984

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Table of Contents

Introduction 1

Purpose 2

List of Symbols and Variables 3

1.0 Power Input vs. Light Output Options 4
- 1.1 Discrete Stepped Control 4
- 1.2 Continuous Dimming - Linear Relationships . . . 4
- 1.3 Continuous Dimming - Non-Linear Relationship . . 4

2.0 Control Schemes 7

3.0 Daylighting Response 11
- 3.1 Daylighting Information for a Single Day 12
- 3.2 Daylighting Variations Over the Year 13

4.0 Maintenance Factors 15

5.0 Economic Analysis 16
- 5.1 Cost/KWH Blocks 16

6.0 Input/Output Capabilities 16
- 6.1 Order of Data Input File 17
- 6.2 Natural Illuminance Calculations File 20

7.0 Examples 23
- 7.1 Example 1 23
- 7.2 Example 2 31
- 7.3 Example 3 38
- 7.4 Example 4 49
- 7.5 Example 5 62

Appendix A: Running the Program on the IBM Personal Computer 80

Appendix B: References 81

Appendix C: Final Report of Completed Project 82

Introduction

In theory, a lighting control system which continuously monitors the available artificial and natural light within a space and supplies only the power required to provide light to meet some specified criteria illuminance level, and no more, should be able to optimize the energy savings capabilities of that lighting control system. Because of the potential for constantly varying power consumption due to this Equi-Illumination Dimming (EID) system, the computer is employed to help in modeling these types of systems.

This computer program, CONTROLITE, provides an unbiased mathematical model from which comparisons can be made, on an economic basis only, of how different systems perform. The program has the option of calculating daylighting values, or allowing the user to specify the daylighting values as input. Calculations can also be done on simple control systems which do not respond to daylighting.

For purposes of allowing for the calculating of daylighting values, program CONTROLITE is augmented with an accurate yet quick subprogram QUICKLITE. QUICKLITE employs what is known as the daylight factor method for calculation of daylighting values. The procedure which is used by QUICKLITE is well documented, and it is recommended that the user consult the references in Appendix B for this documentation.

The CONTROLITE program analyses control schemes exclusively on an economic basis, considering only the energy consumed directly by the lighting system. No attempt has been made to account for any additional savings realized in HVAC systems when lighting systems are controlled. The program makes no statement about the user acceptance of lighting control systems or about the aesthetic qualities of the use of daylighting within interior spaces.

The major components of the program are discussed in this documentation and several examples are included to explain how to run the program.

Appendix C contains a report of the scope of work performed to bring CONTROLITE to its present form.

Purpose

As the cost of energy continues to increase, sophisticated lighting control systems designed to minimize energy consumption are proving more cost effective. If a designer is to evaluate the performance of lighting control systems for their energy savings capabilities, an unbiased mathematical model which compares different control systems on an equal basis is an important tool. It is the purpose of this program to provide that unbiased model.

List of Symbols and Variables

Ec - A value in footcandles which is the criterion illuminance value to be maintianed over some specified time span. This level is to be maintained by the combined contribution of natural and artifical light.

En - A value in footcandles which is the amount of natural light available from daylighting contributions at any point in time. A continuous curve of this value is constructed from input or calculated data points for either three or seven days during the year.

EID - Equi-Illumination Dimming is the concept of lighting control systems for which this program was particularly developed. A sensing device monitors all available light within a space, and as En increases or decreases, the light output and, consequently, the power input of the artificial lighting system is altered to maintain a specified criterion illuminance value.

MF - Maintenance Factor. A number expressing the combined effect of all factors contributing to a decrease in total light output of an artificial lighting system over time. Year end values for a five year period are expected input.

1.0 Power Input vs. Light Output Options

Any one of three different power input vs. light output relationships can be used to express the characteristics of the lighting control system.

This data is usually expressed as a percentage, and to convert to actual power input and light output values, the total area of the controlled space, the maximum artificial footcandle level available and the watts per square foot loading to provide that footcandle level are required input. The three options available are : (1) discrete steps of power input and light output; (2) continuous dimming where power input vs. light output is a linear relationship; and (3) continuous dimming where power input vs. light output is a non-linear relationship.

1.1 Discrete Stepped Control

Up to 15 different ordered pairs ([%] power input, [%] light output) ranging from 0 to 100% can be input to describe this relationship. If Ec for a time block does not match an input step, the next higher value of power input and corresponding light output will be used. Ordered pairs should be input in increasing order.

1.2 Continuous Dimming - Linear Relationship

The maximum and minimum values of the power input range and the corresponding light output at those values must be known. All values should be expressed in percent.

1.3 Continuous Dimming - Non-Linear Relationship

Up to 15 ordered pairs ([%] power input, [%] light output) ranging from 0 to 100% can be used to build a curve which describes this relationship. The curve is formed by simple linear interpolation between input points. Ordered pairs should be input in increasing order.

Figure 1 shows a sample curve for each of these three options. The complete control system input which creates a curve representing the actual conditions is shown in Figure 2.

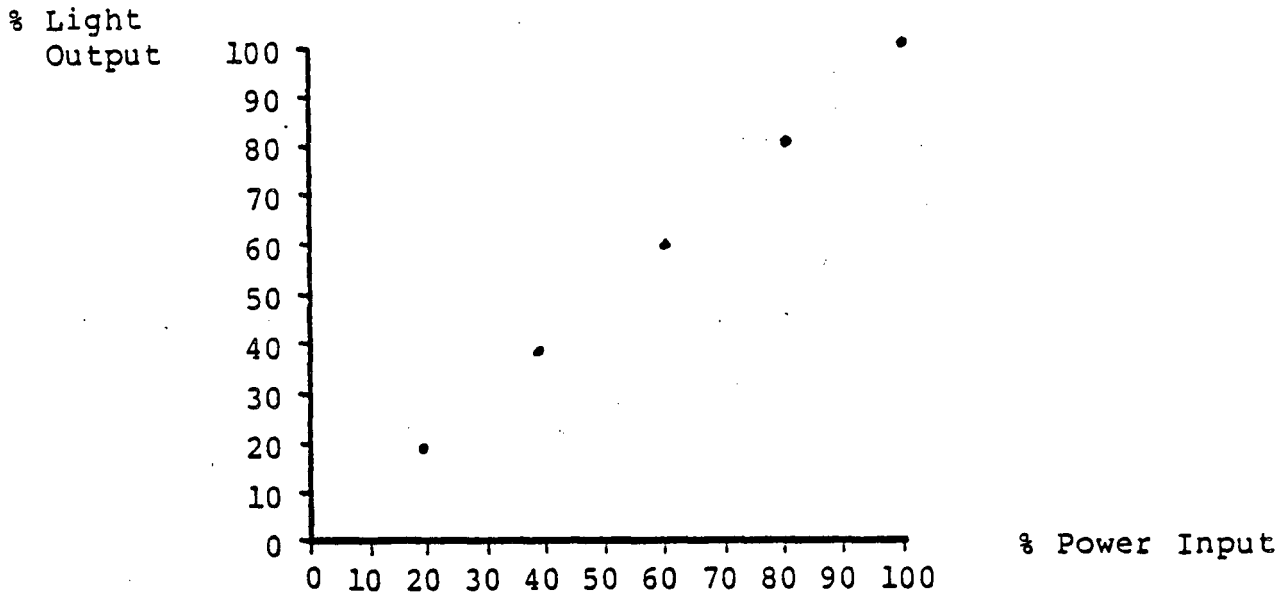


Fig. 1.a Discrete stepped relationship

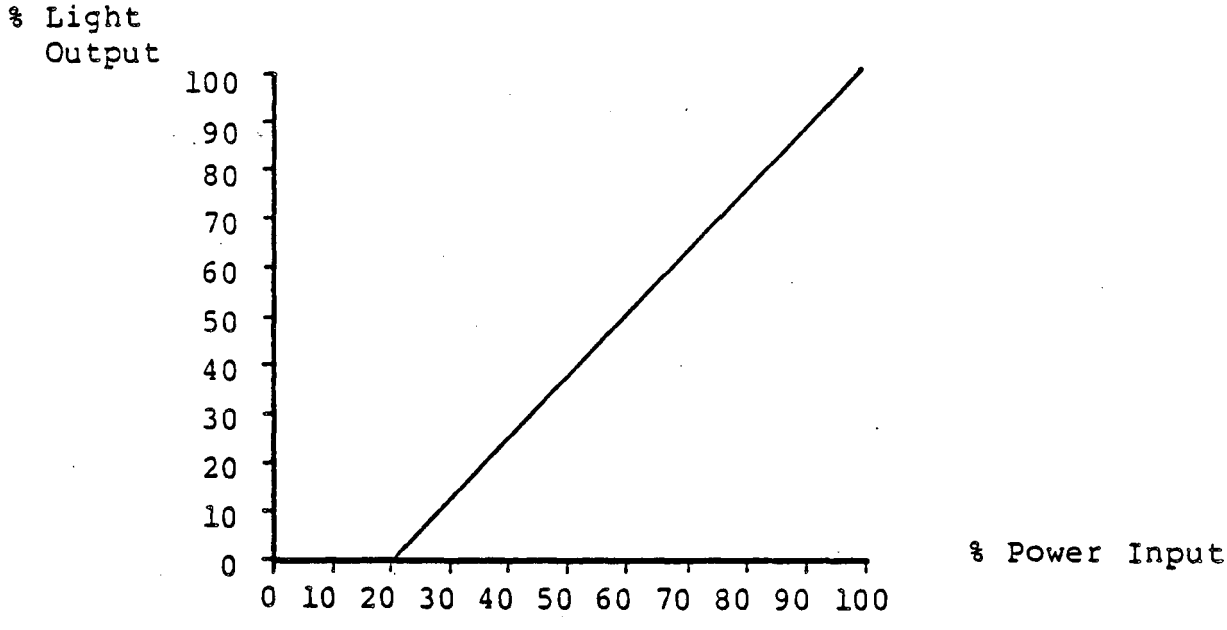


Fig. 1.b Continuous dimming, linear relationship

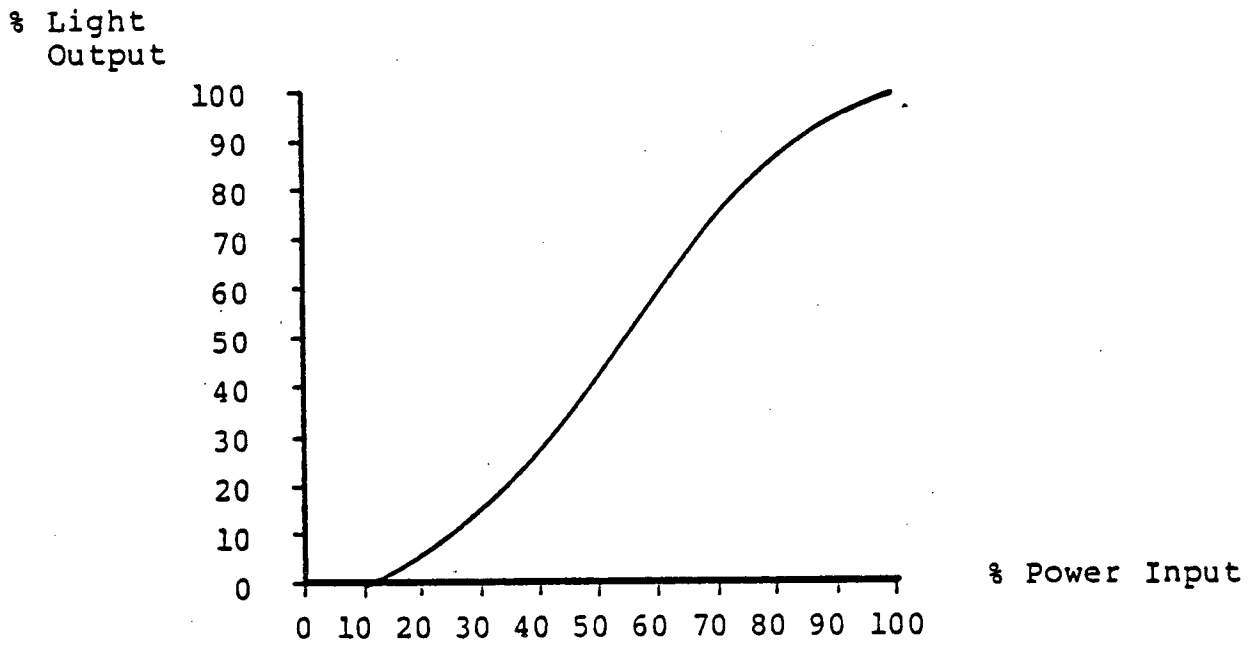


Fig. 1.c Continuous dimming, non-linear relationship

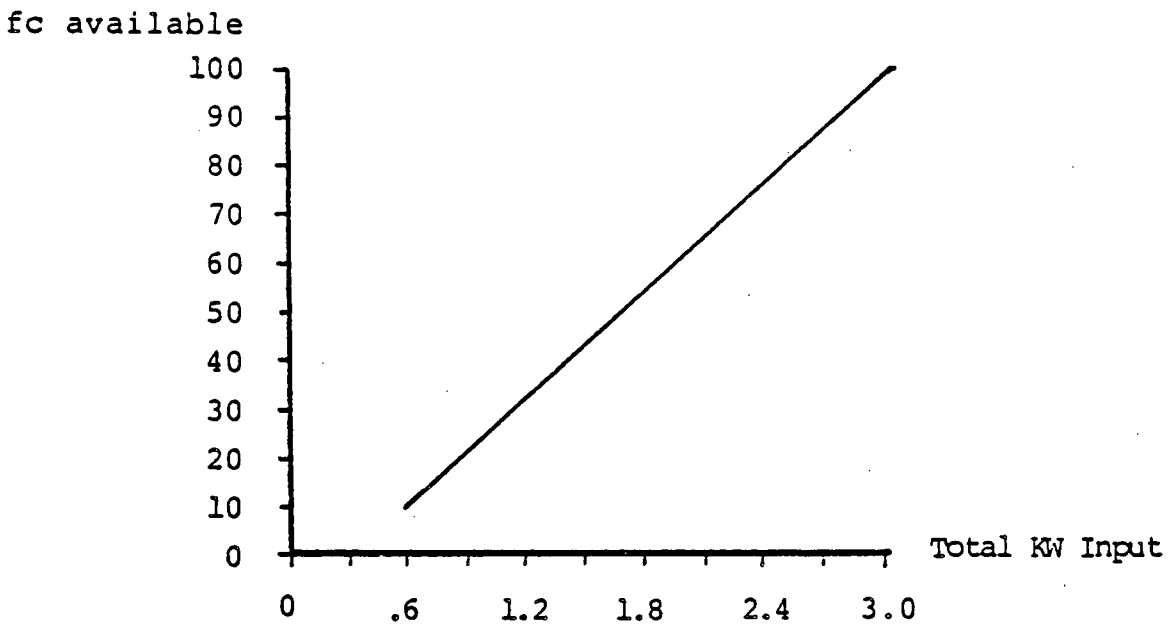


Fig. 2

Type of Control:	Continuous Dimming - Linear
Area in Square Feet:	1,000
Maximum Power Input:	100%
Minimum Power Input:	20%
Maximum Light Output:	100%
Minimum Light Output:	10%
Max. Artificial Footcandles:	100
Watts/Sq. Ft. at Maximum:	3.0

Caution: If an Ec value is specified which extends beyond the range that the control system is capable of providing, the program will not give accurate results.

2.0 Control Schemes

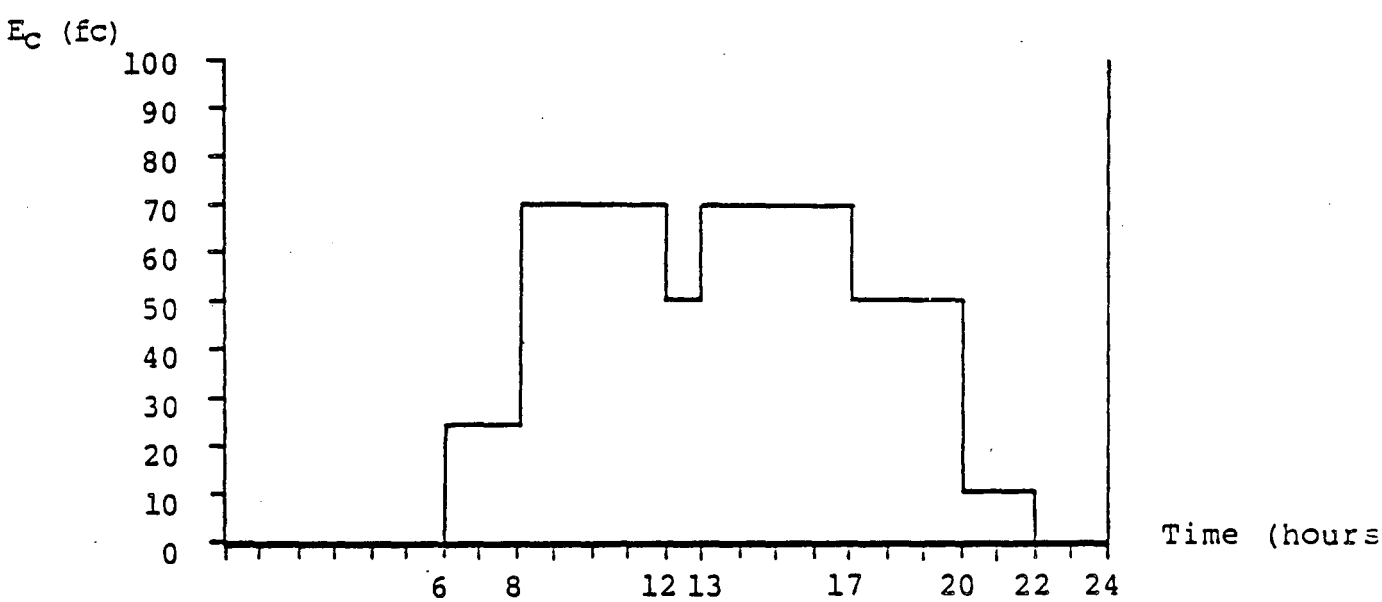


Fig. 3 Sample E_C histogram for a typical control day

The graph of Figure 3 could be thought of as an Ec histogram over the course of a typical day for a controlled lighting system. If there is no daylighting contribution into the space, the artificial lighting system alone will be controlled to provide the criteria illuminance levels specified for the time blocks shown. Compared against a baseline condition of full power input over the entire day, the resultant energy savings for the control scheme can be determined in a straightforward manner.

If the control system responds to daylighting in an equi-illumination dimming (EID) fashion, power consumption is a continuously varying quantity which is monitored over the hours of building operation.

Up to seven different daily control schemes can be described. It is assumed that the control scheme(s) input occur on a weekly basis throughout the entire year. The program is not set up to conveniently model an event such as having the system turned off for one week in December, for example, since yearly patterns are built up from day of the week control schemes which occur every week of the year.

A typical control system may occur five days of the week, with another pattern of control on weekends. This can be input conveniently by indicating the control scheme characteristics with a weighting factor for the number of days per week this particular scheme is in operation.

The baseline condition is the energy consumed over the hours of control system operation, from start to stop, with the system power input set to provide the maximum artificial illumination level for that entire time period.

Variations from the overall criterion illumination level can be input to respond to specific criterion levels for each control scheme. Start and stop times and the Ec for that time block or blocks are needed to describe this behavior. The relationship of this option is best shown by the following simple example:

> Assume that the building is in operation from 6:00 a.m. to 6:00 p.m., with an overall criterion illumination level of 70 footcandles. This condition is represented by Figure 4.

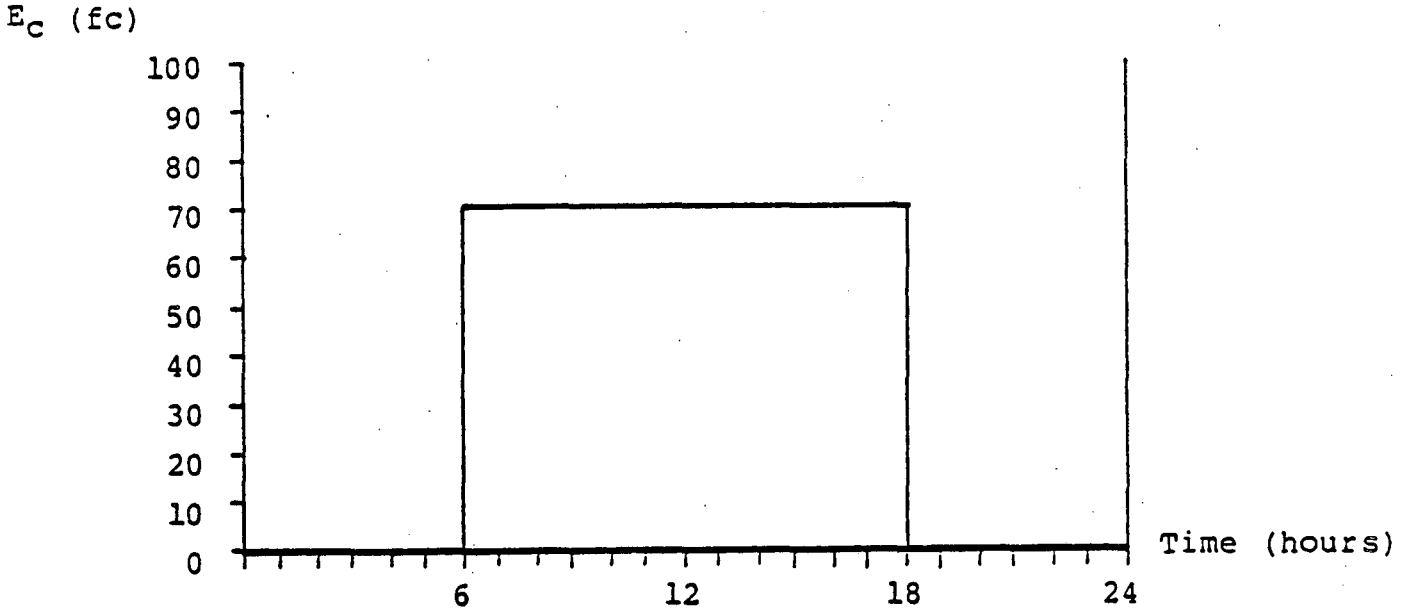


Fig. 4 General Overall Criterion of 70 fc from 6:00 a.m. to 6:00 p.m.

Task requirements are met by the overall criterion value in the morning, but the nature of the task requires an Ec of 90 footcandles from 1:00 p.m. to 5:00 p.m. This is shown in Figure 5.

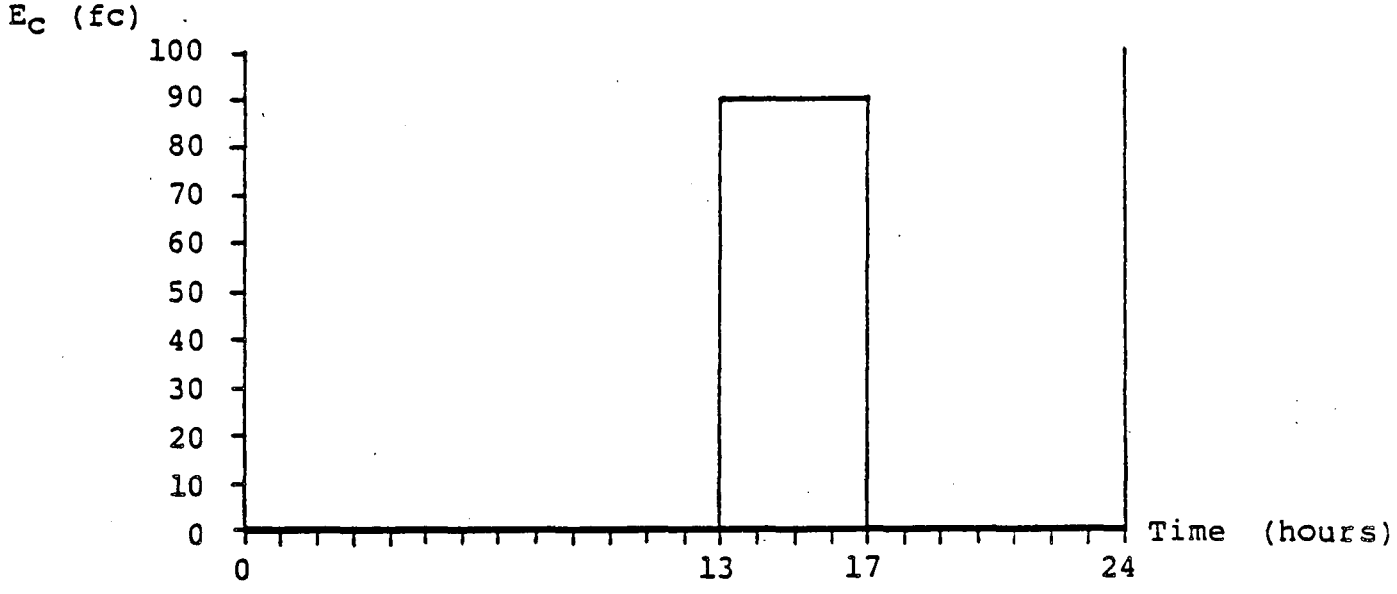


Fig. 5 E_c value of 90 footcandles from 1:00 p.m. until 5:00 p.m. to meet task requirements

Building occupancy patterns are such that from 6:00 a.m. to 7:30 a.m., 12:00 noon to 1:00 p.m., and from 5:30 p.m. to 6:00 p.m., a general light level of 35 footcandles is sufficient, as indicated by Figure 6.

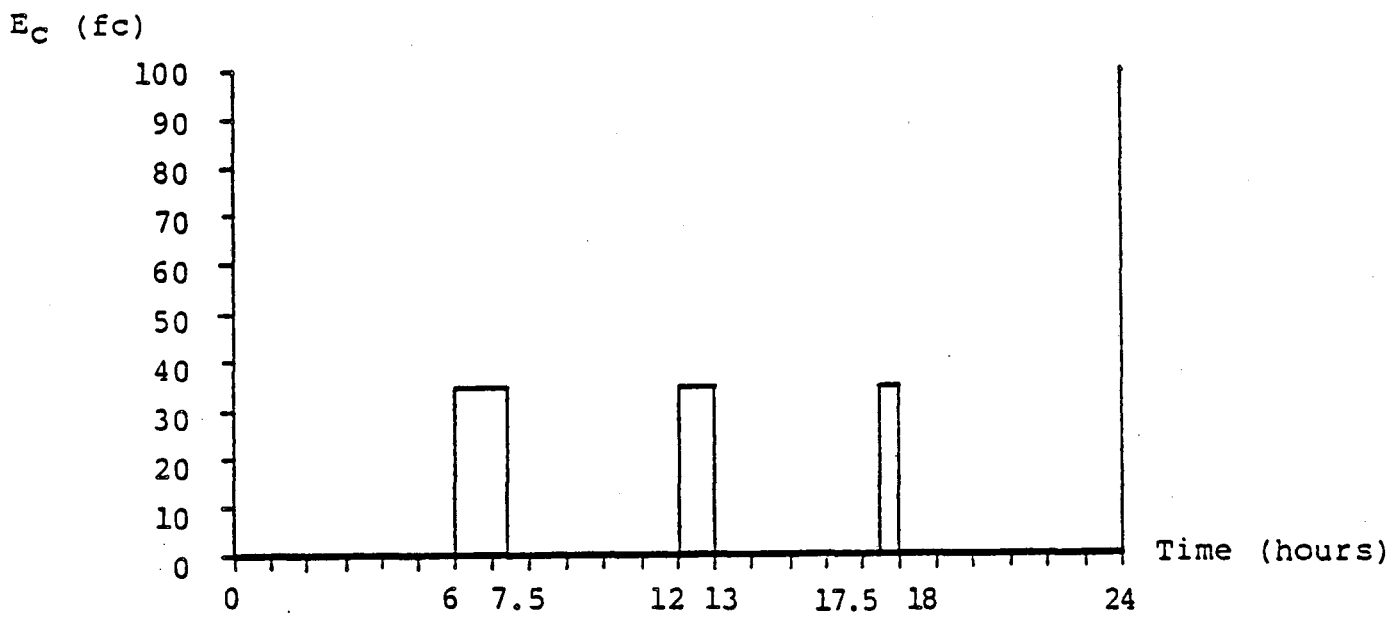


Fig. 6 E_c value of 35 footcandles at time blocks shown to meet building occupancy pattern

There are no other control criterion for this space. Figure 7 shows the combined effect of this information and the resultant Ec histogram for this particular control scheme.

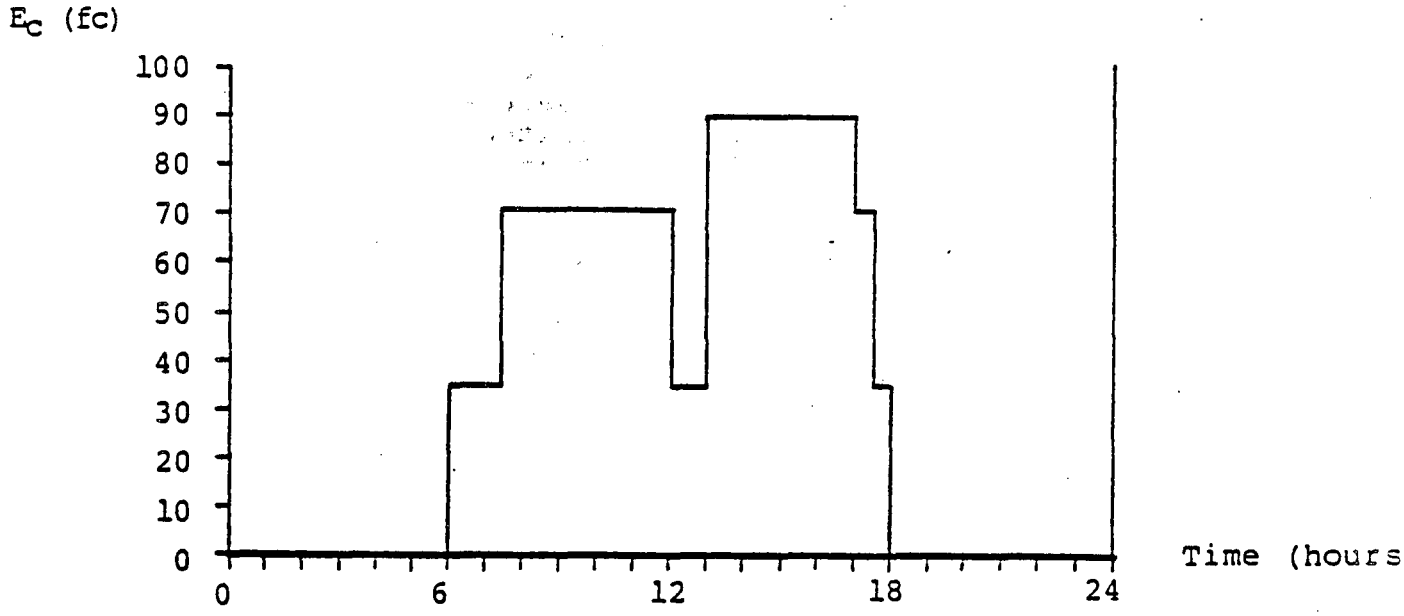


Fig. 7 Combined effect of overall E_C value with task and occupancy scheduling requirements

Notes: All start and stop time blocks are to be specified in decimal hours from 0.00 to 24.00.

Days per week control blocks in operation should sum correctly to the days per week building is used.

3.0 Daylighting Response

In some instances, a control system which monitors the available natural light, En, and alters the artificial light accordingly to maintain a specific Ec, proves to be the most cost effective control system. Such a system is often referred to as an Equi-Illumination Dimming system (EID). It is because of this type of system that this program was written, as the continuously varying light level available from daylighting does not lend itself to hand calculations. Non-daylighting systems which could be evaluated by hand can, of course, be handled easily by this program.

The mathematical model which formed the basis of this program is elaborated in a paper entitled "An Economic Analysis of Supplemental Skylighting for Industrial and Office Building", by S. Stannard, which appeared in the Journal of the Illuminating Engineering Society, July, 1979. The highlights of that model will be reviewed herein.

3.1 Daylighting Information for a Single Day

The curve expressing the available natural illuminance, En, at a lighting control sensor device over the course of a day is built by constructing a fourier series from several known values of En at specific times of the day. The longitude of the site and the number of time zones west of Greenwich are needed to determine the solar sunrise time for the location. Table 1 lists time zones west of Greenwich for location in the United States. Solar sunrise and solar sunset assume En = 0, and input values of En are required at equally spaced times between these values. If three input data points are sufficient to describe the behavior of daylighting throughout the day, then En values at solar mid-morning, solar noon and solar mid-afternoon must be known. The nature of the Fourier series used to fit data requires an odd number of input values. See Figure 8.

TABLE 1

Time	Time Zone
Eastern Standard Time	5
Central Standard Time	6
Mountain Standard Time	7
Pacific Standard Time	8
Hawaiian Standard Time	10
Eastern Daylight Time	4
Central Daylight Time	5
Mountain Daylight Time	6
Pacific Daylight Time	7

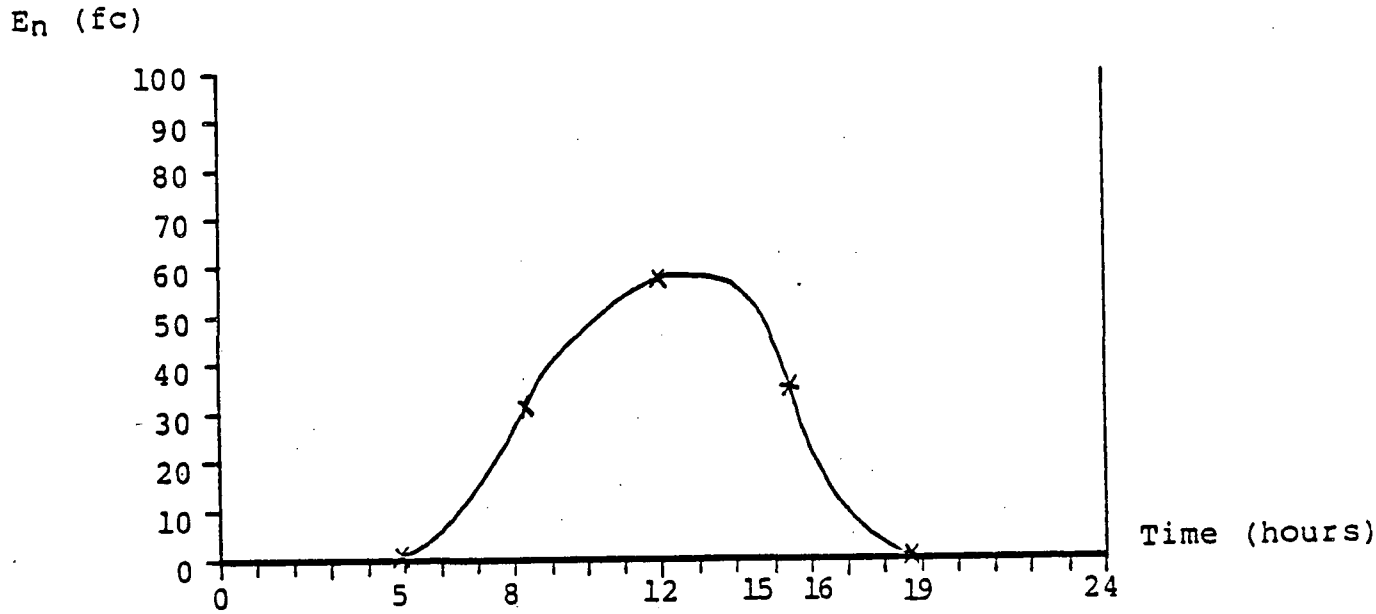


Fig. 8 Example of a curve of E_n built from 3 input points with solar sunrise and solar sunset defined to be zero

3.2 Daylighting Variations Over the Year

Fourier series curve fitting techniques are again used to model the yearly variations of the energy consumed by an EID system responding to daylighting. By inputting available En values over the course of a day, the total energy consumed by the system can be calculated for that day.

Daylighting data for various days throughout the year can be specified or calculated on a four or twelve day basis to build a curve of anticipated variations in total energy consumption throughout the year as that value is altered due to the system's responses to available daylight. The option of four and twelve day analysis is available to enable a more accurate model of the yearly daylighting conditions.

For purposes of calculating daylighting data the program QUICKLITE is appended to the main program. Program QUICKLITE enables a quick and convenient estimate of interior daylighting levels. The program so incorporated for this use generates average natural illuminances based on the measurement grid and input information specified in the natural illuminance calculation file. The user should be aware of the following limitations of QUICKLITE. The program does not:

1) Compute direct sun component.
2) Directly handle obstructions.
3) Account for sloping ground.
4) Account for light shelves.
5) Account for irregular shaped rooms.
6) Model skylights.

It is recommended that the user consult the References listed in Appendix B for more details on program QUICKLITE.

Daylighting data for the four day analysis consists of total energy information on March 21, June 21 and December 21. September 21 data is equal to March 21 data, thus four points are available.

Daylighting data for the twelve day analysis consists of total energy information on January 21, February 21, March 21, April 21, May 21, June 21,and December 21. July 21 data is equal to May 21 data, August 21 data is equal to April 21 data, September 21 data is equal to March 21 data, October 21 data is equal to February 21 date, and November 21 data is equal to January 21 data, thus twelve points are available.

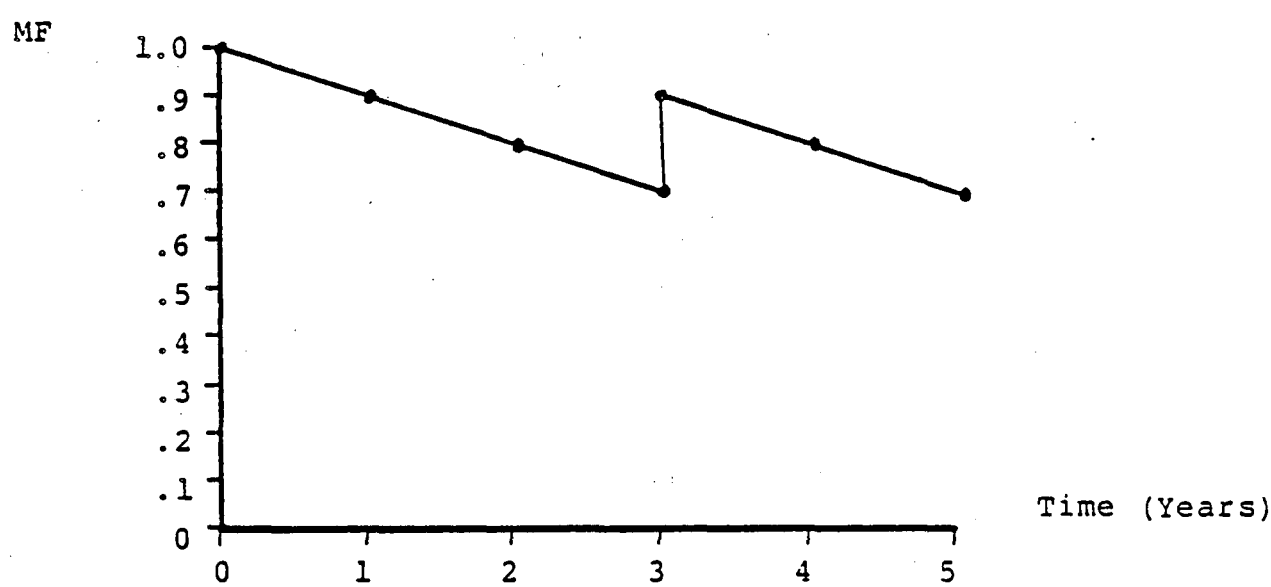
Daylighting calculation techniques for clear sky or cloudy sky conditions are well known, and both conditions can be accounted for in the program, if appropriate. An input parameter of % clear sky for each month of the year provides for a proper weighting factor of the energy savings resulting from clear or cloudy sky conditions.

The mathematical model discussed in Stannard's paper employed Fourier series integration techniques to determine the energy consumed throughout the day. That approach has been abandoned because of the complexity of it when discontinuities occur in the Ec histogram. A finite element approach has been used instead. Each time block with a specific Ec value is divided up into a large number of equal time increments. At the center of each time increment, the En curve is evaluated to get the available En at that time. Knowing the En available, and the Ec, the quantity of artificial light needed to maintain Ec is determined, and the resultant power to supply that light is calculated. Knowing the power needed and the length of the time increment, the energy required is then known. These values are added up along the time line from start to stop to get the total energy required for a given Ec histogram and corresponding daylight condition.

4.0 Maintenance Factors

To maintain a specified Ec value as the artificial lighting level available decreases over time due to lamp and luminaire depreciation, more light and, consequently, more power will be required. In order to account for the resulting energy and cost increases, year-end maintenance factors (MF) for a five year period can be input. Linear interpolation between year end values gives the appropriate maintenance factor to be applied thoughout the course of the year. If cleaning and/or relamping occur before the end of the five year period, adjusted maintenance factors can be input to reflect this. The beginning of the five year period is assumed to have a maintenance factor of 1.0.

Figure 9 indicates the maintenance factor curve over the five year period if the year end maintenance factors are as shown and intermediate maintenance at the end of the third year will bring the system back up to a MF = .90.



Year	MF at Year's End	
1	.9	
2	.8	
3	.7	(prior to intermediate maintenance)
4	.8	
5	.7	

Fig. 9 Five year maintenance factor curve for the year end values given.

Maintenance factors are required input in all analysis modes except for the stepped control, non-daylight response mode. Practical usage of that type of control is typically not designed to change the power input and light output to meet a specified Ec level as the system depreciates over time.

5.0 Economic Analysis

Before a control system can be said to be effective in saving energy, and ultimately dollars, it must be shown to be a good investment. There are numerous ways to analyze the economic performance of a particular system which requires a certain expenditure initially to save money in the future, and the well known techniques of Present Worth and Savings Investment Ratio are used here. These life cycle cost methods, and others, are discussed thoroughly in any of several books on engineering economy. The required input and the program output related to economic analysis can best be seen by referring to the examples at the end of the user's guide.

5.1 Cost/KWH Blocks

The operating cost of the lighting system, expressed in dollars/KWH, may vary over the course of a day. The realistic conditions of on-peak and off-peak energy costs can be input with up to four different cost blocks being specified. All subsequent economic analysis will account for these cost differences. The effect of rate structures can also be studied in their impact on the life cycle costs performance of one control scheme over another.

6.0 Input/Output Capabilities

This program can be used either in the interactive mode or by reading from a stored data file. When operating in either mode, the user may elect to have his/her responses stored into a data file for future use, or have the output printed directly at the terminal.

An example of how these options are chosen when running the program is shown below:

```
Is the input data in a data file?  (Y/N)
N
Do you want your response saved?  (Y/N)
Y
Enter filename (xxx_____.xxx):
IN.DAT
Do you wish output to go to a file?  (Y/N)
Y
Enter filename (xxx____.xxx):
OUT.DAT
```

If a file name is specified for input or output storage which does not exist, the program will create the file for the user. An empty file need not be created prior to running the program. If a filename is specified for an existing data input file which does not exist, an error message will occur and the program will abort.

6.1 Order of Data Input File

The list below indicates the required data needed to run the program. Data is listed in the order in which it must appear. For the sake of clarity, Table 2 lists each piece of data on a separate line, although data can be grouped in any convenient manner in the actual data input file. An asterisk at the beginning of a line indicates that the data must start on a new line. Data indented is optional and may or may not be required, depending on previous information.

TABLE 2

* Area affected by control scheme (Sq. Ft.)
* Stepped or continuous dimmer control

(if stepped control)

* No. of steps for power input vs. light output relationship (up to 15 pairs)
* Ordered pairs in increasing order of: ([%] power input, [%] light output)

(if continuous dimming)

* Linear or non-linear continuous dimming

(if linear continuous dimming)

* Maximum power input (%)
  Minimum power input (%)
* Light output (%) at maximum power
  Light output (%) at minimum power

(if non-linear continuous dimming)

* No. of ordered pairs of power input vs. light output (up to 15 pairs)
* Ordered pairs in increasing order of: ([%] power input, [%] light output)

* Maximum artificial illuminance (fc)
* Watts/Sq. Foot load at maximum artificial illuminance
* Control system response to daylighting (yes or no)

(if daylighting)

- * Longitude of site
- * Number of time zones West of Greenwich
- % Clear sky per month for:
  - * January, February, March
  - * April, May, June
  - * July, August, September
  - * October, November, December
- * Sky conditions - clear or cloudy
- * Optional four or twelve day analysis (4 or 12)
- * Odd number of input daylighting values
- * Optional input or calculated natural illuminances (yes or no)

(If 4 day analysis, the following input is included for December 21, March 21, and June 21; if 12 day analysis the following input is included for December 21, January 21, February 21, March 21, April 21, May 21 and June 21)

- * Decimal hour of civil sunrise, December 21

(if calculated natural illuminances)

- * Natural illuminance calculation filename (the contents and format of this file is discussed in Section 6.2) Note: Only input once (with calculation of first natural illuminance.)
- * Windows to be included in illuminance calculations for December 21. (1 activates window, 0 inactivates window - entry must be made on new line for each window for each time of day)
- * Change window list (1 to change, 0 to leave the same - enables user to branch back to window options in case of input error)

(if input natural illuminance)

- * Values of natural illuminance on December 21

* System maintained before end of 5-year cycle (yes or no)
  - * How many times (Note: cleaning must occur at year end)
  - * At the end of what year(s) will the system be maintained
* Maintenance factors at year end: yr 1, yr 2, yr 3, yr 4, yr 5
  - * Maintenance factor after indicated cleaning at end of year(s)

* Number of days per week system is utilized
* Number of different daily control schemes

* Decimal hours of control system operation: start, stop
* Overall criterion illumination level
* Number of days control scheme in operation
* Number of time blocks with specific Ec
* Time block start time
  Time block stop time
  Ec for block

* Overall cost per kilowatt hour (dollars)
* Number of time blocks with a different cost/kilowatt hour
* Start time of cost block
  Stop time of cost block
  Cost/KWH (dollars) for time block

* Cost to design control system (dollars/sq. ft.)
* Cost of control system equipment (dollars/sq. ft.)
* Cost to install control system (dollars/sq. ft.)
* Differential annual maintenance cost of control system (dollars/sq. ft.)
* Salvage value of control system
* Economic life of system
* Overall interest rate (%)

6.2 Natural Illuminance Calculation File

The following is an example of the input file necessary for the optional calculation of natural illuminance. The content and format of this file is identical to that which is used by program QUICKLITE so that stored files may be used for both CONTROLITE and QUICKLITE. The file is stored, or modified and reused under a different filename, in the format seen below. The file has comments sufficient to make it self-explanatory. It is important to acknowledge the column criterion as this is the mechanism in which the program seperates comment lines from actual input information.

Example of input file (used in examples 5 and 6):

```
*   THE FORMAT OF THE INPUT FILE IS
    ARRAY-VALUE, COMMENT, VALUE IN 1X,I3
    ,9A4,F13.6 FORMAT. COMMENTS MUST NOT
    BE LONGER THAN 36 COLUMNS LONG.  A
    BLANK INTERGER FIELD IS READ AS 0 AND
    CAN BE USED TO PREFACE COMMENTS.  TO
    USE THE INPUT FILE EDIT THE VALUES
    & STORE THE EDITED FILE UNDER A
    DIFFERENT NAME.

    TEST FILE

    ROOM PARAMETERS
    Y-AXIS RUNS NORTH-SOUTH
    X-AXIS RUNS EAST-WEST

  1     WIDTH  (ALONG X-AXIS)            20.0
  2     DEPTH  (ALONG Y-AXIS)            30.0
  3     HEIGHT                           8.67
  4     AZIMUTH (CLOCKWISE FROM NORTH)   0.0

    REFLECTANCES

  5     CEILING                          0.8
  6     FLOOR                            0.2
  7     WALLS                            0.5
  8     GROUND                           0.2

    MEASUREMENT GRID

  9     HEIGHT                           2.5
 10     Y-MIN                            5.0
 11     Y-MAX                            25.0
 12     NUMBER OF Y POINTS               3.0
 13     X-MIN                            5.0
 14     X-MAX                            15.0
 15     NUMBER OF X POINTS               3.0
```

SKY PARAMETERS

LATITUDE AND TIME
(USED TO CALCULATE DEFAULT SUN
ANGLES AND ILLUMINANCE)
THE MONTH,DATE,AND TIME ARE
IGNORED WHEN USED BY PROGRAM
CONTROLITE BECAUSE PARAMETERS
ARE SUPPLIED.

16	LATITUDE	40.0
17	MONTH (1-12)	2.0
18	DATE (1-31)	25.0
19	TIME (HOUR.MINUTES)	12.135

DEFAULT OVER-RIDE
USE 0< VALUE FOR DEFAULT SUN ALT.
0<= VALUE FOR DEFAULT ILLUMINANCES
THESE VALUES ARE TO BE SET TO
DEFAULT OVER-RIDE WHEN USED BY
PROGRAM CONTROLITE.

20	SUN ALTITUDE	-1.0
21	SUN AZIMUTH(CLOCKWISE FROM SOUTH)	0.0
22	SUN ILLUMINATION	-1.0
23	OVERCAST SKY ILLUMINATION	-1.0
24	CLEAR SKY ILLUMINATION	-1.0
25	UNIFORM SKY ILLUMINATION	-1.0

END OF ROOM & SKY DATA
IF DATA IS INCOMPLETE (ARRAY VALUES
16-19 OR 20-25 LEFT OUT) A -1 ARRAY
ENTRY MUST PRECEDE WINDOW FIELD.

BEGIN WINDOW DATA
UP TO 10 WINDOWS ARE ALLOWED. A -2
ARRAY INDEX TERMINATES FILE BEFORE
10 WINDOWS IF DESIRED.
WINDOW DISTANCES ARE MEASURED FROM
THE LOWER LEFT HAND CORNER OF THE
INTERIOR FACE ON EACH WALL.
SOUTH WINDOW (WALL #1)
WEST WINDOW (WALL #2)
NORTH WINDOW (WALL #3)
EAST WINDOW (WALL #4)

WINDOW 1

1	DISTANCE TO LEFT SIDE OF WINDOW	1.0
2	RIGHT SIDE OF WINDOW	29.0
3	BOTTOM OF WINDOW	2.0
4	TOP OF WINDOW	7.0
5	NORMAL TRANSMITTANCE	.78
6	REFLECTANCE	.14
7	WALL NUMBER	4.0

WINDOW 2

1	DISTANCE TO LEFT SIDE OF WINDOW	1.0
2	RIGHT SIDE OF WINDOW	15.0
3	BOTTOM OF WINDOW	2.0
4	TOP OF WINDOW	7.0
5	NORMAL TRANSMITTANCE	.78
6	REFLECTANCE	.14
7	WALL NUMBER	2.0

WINDOW 3

1	LEFT SIDE	15.0
2	RIGHT SIDE	29.0
3	BOTTOM	2.0
4	TOP	7.0
5	NORMAL TRANSMITTANCE	.78
6	REFLECTANCE	.14
7	WALL NUMBER	2.0

-2

7.0 Examples

7.1 Example 1

A single story, 12,000 square foot office building has a uniform lighting layout throughout the space producing an overall average of 75 footcandles at 2.4 watts/square foot. There are no individual switches for lights, and all lights are turned on at 7:00 a.m. when the first employee arrives and are left on until 11:00 p.m. after final mainteance work is done. The building will not be used on the weekends.

The power profile for a typical day is shown in Figure EX1.1.

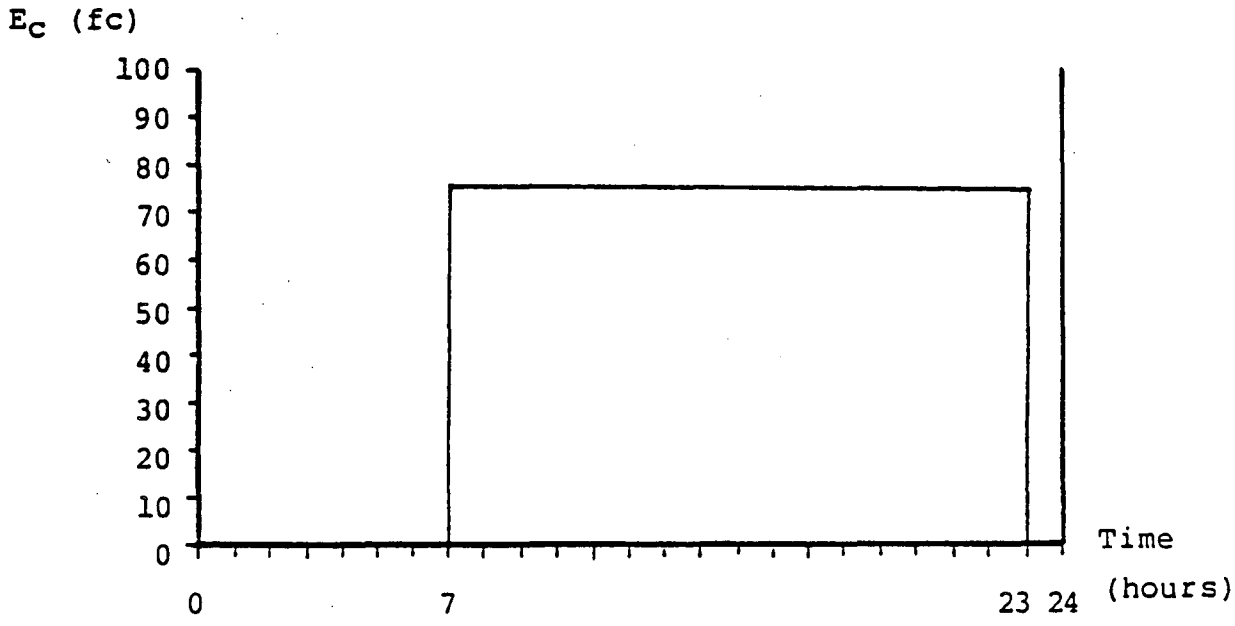


Figure EX1.1 Overall average of 75 footcandles with all lights turned on.

A control scheme utilizing three level switching, controlled by time clocks is proposed which would respond more realistically to building occupancy needs. Since the office tends to be open late on Fridays, two different power profiles are as shown in Figure EX1.2.

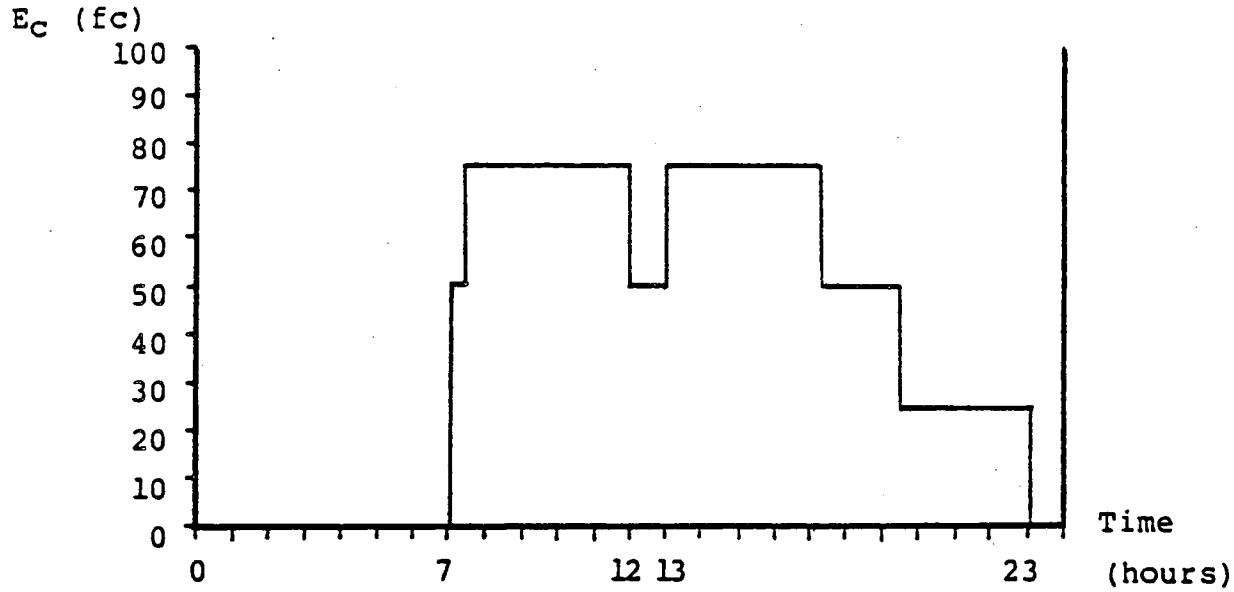


Figure EX1.2a E_c histogram for Monday thru Thursday schedule.

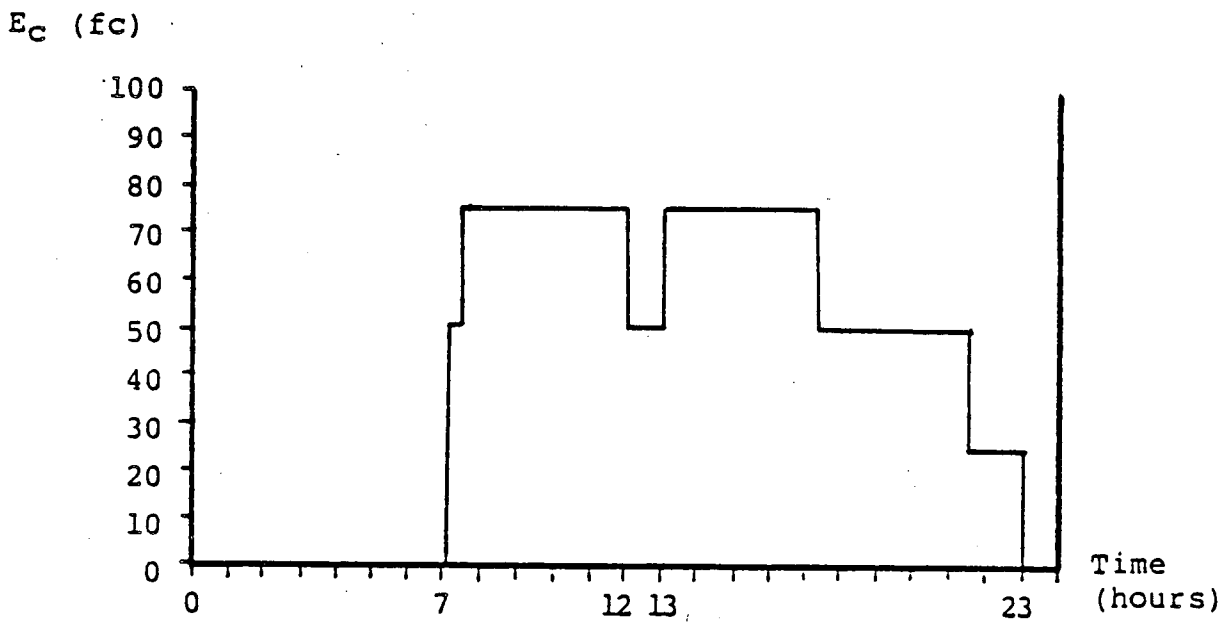


Figure EX1.2b E_c histogram for Friday occupancy schedule.

All luminaires are three lamp 2'x 4' recessed fluorescent troffers, and reductions in overall light levels will come from simply operating these units at one, two or three lamp output. Energy costs are at $.045/KWH, and control system equipment costs are for an installed system, thus no separate installed costs.

```
Is the input data in a data file?(Y/N)
N
Do you want your responses saved?(Y/N)
Y
Enter filename(xx------x.xxx):
EX1.IN
Do you wish output to go to a file?(Y/N)
Y
Enter filename(xx------x.xxx):
EX1.OUT


AREA AFFECTED BY CONTROL SCHEME (SQ. FT.)?
12000


WILL CONTROL SYSTEM UNDER CONSIDERATION BE
CONTINUOUS DIMMING OR STEPPED CONTROL?
STEPPED

NUMBER OF DISCRETE STEPS FOR WHICH POWER INPUT
VS. LIGHT OUTPUT RELATIONSHIP IS KNOWN?
3

INPUT  3 ORDERED PAIRS OF POWER INPUT AND
LIGHT OUTPUT? POWER(%), LIGHT(%)
100,100
67,67
34,34

MAXIMUM ARTIFICIAL ILLUMINANCE AVAILABLE (FC)?
75

MAXIMUM POWER AVAILABLE (WATTS/SQ.FT.)?
2.4

DOES CONTROL SYSTEM UNDER ANALYSIS RESPOND TO DAYLIGHTING?
NO


NUMBER OF DAYS PER WEEK BUILDING LIGHTING SYSTEM IS UTILIZED?
5

NUMBER OF DIFFERENT DAILY CONTROL SCHEMES USED?
2


                    FOR CONTROL SCHEME NUMBER 1


HOURS OF CONTROL SYSTEM OPERATION? START,STOP?
7,23

OVERALL CRITERION ILLUMINATION LEVEL?
75
```

```
NUMBER OF DAYS OF THE WEEK CONTROL SCHEME 1 IS IN OPERATION?
4

NUMBER OF TIME BLOCKS WITH A SPECIFIC CRITERION
ILLUMINATION LEVEL FOR CONTROL?
4

START TIME,STOP TIME AND CRITERION ILLUMINATION FOR EACH BLOCK?
7,7.5,50
12,13,50
17.5,19.5,50
19.5,23,25

OVERALL COST/KWH(DOLLARS)?
.045

NUMBER OF TIME BLOCKS WITH A DIFFERENT COST/KWH?
0
```

FOR CONTROL SCHEME NUMBER 2

```
HOURS OF CONTROL SYSTEM OPERATION? START,STOP?
7,23

OVERALL CRITERION ILLUMINATION LEVEL?
75

NUMBER OF DAYS OF THE WEEK CONTROL SCHEME 2 IS IN OPERATION?
1

NUMBER OF TIME BLOCKS WITH A SPECIFIC CRITERION
ILLUMINATION LEVEL FOR CONTROL?
4

START TIME,STOP TIME AND CRITERION ILLUMINATION FOR EACH BLOCK?
7,7.5,50
12,13,50
17.5,21.5,50
21.5,23,25

OVERALL COST/KWH(DOLLARS)?
.045

NUMBER OF TIME BLOCKS WITH A DIFFERENT COST/KWH?
0
```

```
CONTROL SYSTEM COST DATA?

COST TO DESIGN CONTROL SYSTEM(DOLLARS/SQ.FT.)?
.025

COST OF CONTROL SYSTEM EQUIPMENT(DOLLARS/SQ.FT.)?
.25

COST TO INSTALL CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

DIFFERENTIAL YEARLY MAINTENANCE COST OF CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

SALVAGE VALUE OF THE CONTROL SYSTEM
AT THE END OF ITS ECONOMIC LIFE(DOLLARS)?
0

ECONOMIC LIFE OF SYSTEM(YEARS)?
10

OVERALL INTEREST RATE(%)?
15
```

CONTROL SYSTEM CHARACTERISTICS

STEPPED CONTROL?

POWER(%)	LIGHT(%)
34.0	34.0
67.0	67.0
100.0	100.0

AREA AFFECTED BY CONTROLS? 12000.00 SQ. FEET

MAXIMUM ARTIFICIAL ILLUMINANCE? 75.0 FOOTCANDLES
MAXIMUM POWER INPUT? 2.4 WATTS/SQ.FT.

BUILDING IS IN OPERATION 5 DAYS PER WEEK

FOR CONTROL SCHEME 1

CONTROL SCHEME STARTS AT 7.00 AND STOPS AT 23.00
IN EFFECT 4 DAYS PER WEEK

NET EFFECTIVE CONTROL BLOCKS SPECIFIED

START	STOP	CRITERION FC VALUE	COST/KWH
7.00	7.50	50.0	.0450
7.50	12.00	75.0	.0450
12.00	13.00	50.0	.0450
13.00	17.50	75.0	.0450
17.50	19.50	50.0	.0450
19.50	23.00	25.0	.0450

FOR CONTROL SCHEME 2

CONTROL SCHEME STARTS AT 7.00 AND STOPS AT 23.00
IN EFFECT 1 DAYS PER WEEK

NET EFFECTIVE CONTROL BLOCKS SPECIFIED

START	STOP	CRITERION FC VALUE	COST/KWH
7.00	7.50	50.0	.0450
7.50	12.00	75.0	.0450
12.00	13.00	50.0	.0450
13.00	17.50	75.0	.0450
17.50	21.50	50.0	.0450
21.50	23.00	25.0	.0450

ENERGY AND COST PERFORMANCE COMPARISON

FIRST COSTS FOR CONTROL SYSTEM

DESIGN COSTS? 300.00
EQUIPMENT COSTS? 3000.00
INSTALLATION COSTS? .00

TOTAL DIFFERENTIAL MAINTENANCE COSTS/YEAR? .00

CONTROL SYSTEM SALVAGE VALUE AT END OF LIFE? .00

ECONOMIC LIFE OF SYSTEM? 10.00
OVERALL INTEREST RATE? 15.00

TOTAL KWH USED FOR THE YEAR = 95111.08
TOTAL KWH SAVED FOR THE YEAR = 25026.08
TOTAL COST FOR THE YEAR = 4280.00
TOTAL COST SAVED FOR THE YEAR= 1126.17

ANNUAL ENERGY COSTS

YEAR	BASE SYSTEM	CONTROLLED SYSTEM
1	5406.17	4280.00
2	5406.17	4280.00
3	5406.17	4280.00
4	5406.17	4280.00
5	5406.17	4280.00
6	5406.17	4280.00
7	5406.17	4280.00
8	5406.17	4280.00
9	5406.17	4280.00
10	5406.17	4280.00

TOTAL PRESENT WORTH(PW) COSTS AND
SAVINGS INVESTMENT RATIO (SIR) AT VARIOUS DIFFERENTIAL
ENERGY RATE INCREASES?

AT .0 % INCREASE/YEAR?

PW BASE?	27132.33
PW CONTROLLED?	24780.33
SIR	1.71

AT 3.0 % INCREASE/YEAR?

PW BASE?	30988.11
PW CONTROLLED?	27832.90
SIR	1.96

AT 6.0 % INCREASE/YEAR?

PW BASE?	35486.68
PW CONTROLLED?	31394.37
SIR	2.24

AT 9.0 % INCREASE/YEAR?

PW BASE?	40740.74
PW CONTROLLED?	35553.94
SIR	2.57

AT 12.0 % INCREASE/YEAR?

PW BASE?	46881.54
PW CONTROLLED?	40415.53
SIR	2.96

AT 15.0 % INCREASE/YEAR?

PW BASE?	54061.72
PW CONTROLLED?	46099.99
SIR	3.41

7.2 Example 2

A drafting area in a large commercial facility is to be a test installation for a new type of lighting control system. The system includes a retrofit fluorescent dimmer pack and a ceiling mounted photo cell. The purpose of the system is to maintain constant illumination in the space throughout its life. Initial power input and light output are below maximum values, and increase as lamp lumen depreciation and luminaire dirt depreciation occur. When the criteria illuminance value can no longer be supplied at full light output, cleaning and relamping will be done and the cycle starts over. (see Figure EX.2)

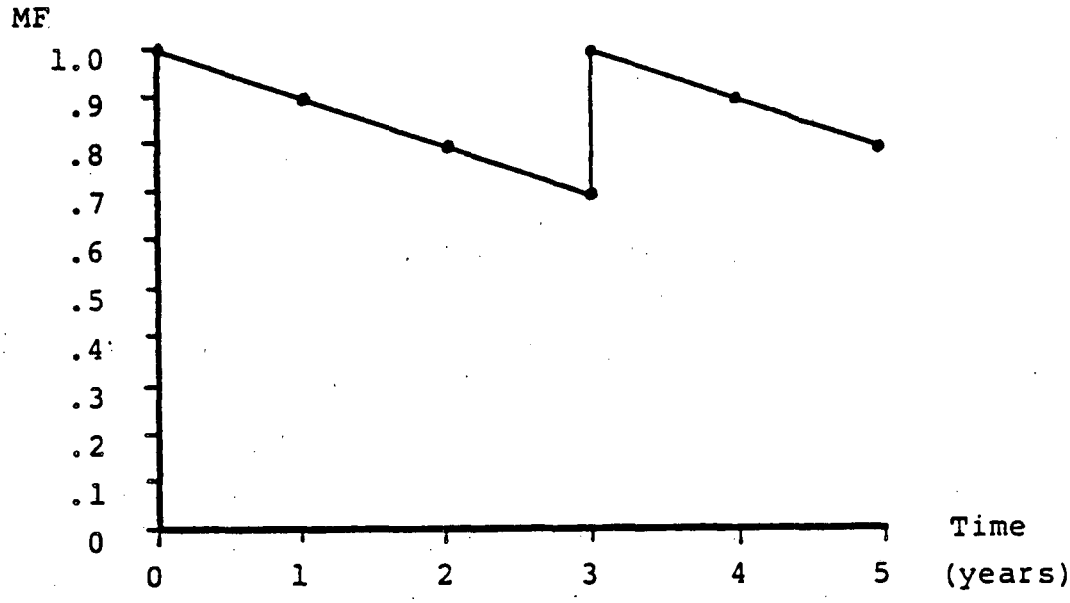


Figure EX.2 Graph of total light loss factor with a three year cleaning cycle.

The area is 1,000 square feet with a constant illuminance criteria of 110 footcandles. A three year cleaning cycle is in effect with depreciation down to 70% light output at the end of three years, thus, 160 footcandles initial must be provided. The watts per square foot loading is 4.2 watts per square foot. The power input vs. light output relationship is linear in the range of concern. No other special controls are planned, and the space is in operation 16 hours per day, 5 days of the week. The energy cost is .055 dollars/KWH.

```
Is the input data in a data file?(Y/N)
N
Do you want your responses saved?(Y/N)
Y
Enter filename(xx------x.xxx):
EX2.IN
Do you wish output to go to a file?(Y/N)
Y
Enter filename(xx------x.xxx):
EX2.OUT


AREA AFFECTED BY CONTROL SCHEME (SQ. FT.)?
1000


WILL CONTROL SYSTEM UNDER CONSIDERATION BE
CONTINUOUS DIMMING OR STEPPED CONTROL?
CONT

IS POWER INPUT VS. LIGHT OUTPUT A LINEAR OR NONLINEAR RELATIONSHIP?
LIN

MAX. POWER INPUT, MIN. POWER INPUT (%)?
100,40

LIGHT OUTPUT AT MAX. POWER      LIGHT OUTPUT AT MIN. POWER(%)?
100,40

MAXIMUM ARTIFICIAL ILLUMINANCE AVAILABLE (FC)?
160

MAXIMUM POWER AVAILABLE (WATTS/SQ.FT.)?
4.2

DOES CONTROL SYSTEM UNDER ANALYSIS RESPOND TO DAYLIGHTING?
NO


WILL SYSTEM BE MAINTAINED BEFORE THE END OF 5 YEAR CYCLE?
YES

HOW MANY TIMES?    (NOTE? CLEANING MUST OCCUR AT YEAR END.)
1

AT THE END OF WHAT YEAR(S) WILL THE SYSTEM BE MAINTAINED?
3
```

```
INPUT MAINTENANCE FACTOR AT YEAR END FOR? YR1,YR2,YR3,YR4,YR5

(NOTE? BEFORE YEAR END MAINTENANCE IS DONE)
.9,.8,.7,.9,.8

INPUT MAINTENANCE FACTOR AFTER INDICATED
CLEANING AT END OF YEAR(S)?YR3  1.0


NUMBER OF DAYS PER WEEK BUILDING LIGHTING SYSTEM IS UTILIZED?
5

NUMBER OF DIFFERENT DAILY CONTROL SCHEMES USED?
1


                    FOR CONTROL SCHEME NUMBER 1


HOURS OF CONTROL SYSTEM OPERATION? START,STOP?
6,22

OVERALL CRITERION ILLUMINATION LEVEL?
110

NUMBER OF DAYS OF THE WEEK CONTROL SCHEME 1 IS IN OPERATION?
5

NUMBER OF TIME BLOCKS WITH A SPECIFIC CRITERION
ILLUMINATION LEVEL FOR CONTROL?
0

OVERALL COST/KWH(DOLLARS)?
.055

NUMBER OF TIME BLOCKS WITH A DIFFERENT COST/KWH?
0
```

```
CONTROL SYSTEM COST DATA?

COST TO DESIGN CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

COST OF CONTROL SYSTEM EQUIPMENT(DOLLARS/SQ.FT.)?
.83

COST TO INSTALL CONTROL SYSTEM(DOLLARS/SQ.FT.)?
.17

DIFFERENTIAL YEARLY MAINTENANCE COST OF CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

SALVAGE VALUE OF THE CONTROL SYSTEM
AT THE END OF ITS ECONOMIC LIFE(DOLLARS)?
0

ECONOMIC LIFE OF SYSTEM(YEARS)?
12

OVERALL INTEREST RATE(%)?
17
```

CONTROL SYSTEM CHARACTERISTICS

CONTINUOUS DIMMING
LINEAR RELATIONSHIP?

MAXIMUM POWER(%)?	100.0
MINIMUM POWER(%)?	40.0
MAXIMUM LIGHT(%)?	100.0
MINIMUM LIGHT(%)?	40.0

AREA AFFECTED BY CONTROLS? 1000.00 SQ. FEET

MAXIMUM ARTIFICIAL ILLUMINANCE? 160.0 FOOTCANDLES
MAXIMUM POWER INPUT? 4.2 WATTS/SQ.FT.

MAINTENANCE FACTORS
AT YEAR END?

YEAR	MF
1	.90
2	.80
3	.70
4	.90
5	.80

MAINTENANCE FACTOR
FOLLOWING INTERMEDIATE
CLEANING? 3 1.00

BUILDING IS IN OPERATION 5 DAYS PER WEEK

FOR CONTROL SCHEME 1

CONTROL SCHEME STARTS AT 6.00 AND STOPS AT 22.00
IN EFFECT 5 DAYS PER WEEK

NET EFFECTIVE CONTROL BLOCKS SPECIFIED

START	STOP	CRITERION FC VALUE	COST/KWH
6.00	22.00	110.0	.0550

ENERGY AND COST PERFORMANCE COMPARISON

YEAR	KWH USED	KWH SAVED
1	12714.17	4805.83
2	14219.79	3300.21
3	16131.70	1388.30
4	12714.17	4805.83
5	14219.79	3300.21

FIRST COSTS FOR CONTROL SYSTEM

DESIGN COSTS? .00
EQUIPMENT COSTS? 830.00
INSTALLATION COSTS? 170.00

TOTAL DIFFERENTIAL MAINTENANCE COSTS/YEAR? .00

CONTROL SYSTEM SALVAGE VALUE AT END OF LIFE? .00

ECONOMIC LIFE OF SYSTEM? 12.00
OVERALL INTEREST RATE? 17.00

ANNUAL ENERGY COSTS

YEAR	BASE SYSTEM	CONTROLLED SYSTEM
1	963.60	699.28
2	963.60	782.09
3	963.60	887.24
4	963.60	699.28
5	963.60	782.09
6	963.60	887.24
7	963.60	699.28
8	963.60	782.09
9	963.60	887.24
10	963.60	699.28
11	963.60	782.09
12	963.60	887.24

TOTAL PRESENT WORTH(PW) COSTS AND
SAVINGS INVESTMENT RATIO (SIR) AT VARIOUS DIFFERENTIAL
ENERGY RATE INCREASES?

AT .0 % INCREASE/YEAR?

PW BASE?	4806.81
PW CONTROLLED?	4889.80
SIR	.92

AT 3.0 % INCREASE/YEAR?

PW BASE?	5553.23
PW CONTROLLED?	5504.33
SIR	1.05

AT 6.0 % INCREASE/YEAR?

PW BASE?	6446.05
PW CONTROLLED?	6240.41
SIR	1.21

AT 9.0 % INCREASE/YEAR?

PW BASE?	7517.01
PW CONTROLLED?	7124.61
SIR	1.39

AT 12.0 % INCREASE/YEAR?

PW BASE?	8804.65
PW CONTROLLED?	8189.22
SIR	1.62

AT 15.0 % INCREASE/YEAR?

PW BASE?	10355.59
PW CONTROLLED?	9473.37
SIR	1.88

7.3 Example 3

A fluorescent Equi-Illumination Dimming System which responds to daylight input as well as light loss variations is being considered for the perimeter zone of a large open office area. Criterion illuminance of 60 footcandle on the desk is desired and the total maintenance factor will be 80 footcandles minimum at the end of a three year cleaning cycle; thus 75 initial footcandles must be provided by the artificial lighting system for times when daylight is not available. A total area of 1400 square feet loaded at 1.8 Watt per square foot is to be controlled by the same sensor. The power input vs light output relationship is slightly non-linear, as shown in Figure Ex. 3.1. The lighting system operates from 6:00 a.m. to 6:00 p.m. five days per week. The off-peak energy rate is .048 dollares/kwh and on-peak rate is .064 dollars/kwh between the hours of 9:00 a.m. and 1:00 p.m. Three input values of daylight available in the space are sufficient to describe the variation in daylight throughout the day, for both clear and cloudy conditions. Daylight values, % clear sky and all other input parameters are included below in the listing of the interactive terminal session.

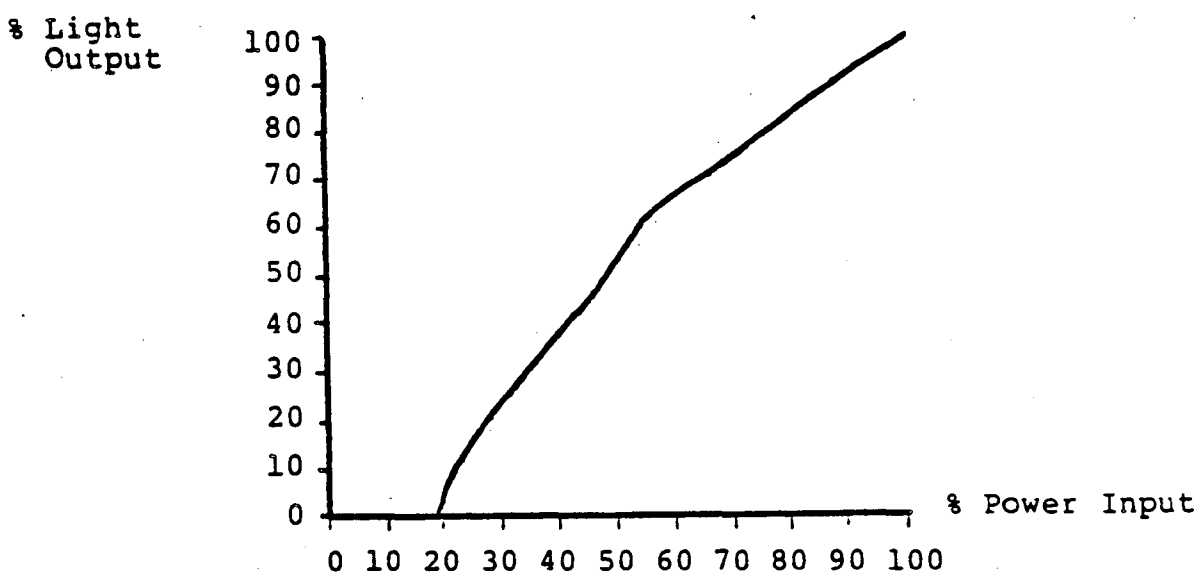


FIG. EX. 3.1. Non-linear relationship for flourescent diming equipment

```
Is the input data in a data file?(Y/N)
N
Do you want your responses saved?(Y/N)
Y
Enter filename(xx------x.xxx):
EX3.IN
Do you wish output to go to a file?(Y/N)
Y
Enter filename(xx------x.xxx):
EX3.OUT


AREA AFFECTED BY CONTROL SCHEME (SQ. FT.)?
1400


WILL CONTROL SYSTEM UNDER CONSIDERATION BE
CONTINUOUS DIMMING OR STEPPED CONTROL?
CONT

IS POWER INPUT VS. LIGHT OUTPUT A LINEAR OR NONLINEAR RELATIONSHIP?
NON

INPUT THE NUMBER OF ORDERED PAIRS OF % POWER INPUT AND % LIGHT OUTPUT
WHICH WILL BE USED TO DESCRIBE THE NON-LINEAR RELATIONSHIP.
11

INPUT 11 ORDERED PAIRS OF POWER INPUT AND
LIGHT OUTPUT? POWER(%), LIGHT(%)
18,0
23,10
28,20
35,30
42,40
47,50
54,60
66,70
77,80
88,90
100,100

MAXIMUM ARTIFICIAL ILLUMINANCE AVAILABLE (FC)?
75

MAXIMUM POWER AVAILABLE (WATTS/SQ.FT.)?
1.8

DOES CONTROL SYSTEM UNDER ANALYSIS RESPOND TO DAYLIGHTING?
YES

LONGITUDE OF SITE?
82
```

```
NUMBER OF TIME ZONES WEST OF GREENWICH?
5

% CLEAR SKY PER MONTH?
JAN FEB MAR
30,30,35

APL MAY JUN
50,55,60

JLY AUG SEP
60,55,50

OCT NOV DEC
50,45,40

INPUT SKY CONDITION FOR DAYLIGHTING INFORMATION? CLEAR OR CLOUDY
CLEAR


                DAYLIGHTING INFORMATION UNDER CLEAR SKY CONDITIONS

NUMBER OF DAYS PER YEAR FOR NATURAL ILLUMINANCE ANALYSIS? (ANSWER 4 OR 12)
4


ODD NUMBER OF VALUES OF NATURAL ILLUMINANCE USED FOR EACH DAY ?
3

ARE NATURAL ILLUMINANCE VALUES TO BE CALCULATED?
NO

HOUR OF SUNRISE IN CIVIL TIME, DEC21 ?
7.6

NATURAL ILLUMINANCE AT?    9.6   11.6   13.5

45,70,90

HOUR OF SUNRISE IN CIVIL TIME, MAR21 ?
6.7

NATURAL ILLUMINANCE AT?    9.1   11.4   13.8

60,85,110

HOUR OF SUNRISE IN CIVIL TIME, JUN21 ?
6.2

NATURAL ILLUMINANCE AT?    8.9   11.5   14.2

80,95,130
```

DAYLIGHTING INFORMATION UNDER CLOUDY SKY CONDITIONS

ODD NUMBER OF VALUES OF NATURAL ILLUMINANCE USED FOR EACH DAY ?
3

ARE NATURAL ILLUMINANCE VALUES TO BE CALCULATED?
NO

FOR DEC21
NATURAL ILLUMINANCE AT? 9.6 11.6 13.5

25,35,40

FOR MAR21
NATURAL ILLUMINANCE AT? 9.1 11.4 13.8

30,40,45

FOR JUN21
NATURAL ILLUMINANCE AT? 8.9 11.5 14.2

40,45,60

WILL SYSTEM BE MAINTAINED BEFORE THE END OF 5 YEAR CYCLE?
YES

HOW MANY TIMES? (NOTE? CLEANING MUST OCCUR AT YEAR END.)
1

AT THE END OF WHAT YEAR(S) WILL THE SYSTEM BE MAINTAINED?
3

INPUT MAINTENANCE FACTOR AT YEAR END FOR? YR1,YR2,YR3,YR4,YR5

(NOTE? BEFORE YEAR END MAINTENANCE IS DONE)
.92,.87,.80,.92,.87

INPUT MAINTENANCE FACTOR AFTER INDICATED
CLEANING AT END OF YEAR(S)?YR3 1.0

NUMBER OF DAYS PER WEEK BUILDING LIGHTING SYSTEM IS UTILIZED?
5

NUMBER OF DIFFERENT DAILY CONTROL SCHEMES USED?
1

FOR CONTROL SCHEME NUMBER 1

```
HOURS OF CONTROL SYSTEM OPERATION? START,STOP?
6,18

OVERALL CRITERION ILLUMINATION LEVEL?
60

NUMBER OF DAYS OF THE WEEK CONTROL SCHEME 1 IS IN OPERATION?
5

NUMBER OF TIME BLOCKS WITH A SPECIFIC CRITERION
ILLUMINATION LEVEL FOR CONTROL?
0

OVERALL COST/KWH(DOLLARS)?
.048

NUMBER OF TIME BLOCKS WITH A DIFFERENT COST/KWH?
1

START TIME,STOP TIME AND COST/KWH (DOLLARS) FOR EACH BLOCK?
9,13,.064


CONTROL SYSTEM COST DATA?

COST TO DESIGN CONTROL SYSTEM(DOLLARS/SQ.FT.)?
.12

COST OF CONTROL SYSTEM EQUIPMENT(DOLLARS/SQ.FT.)?
1.05

COST TO INSTALL CONTROL SYSTEM(DOLLARS/SQ.FT.)?
.30

DIFFERENTIAL YEARLY MAINTENANCE COST OF CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

SALVAGE VALUE OF THE CONTROL SYSTEM
AT THE END OF ITS ECONOMIC LIFE(DOLLARS)?
0

ECONOMIC LIFE OF SYSTEM(YEARS)?
15

OVERALL INTEREST RATE(%)?
15
```

CONTROL SYSTEM CHARACTERISTICS

CONTINUOUS DIMMING
NON-LINEAR RELATIONSHIP?

POWER(%)	LIGHT(%)
18.0	.0
23.0	10.0
28.0	20.0
35.0	30.0
42.0	40.0
47.0	50.0
54.0	60.0
66.0	70.0
77.0	80.0
88.0	90.0
100.0	100.0

AREA AFFECTED BY CONTROLS? 1400.00 SQ. FEET

MAXIMUM ARTIFICIAL ILLUMINANCE? 75.0 FOOTCANDLES
MAXIMUM POWER INPUT? 1.8 WATTS/SQ.FT.

MAINTENANCE FACTORS
AT YEAR END?

YEAR	MF
1	.92
2	.87
3	.80
4	.92
5	.87

MAINTENANCE FACTOR
FOLLOWING INTERMEDIATE
CLEANING? 3 1.00

BUILDING IS IN OPERATION 5 DAYS PER WEEK

FOR CONTROL SCHEME 1

CONTROL SCHEME STARTS AT 6.00 AND STOPS AT 18.00
IN EFFECT 5 DAYS PER WEEK

NET EFFECTIVE CONTROL BLOCKS SPECIFIED

START	STOP	CRITERION FC VALUE	COST/KWH
6.00	9.00	60.0	.0480
9.00	13.00	60.0	.0640
13.00	18.00	60.0	.0480

DAYLIGHTING INFORMATION

LONGITUDE OF SITE? 82.0

TIME ZONES WEST OF GREENWICH? 5

INPUT TIMES AND LIGHTING LEVELS? CLEAR SKY CONDITIONS

MONTH	SOLAR SUNRISE	TIME	FC
DEC 21	7.6	9.6	45.0
		11.6	70.0
		13.5	90.0
MAR 21	6.7	9.1	60.0
		11.4	85.0
		13.8	110.0
JUN 21	6.2	8.9	80.0
		11.5	95.0
		14.2	130.0

INPUT TIMES AND LIGHTING LEVELS? CLOUDY SKY CONDITIONS

MONTH	SOLAR SUNRISE	TIME	FC
DEC 21	7.6	9.6	25.0
		11.6	35.0
		13.5	40.0
MAR 21	6.7	9.1	30.0
		11.4	40.0
		13.8	45.0
JUN 21	6.2	8.9	40.0
		11.5	45.0
		14.2	60.0

ENERGY AND COST PERFORMANCE COMPARISON

MONTHLY VARIATIONS FOR YEAR 1

MONTH	%CL	%CD	KWHUSED	KWHSAVED	COST	SAVINGS
JAN	30.	70.	355.45	314.15	18.28	17.44
FEB	30.	70.	311.30	293.50	15.99	16.26
MAR	35.	65.	319.65	349.95	16.40	19.31
APL	50.	50.	269.29	378.71	13.80	20.76
MAY	55.	45.	248.98	420.62	12.79	22.92
JUN	60.	40.	225.33	422.67	11.59	22.97
JLY	60.	40.	237.98	431.62	12.23	23.48
AUG	55.	45.	262.82	406.78	13.47	22.24
SEP	50.	50.	285.62	362.38	14.62	19.94
OCT	50.	50.	320.37	349.23	16.39	19.33
NOV	45.	55.	329.86	318.14	16.90	17.66
DEC	40.	60.	350.75	318.85	18.00	17.71

TOTAL KWH USED= 3517.39
TOTAL KWH SAVED= 4366.60

MONTHLY VARIATIONS FOR YEAR 2

JAN	30.	70.	381.58	288.02	19.58	16.13
FEB	30.	70.	332.16	272.64	17.03	15.22
MAR	35.	65.	338.42	331.18	17.34	18.38
APL	50.	50.	282.91	365.09	14.47	20.09
MAY	55.	45.	260.51	409.09	13.36	22.35
JUN	60.	40.	235.38	412.62	12.09	22.47
JLY	60.	40.	248.69	420.91	12.76	22.95
AUG	55.	45.	275.46	394.14	14.10	21.62
SEP	50.	50.	301.13	346.87	15.38	19.18
OCT	50.	50.	340.39	329.21	17.38	18.34
NOV	45.	55.	353.17	294.83	18.06	16.50
DEC	40.	60.	377.04	292.56	19.31	16.40

TOTAL KWH USED= 3726.83
TOTAL KWH SAVED= 4157.17

MONTHLY VARIATIONS FOR YEAR 3

JAN	30.	70.	406.29	263.31	20.81	14.90
FEB	30.	70.	355.12	249.68	18.18	14.08
MAR	35.	65.	362.81	306.79	18.55	17.17
APL	50.	50.	302.51	345.49	15.44	19.12
MAY	55.	45.	276.92	392.68	14.17	21.55
JUN	60.	40.	248.97	399.03	12.76	21.80
JLY	60.	40.	263.55	406.05	13.49	22.22
AUG	55.	45.	293.82	375.78	15.00	20.71
SEP	50.	50.	322.44	325.56	16.43	18.13
OCT	50.	50.	363.93	305.67	18.54	17.17
NOV	45.	55.	376.23	271.77	19.20	15.36
DEC	40.	60.	400.73	268.87	20.48	15.23

TOTAL KWH USED= 3973.32
TOTAL KWH SAVED= 3910.68

MONTHLY VARIATIONS FOR YEAR 4

JAN	30.	70.	355.45	314.15	18.28	17.44
FEB	30.	70.	311.30	293.50	15.99	16.26
MAR	35.	65.	319.65	349.95	16.40	19.31
APL	50.	50.	269.29	378.71	13.80	20.76
MAY	55.	45.	248.98	420.62	12.79	22.92
JUN	60.	40.	225.33	422.67	11.59	22.97
JLY	60.	40.	237.98	431.62	12.23	23.48
AUG	55.	45.	262.82	406.78	13.47	22.24
SEP	50.	50.	285.62	362.38	14.62	19.94
OCT	50.	50.	320.37	349.23	16.39	19.33
NOV	45.	55.	329.86	318.14	16.90	17.66
DEC	40.	60.	350.75	318.85	18.00	17.71

TOTAL KWH USED= 3517.39
TOTAL KWH SAVED= 4366.60

MONTHLY VARIATIONS FOR YEAR 5

JAN	30.	70.	381.58	288.02	19.58	16.13
FEB	30.	70.	332.16	272.64	17.03	15.22
MAR	35.	65.	338.42	331.18	17.34	18.38
APL	50.	50.	282.91	365.09	14.47	20.09
MAY	55.	45.	260.51	409.09	13.36	22.35
JUN	60.	40.	235.38	412.62	12.09	22.47
JLY	60.	40.	248.69	420.91	12.76	22.95
AUG	55.	45.	275.46	394.14	14.10	21.62
SEP	50.	50.	301.13	346.87	15.38	19.18
OCT	50.	50.	340.39	329.21	17.38	18.34
NOV	45.	55.	353.17	294.83	18.06	16.50
DEC	40.	60.	377.04	292.56	19.31	16.40

TOTAL KWH USED= 3726.83
TOTAL KWH SAVED= 4157.17

FIRST COSTS FOR CONTROL SYSTEM

DESIGN COSTS? 168.00
EQUIPMENT COSTS? 1470.00
INSTALLATION COSTS? 420.00

TOTAL DIFFERENTIAL MAINTENANCE COSTS/YEAR? .00

CONTROL SYSTEM SALVAGE VALUE AT END OF LIFE? .00

ECONOMIC LIFE OF SYSTEM? 15.00
OVERALL INTEREST RATE? 15.00

ANNUAL ENERGY COSTS

YEAR	BASE SYSTEM	CONTROLLED SYSTEM
1	420.48	180.47
2	420.48	190.85
3	420.48	203.03
4	420.48	180.47
5	420.48	190.85
6	420.48	203.03
7	420.48	180.47
8	420.48	190.85
9	420.48	203.03
10	420.48	180.47
11	420.48	190.85
12	420.48	203.03
13	420.48	180.47
14	420.48	190.85
15	420.48	203.03

TOTAL PRESENT WORTH(PW) COSTS AND
SAVINGS INVESTMENT RATIO (SIR) AT VARIOUS DIFFERENTIAL
ENERGY RATE INCREASES?

AT .0 % INCREASE/YEAR?

PW BASE?	2458.70
PW CONTROLLED?	3171.36
SIR	.65

AT 3.0 % INCREASE/YEAR?

PW BASE?	2918.10
PW CONTROLLED?	3380.91
SIR	.78

AT 6.0 % INCREASE/YEAR?

PW BASE?	3493.74
PW CONTROLLED?	3643.66
SIR	.93

AT 9.0 % INCREASE/YEAR?

PW BASE?	4219.32
PW CONTROLLED?	3975.06
SIR	1.12

AT 12.0 % INCREASE/YEAR?

PW BASE?	5138.38
PW CONTROLLED?	4395.13
SIR	1.36

AT 15.0 % INCREASE/YEAR?

PW BASE?	6307.20
PW CONTROLLED?	4929.74
SIR	1.67

7.4 Example 4

A fluorescent Equi-Illumination Dimming System which responds to daylight is being tested with a free standing mockup room at Lawrence Berkeley Laboratory in Berkeley California. The room is 20 feet wide (West to East dimension), 30 feet deep (North to South dimension), and 8.67 feet high. The reflectance of the ceiling, floor and walls are 80%, 20% and 50% respectively. The room was built on the top of a research building which has a gravel roof of 20% reflectance. There are three windows in the room, two of which are on the West wall, the other on the East. The window on the East wall is 28 feet long at a distance 2 feet from the floor. The two windows on the west wall are dimensioned and positioned to produce the same fenestration as on the East wall. the glass used for all windows are of 78% transmittance and 14% reflectance.

A criterion illuminance of 70 footcandles at a work plane height of 2.5 feet above the floor is desired with an assumed 5% depreciation in the maintenance factor after each year (starting at 100%). The total area is controlled at 1.8 watts per square foot. The power input vs light output relationship is linear, as shown in Figure EX4.1. The lighting system operates fro 6:00 a.m. to 5:00 p.m. five days per week. The energy rate is .06 dollars/kwh.

The daylighting values were measured at 3 times of the day on the 21st of each month for a period of a year. The times of day, % clear sky and all other input parameter are included in the listing of the interactive terminal session. (See Natural Illuminance calculation file used for this example in description section titled Natural Illuminance Calculation File)

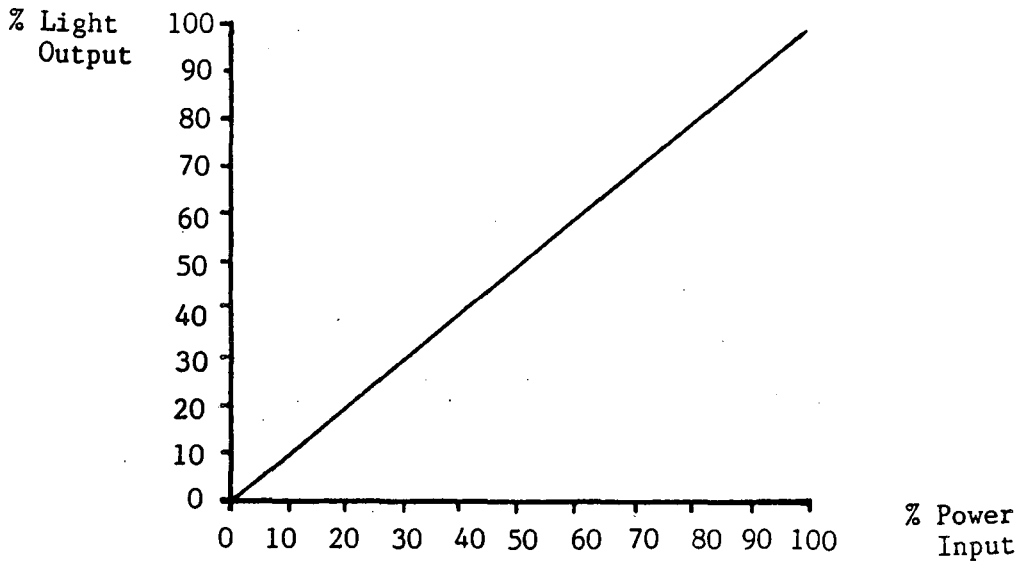


FIG. EX. 4.1 Continuous linear relationship for fluorescent dimming equipment.

```
Is the input data in a data file?(Y/N)
N
Do you want your responses saved?(Y/N)
Y
Enter filename(xx------x.xxx):
EX4.IN
Do you wish output to go to a file?(Y/N)
Y
Enter filename(xx------x.xxx):
EX4.OUT


AREA AFFECTED BY CONTROL SCHEME (SQ. FT.)?
600


WILL CONTROL SYSTEM UNDER CONSIDERATION BE
CONTINUOUS DIMMING OR STEPPED CONTROL?
CONT

IS POWER INPUT VS. LIGHT OUTPUT A LINEAR OR NONLINEAR RELATIONSHIP?
LIN

MAX. POWER INPUT, MIN. POWER INPUT (%)?
100,0

LIGHT OUTPUT AT MAX. POWER      LIGHT OUTPUT AT MIN. POWER(%)?
100,0

MAXIMUM ARTIFICIAL ILLUMINANCE AVAILABLE (FC)?
70

MAXIMUM POWER AVAILABLE (WATTS/SQ.FT.)?
1.2

DOES CONTROL SYSTEM UNDER ANALYSIS RESPOND TO DAYLIGHTING?
YES

LONGITUDE OF SITE?
122

NUMBER OF TIME ZONES WEST OF GREENWICH?
8

% CLEAR SKY PER MONTH?
JAN FEB MAR
50,50,50

APL MAY JUN
50,50,50

JLY AUG SEP
50,50,50
```

```
OCT NOV DEC
50,50,50

INPUT SKY CONDITION FOR DAYLIGHTING INFORMATION? CLEAR OR CLOUDY
CLEAR


                    DAYLIGHTING INFORMATION UNDER CLEAR SKY CONDITIONS

NUMBER OF DAYS PER YEAR FOR NATURAL ILLUMINANCE ANALYSIS? (ANSWER 4 OR 12)
12


ODD NUMBER OF VALUES OF NATURAL ILLUMINANCE USED FOR EACH DAY ?
3

ARE NATURAL ILLUMINANCE VALUES TO BE CALCULATED?
NO

HOUR OF SUNRISE IN CIVIL TIME, DEC21 ?
7.1

NATURAL ILLUMINANCE AT?    9.5   11.9   14.3

144,160,150

HOUR OF SUNRISE IN CIVIL TIME, JAN21 ?
6.7

NATURAL ILLUMINANCE AT?    9.2   11.7   14.2

140,170,180

HOUR OF SUNRISE IN CIVIL TIME, FEB21 ?
6.2

NATURAL ILLUMINANCE AT?    8.9   11.6   14.4

190,210,220

HOUR OF SUNRISE IN CIVIL TIME, MAR21 ?
5.8

NATURAL ILLUMINANCE AT?    8.8   11.7   14.7

240,260,280

HOUR OF SUNRISE IN CIVIL TIME, APR21 ?
5.4

NATURAL ILLUMINANCE AT?    8.6   11.9   15.1

280,300,320
```

```
HOUR OF SUNRISE IN CIVIL TIME, MAY21 ?
4.9

NATURAL ILLUMINANCE AT?    8.4   11.9   15.4

290,310,330

HOUR OF SUNRISE IN CIVIL TIME, JUN21 ?
4.5

NATURAL ILLUMINANCE AT?    8.2   11.8   15.5

290,310,330
```

DAYLIGHTING INFORMATION UNDER CLOUDY SKY CONDITIONS

```
ODD NUMBER OF VALUES OF NATURAL ILLUMINANCE USED FOR EACH DAY ?
3

ARE NATURAL ILLUMINANCE VALUES TO BE CALCULATED?
NO

FOR  DEC21
NATURAL ILLUMINANCE AT?    9.5   11.9   14.3

60,80,50

FOR  JAN21
NATURAL ILLUMINANCE AT?    9.2   11.7   14.2

50,90,70

FOR  FEB21
NATURAL ILLUMINANCE AT?    8.9   11.6   14.4

80,110,90

FOR  MAR21
NATURAL ILLUMINANCE AT?    8.8   11.7   14.7

100,140,100

FOR  APR21
NATURAL ILLUMINANCE AT?    8.6   11.9   15.1

120,160,110

FOR  MAY21
NATURAL ILLUMINANCE AT?    8.4   11.9   15.4

130,170,110
```

```
FOR  JUN21
NATURAL ILLUMINANCE AT?    8.2   11.8   15.5

120,170,110


WILL SYSTEM BE MAINTAINED BEFORE THE END OF 5 YEAR CYCLE?
NO

INPUT MAINTENANCE FACTOR AT YEAR END FOR? YR1,YR2,YR3,YR4,YR5
1,.95,.9,.85,.8


NUMBER OF DAYS PER WEEK BUILDING LIGHTING SYSTEM IS UTILIZED?
5

NUMBER OF DIFFERENT DAILY CONTROL SCHEMES USED?
1


                         FOR CONTROL SCHEME NUMBER 1


HOURS OF CONTROL SYSTEM OPERATION? START,STOP?
7,16

OVERALL CRITERION ILLUMINATION LEVEL?
70

NUMBER OF DAYS OF THE WEEK CONTROL SCHEME 1 IS IN OPERATION?
5

NUMBER OF TIME BLOCKS WITH A SPECIFIC CRITERION
ILLUMINATION LEVEL FOR CONTROL?
1

START TIME,STOP TIME AND CRITERION ILLUMINATION FOR EACH BLOCK?
7,16,70

OVERALL COST/KWH(DOLLARS)?
.06

NUMBER OF TIME BLOCKS WITH A DIFFERENT COST/KWH?
0
```

```
CONTROL SYSTEM COST DATA?

COST TO DESIGN CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

COST OF CONTROL SYSTEM EQUIPMENT(DOLLARS/SQ.FT.)?
2

COST TO INSTALL CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

DIFFERENTIAL YEARLY MAINTENANCE COST OF CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

SALVAGE VALUE OF THE CONTROL SYSTEM
AT THE END OF ITS ECONOMIC LIFE(DOLLARS)?
0

ECONOMIC LIFE OF SYSTEM(YEARS)?
10

OVERALL INTEREST RATE(%)?
10
```

CONTROL SYSTEM CHARACTERISTICS

CONTINUOUS DIMMING
LINEAR RELATIONSHIP?

MAXIMUM POWER(%)?	100.0
MINIMUM POWER(%)?	.0
MAXIMUM LIGHT(%)?	100.0
MINIMUM LIGHT(%)?	.0

AREA AFFECTED BY CONTROLS? 600.00 SQ. FEET

MAXIMUM ARTIFICIAL ILLUMINANCE? 70.0 FOOTCANDLES
MAXIMUM POWER INPUT? 1.2 WATTS/SQ.FT.

MAINTENANCE FACTORS
AT YEAR END?

YEAR	MF
1	1.00
2	.95
3	.90
4	.85
5	.80

NO INTERMEDIATE MAINTENANCE

BUILDING IS IN OPERATION 5 DAYS PER WEEK

FOR CONTROL SCHEME 1

CONTROL SCHEME STARTS AT 7.00 AND STOPS AT 16.00
IN EFFECT 5 DAYS PER WEEK

NET EFFECTIVE CONTROL BLOCKS SPECIFIED

START	STOP	CRITERION FC VALUE	COST/KWH
7.00	16.00	70.0	.0600

DAYLIGHTING INFORMATION

LONGITUDE OF SITE? 122.0

TIME ZONES WEST OF GREENWICH? 8

INPUT TIMES AND LIGHTING LEVELS? CLEAR SKY CONDITIONS

MONTH	SOLAR SUNRISE	TIME	FC
DEC 21	7.1	9.5	144.0
		11.9	160.0
		14.3	150.0
JAN 21	6.7	9.2	140.0
		11.7	170.0
		14.2	180.0
FEB 21	6.2	8.9	190.0
		11.6	210.0
		14.4	220.0
MAR 21	5.8	8.8	240.0
		11.7	260.0
		14.7	280.0
APR 21	5.4	8.6	280.0
		11.9	300.0
		15.1	320.0
MAY 21	4.9	8.4	290.0
		11.9	310.0
		15.4	330.0
JUN 21	4.5	8.2	290.0
		11.8	310.0
		15.5	330.0

INPUT TIMES AND LIGHTING LEVELS? CLOUDY SKY CONDITIONS

MONTH	SOLAR SUNRISE	TIME	FC
DEC 21	7.1	9.5	60.0
		11.9	80.0
		14.3	50.0
JAN 21	6.7	9.2	50.0
		11.7	90.0
		14.2	70.0
FEB 21	6.2	8.9	80.0
		11.6	110.0
		14.4	90.0
MAR 21	5.8	8.8	100.0
		11.7	140.0
		14.7	100.0
APR 21	5.4	8.6	120.0
		11.9	160.0
		15.1	110.0
MAY 21	4.9	8.4	130.0
		11.9	170.0
		15.4	110.0
JUN 21	4.5	8.2	120.0
		11.8	170.0
		15.5	110.0

ENERGY AND COST PERFORMANCE COMPARISON

MONTHLY VARIATIONS FOR YEAR 1

MONTH	%CL	%CD	KWHUSED	KWHSAVED	COST	SAVINGS
JAN	50.	50.	19.63	123.86	1.18	7.43
FEB	50.	50.	6.47	123.13	.39	7.39
MAR	50.	50.	1.43	142.06	.09	8.52
APL	50.	50.	.37	138.49	.02	8.31
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.04	138.82	.00	8.33
JLY	50.	50.	.02	143.47	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	1.00	137.85	.06	8.27
OCT	50.	50.	3.70	139.78	.22	8.39
NOV	50.	50.	15.01	123.85	.90	7.43
DEC	50.	50.	23.81	119.68	1.43	7.18

TOTAL KWH USED= 71.46
TOTAL KWH SAVED= 1617.96

MONTHLY VARIATIONS FOR YEAR 2

JAN	50.	50.	20.23	123.25	1.21	7.40
FEB	50.	50.	6.59	123.01	.40	7.38
MAR	50.	50.	1.49	142.00	.09	8.52
APL	50.	50.	.36	138.50	.02	8.31
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.03	138.82	.00	8.33
JLY	50.	50.	.02	143.47	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	1.02	137.84	.06	8.27
OCT	50.	50.	3.81	139.68	.23	8.38
NOV	50.	50.	15.35	123.51	.92	7.41
DEC	50.	50.	24.84	118.64	1.49	7.12

TOTAL KWH USED= 73.74
TOTAL KWH SAVED= 1615.68

MONTHLY VARIATIONS FOR YEAR 3

JAN	50.	50.	21.30	122.19	1.28	7.33
FEB	50.	50.	6.95	122.65	.42	7.36
MAR	50.	50.	1.56	141.93	.09	8.52
APL	50.	50.	.38	138.47	.02	8.31
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.04	138.82	.00	8.33
JLY	50.	50.	.02	143.47	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	1.07	137.78	.06	8.27
OCT	50.	50.	4.01	139.47	.24	8.37
NOV	50.	50.	16.19	122.67	.97	7.36
DEC	50.	50.	26.08	117.41	1.56	7.04

TOTAL KWH USED= 77.60
TOTAL KWH SAVED= 1611.83

MONTHLY VARIATIONS FOR YEAR 4

JAN	50.	50.	22.43	121.06	1.35	7.26
FEB	50.	50.	7.36	122.24	.44	7.33
MAR	50.	50.	1.64	141.84	.10	8.51
APL	50.	50.	.41	138.45	.02	8.31
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.04	138.82	.00	8.33
JLY	50.	50.	.02	143.46	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	1.14	137.72	.07	8.26
OCT	50.	50.	4.23	139.25	.25	8.36
NOV	50.	50.	17.10	121.76	1.03	7.31
DEC	50.	50.	27.33	116.15	1.64	6.97

TOTAL KWH USED= 81.70
TOTAL KWH SAVED= 1607.72

MONTHLY VARIATIONS FOR YEAR 5

JAN	50.	50.	23.61	119.88	1.42	7.19
FEB	50.	50.	7.80	121.80	.47	7.31
MAR	50.	50.	1.74	141.75	.10	8.50
APL	50.	50.	.44	138.42	.03	8.31
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.04	138.82	.00	8.33
JLY	50.	50.	.02	143.46	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	1.21	137.65	.07	8.26
OCT	50.	50.	4.49	139.00	.27	8.34
NOV	50.	50.	18.05	120.81	1.08	7.25
DEC	50.	50.	28.67	114.81	1.72	6.89

TOTAL KWH USED= 86.07
TOTAL KWH SAVED= 1603.36

FIRST COSTS FOR CONTROL SYSTEM

DESIGN COSTS? .00
EQUIPMENT COSTS? 1200.00
INSTALLATION COSTS? .00

TOTAL DIFFERENTIAL MAINTENANCE COSTS/YEAR? .00

CONTROL SYSTEM SALVAGE VALUE AT END OF LIFE? .00

ECONOMIC LIFE OF SYSTEM? 10.00
OVERALL INTEREST RATE? 10.00

ANNUAL ENERGY COSTS

YEAR	BASE SYSTEM	CONTROLLED SYSTEM
1	101.37	4.29
2	101.37	4.42
3	101.37	4.66
4	101.37	4.90
5	101.37	5.16
6	101.37	4.29
7	101.37	4.42
8	101.37	4.66
9	101.37	4.90
10	101.37	5.16

TOTAL PRESENT WORTH(PW) COSTS AND
SAVINGS INVESTMENT RATIO (SIR) AT VARIOUS DIFFERENTIAL
ENERGY RATE INCREASES?

AT .0 % INCREASE/YEAR?

PW BASE?	622.85
PW CONTROLLED?	1228.54
SIR	.50

AT 3.0 % INCREASE/YEAR?

PW BASE?	718.71
PW CONTROLLED?	1233.03
SIR	.57

AT 6.0 % INCREASE/YEAR?

PW BASE?	831.51
PW CONTROLLED?	1238.31
SIR	.66

AT 9.0 % INCREASE/YEAR?

PW BASE?	964.33
PW CONTROLLED?	1244.55
SIR	.77

AT 12.0 % INCREASE/YEAR?

PW BASE?	1120.76
PW CONTROLLED?	1251.91
SIR	.89

AT 15.0 % INCREASE/YEAR?

PW BASE?	1304.98
PW CONTROLLED?	1260.60
SIR	1.04

7.5 Example 5

The same mockup conditions of Example 4 are used to predict the performance of the Equi-Illumination Dimming System in this Example. The only difference being that the daylighting values are to be calculated. (See natural Illuminance Calculation File used for this example in description section titled Natural Illuminance Calculation File)

```
Is the input data in a data file?(Y/N)
N
Do you want your responses saved?(Y/N)
Y
Enter filename(xx------x.xxx):
EX5.IN
Do you wish output to go to a file?(Y/N)
Y
Enter filename(xx------x.xxx):
EX5.OUT


AREA AFFECTED BY CONTROL SCHEME (SQ. FT.)?
600


WILL CONTROL SYSTEM UNDER CONSIDERATION BE
CONTINUOUS DIMMING OR STEPPED CONTROL?
CONT

IS POWER INPUT VS. LIGHT OUTPUT A LINEAR OR NONLINEAR RELATIONSHIP?
LIN

MAX. POWER INPUT, MIN. POWER INPUT (%)?
100,0

LIGHT OUTPUT AT MAX. POWER      LIGHT OUTPUT AT MIN. POWER(%)?
100,0

MAXIMUM ARTIFICIAL ILLUMINANCE AVAILABLE (FC)?
70

MAXIMUM POWER AVAILABLE (WATTS/SQ.FT.)?
1.2

DOES CONTROL SYSTEM UNDER ANALYSIS RESPOND TO DAYLIGHTING?
YES

LONGITUDE OF SITE?
122

NUMBER OF TIME ZONES WEST OF GREENWICH?
8

% CLEAR SKY PER MONTH?
JAN FEB MAR
50,50,50

APL MAY JUN
50,50,50

JLY AUG SEP
50,50,50
```

```
OCT NOV DEC
50,50,50

INPUT SKY CONDITION FOR DAYLIGHTING INFORMATION? CLEAR OR CLOUDY
CLEAR


                DAYLIGHTING INFORMATION UNDER CLEAR SKY CONDITIONS

NUMBER OF DAYS PER YEAR FOR NATURAL ILLUMINANCE ANALYSIS? (ANSWER 4 OR 12)
4


ODD NUMBER OF VALUES OF NATURAL ILLUMINANCE USED FOR EACH DAY ?
3

ARE NATURAL ILLUMINANCE VALUES TO BE CALCULATED?
YES

HOUR OF SUNRISE IN CIVIL TIME, DEC21 ?
7.1

NATURAL ILLUMINANCE AT?    9.5   11.9   14.3

Enter Natural Illuminance Calculation
Filename (xx______xx.xxx):
NICF.DAT

WINDOW OPTIONS FOR DEC AT,     9.5 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0
```

```
WINDOW OPTIONS FOR DEC AT,    11.9 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR DEC AT,    14.3 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

HOUR OF SUNRISE IN CIVIL TIME, MAR21 ?
5.8

NATURAL ILLUMINANCE AT?    8.8   11.7   14.7
```

```
WINDOW OPTIONS FOR MAR AT,     8.8 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR MAR AT,    11.7 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR MAR AT,    14.7 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0
```

```
HOUR OF SUNRISE IN CIVIL TIME, JUN21 ?
4.5

NATURAL ILLUMINANCE AT?    8.2   11.8   15.5


WINDOW OPTIONS FOR JUN AT,     8.2 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR JUN AT,    11.8 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0
```

```
WINDOW OPTIONS FOR JUN AT,     15.5 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0


                DAYLIGHTING INFORMATION UNDER CLOUDY SKY CONDITIONS

ODD NUMBER OF VALUES OF NATURAL ILLUMINANCE USED FOR EACH DAY ?
3

ARE NATURAL ILLUMINANCE VALUES TO BE CALCULATED?
YES

FOR DEC21
NATURAL ILLUMINANCE AT?    9.5   11.9   14.3


WINDOW OPTIONS FOR DEC AT,     9.5 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0
```

```
WINDOW OPTIONS FOR DEC AT,    11.9 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR DEC AT,    14.3 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

FOR MAR21
NATURAL ILLUMINANCE AT?    8.8   11.7   14.7
```

```
WINDOW OPTIONS FOR MAR AT,     8.8 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR MAR AT,    11.7 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR MAR AT,    14.7 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0
```

```
FOR JUN21
NATURAL ILLUMINANCE AT?    8.2   11.8   15.5


WINDOW OPTIONS FOR JUN AT,     8.2 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0

WINDOW OPTIONS FOR JUN AT,    11.8 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0
```

```
WINDOW OPTIONS FOR JUN AT,    15.5 :
WINDOWS TO BE INCLUDED IN CALCULATION
 1 ACTIVATES WINDOW, 0 INACTIVATES IT
    WINDOW#  1 ?

1

    WINDOW#  1 IS ACTIVE
    WINDOW#  2 ?
1

    WINDOW#  2 IS ACTIVE
    WINDOW#  3 ?
1

    WINDOW#  3 IS ACTIVE
ENTER 1 TO CHANGE WINDOW LIST AGAIN
0


WILL SYSTEM BE MAINTAINED BEFORE THE END OF 5 YEAR CYCLE?
NO

INPUT MAINTENANCE FACTOR AT YEAR END FOR? YR1,YR2,YR3,YR4,YR5
1,.95,.90,.85,.80


NUMBER OF DAYS PER WEEK BUILDING LIGHTING SYSTEM IS UTILIZED?
5

NUMBER OF DIFFERENT DAILY CONTROL SCHEMES USED?
1


                         FOR CONTROL SCHEME NUMBER 1


HOURS OF CONTROL SYSTEM OPERATION? START,STOP?
7,16

OVERALL CRITERION ILLUMINATION LEVEL?
70

NUMBER OF DAYS OF THE WEEK CONTROL SCHEME 1 IS IN OPERATION?
5

NUMBER OF TIME BLOCKS WITH A SPECIFIC CRITERION
ILLUMINATION LEVEL FOR CONTROL?
1

START TIME,STOP TIME AND CRITERION ILLUMINATION FOR EACH BLOCK?
7,16,70
```

```
OVERALL COST/KWH(DOLLARS)?
.06

NUMBER OF TIME BLOCKS WITH A DIFFERENT COST/KWH?
0


CONTROL SYSTEM COST DATA?

COST TO DESIGN CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

COST OF CONTROL SYSTEM EQUIPMENT(DOLLARS/SQ.FT.)?
2

COST TO INSTALL CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

DIFFERENTIAL YEARLY MAINTENANCE COST OF CONTROL SYSTEM(DOLLARS/SQ.FT.)?
0

SALVAGE VALUE OF THE CONTROL SYSTEM
AT THE END OF ITS ECONOMIC LIFE(DOLLARS)?
0

ECONOMIC LIFE OF SYSTEM(YEARS)?
10

OVERALL INTEREST RATE(%)?
10
```

CONTROL SYSTEM CHARACTERISTICS

CONTINUOUS DIMMING
LINEAR RELATIONSHIP?

MAXIMUM POWER(%)?	100.0
MINIMUM POWER(%)?	.0
MAXIMUM LIGHT(%)?	100.0
MINIMUM LIGHT(%)?	.0

AREA AFFECTED BY CONTROLS? 600.00 SQ. FEET

MAXIMUM ARTIFICIAL ILLUMINANCE? 70.0 FOOTCANDLES
MAXIMUM POWER INPUT? 1.2 WATTS/SQ.FT.

MAINTENANCE FACTORS
AT YEAR END?

YEAR	MF
1	1.00
2	.95
3	.90
4	.85
5	.80

NO INTERMEDIATE MAINTENANCE

BUILDING IS IN OPERATION 5 DAYS PER WEEK

FOR CONTROL SCHEME 1

CONTROL SCHEME STARTS AT 7.00 AND STOPS AT 16.00
IN EFFECT 5 DAYS PER WEEK

NET EFFECTIVE CONTROL BLOCKS SPECIFIED

START	STOP	CRITERION FC VALUE	COST/KWH
7.00	16.00	70.0	.0600

DAYLIGHTING INFORMATION

ROOM DIMENSIONS?

WIDTH	20.0
DEPTH	30.0
HEIGHT	8.7

ROOM REFLECTANCES?

CEILING	.80
FLOOR	.20
WALLS	.50
GROUND	.20

HEIGHT OF CALCULATION PLANE? 2.5

LATITUDE OF SITE? 40.0

LONGITUDE OF SITE? 122.0

TIME ZONES WEST OF GREENWICH? 8

INPUT TIMES AND CALCULATED LIGHTING LEVELS? CLEAR SKY CONDITIONS

MONTH	SOLAR SUNRISE	TIME	FC
DEC 21	7.1	9.5	139.5
		11.9	163.0
		14.3	161.2
MAR 21	5.8	8.8	234.2
		11.7	262.6
		14.7	287.1
JUN 21	4.5	8.2	288.8
		11.8	312.5
		15.5	346.9

INPUT TIMES AND CALCULATED LIGHTING LEVELS? CLOUDY SKY CONDITIONS

MONTH	SOLAR SUNRISE	TIME	FC
DEC 21	7.1	9.5	60.0
		11.9	86.4
		14.3	63.3
MAR 21	5.8	8.8	93.7
		11.7	143.8
		14.7	113.2
JUN 21	4.5	8.2	119.0
		11.8	179.3
		15.5	129.3

ENERGY AND COST PERFORMANCE COMPARISON

MONTHLY VARIATIONS FOR YEAR 1

MONTH	%CL	%CD	KWHUSED	KWHSAVED	COST	SAVINGS
JAN	50.	50.	18.45	125.03	1.11	7.50
FEB	50.	50.	9.85	119.75	.59	7.18
MAR	50.	50.	3.11	140.38	.19	8.42
APL	50.	50.	.00	138.86	.00	8.33
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.00	138.86	.00	8.33
JLY	50.	50.	.00	143.49	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	.77	138.09	.05	8.29
OCT	50.	50.	7.61	135.87	.46	8.15
NOV	50.	50.	15.62	123.24	.94	7.39
DEC	50.	50.	20.90	122.59	1.25	7.36

TOTAL KWH USED= 76.31
TOTAL KWH SAVED= 1613.12

MONTHLY VARIATIONS FOR YEAR 2

JAN	50.	50.	18.65	124.84	1.12	7.49
FEB	50.	50.	9.98	119.62	.60	7.18
MAR	50.	50.	3.18	140.31	.19	8.42
APL	50.	50.	.00	138.86	.00	8.33
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.00	138.86	.00	8.33
JLY	50.	50.	.00	143.49	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	.81	138.04	.05	8.28
OCT	50.	50.	7.73	135.76	.46	8.15
NOV	50.	50.	15.79	123.07	.95	7.38
DEC	50.	50.	21.12	122.37	1.27	7.34

TOTAL KWH USED= 77.25
TOTAL KWH SAVED= 1612.18

MONTHLY VARIATIONS FOR YEAR 3

JAN	50.	50.	19.54	123.95	1.17	7.44
FEB	50.	50.	10.46	119.14	.63	7.15
MAR	50.	50.	3.34	140.15	.20	8.41
APL	50.	50.	.00	138.86	.00	8.33
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.00	138.86	.00	8.33
JLY	50.	50.	.00	143.49	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	.86	137.99	.05	8.28
OCT	50.	50.	8.10	135.38	.49	8.12
NOV	50.	50.	16.54	122.31	.99	7.34
DEC	50.	50.	22.12	121.37	1.33	7.28

TOTAL KWH USED= 80.97
TOTAL KWH SAVED= 1608.46

MONTHLY VARIATIONS FOR YEAR 4

JAN	50.	50.	20.47	123.01	1.23	7.38
FEB	50.	50.	10.97	118.63	.66	7.12
MAR	50.	50.	3.52	139.97	.21	8.40
APL	50.	50.	.00	138.86	.00	8.33
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.00	138.86	.00	8.33
JLY	50.	50.	.00	143.49	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	.92	137.94	.06	8.28
OCT	50.	50.	8.50	134.98	.51	8.10
NOV	50.	50.	17.34	121.52	1.04	7.29
DEC	50.	50.	23.17	120.31	1.39	7.22

TOTAL KWH USED= 84.89
TOTAL KWH SAVED= 1604.54

MONTHLY VARIATIONS FOR YEAR 5

JAN	50.	50.	21.40	122.09	1.28	7.33
FEB	50.	50.	11.47	118.13	.69	7.09
MAR	50.	50.	3.70	139.78	.22	8.39
APL	50.	50.	.00	138.86	.00	8.33
MAY	50.	50.	.00	143.49	.00	8.61
JUN	50.	50.	.00	138.86	.00	8.33
JLY	50.	50.	.00	143.49	.00	8.61
AUG	50.	50.	.00	143.49	.00	8.61
SEP	50.	50.	.99	137.87	.06	8.27
OCT	50.	50.	8.91	134.58	.53	8.07
NOV	50.	50.	18.13	120.73	1.09	7.24
DEC	50.	50.	24.21	119.27	1.45	7.16

TOTAL KWH USED= 88.82
TOTAL KWH SAVED= 1600.61

FIRST COSTS FOR CONTROL SYSTEM

DESIGN COSTS? .00
EQUIPMENT COSTS? 1200.00
INSTALLATION COSTS? .00

TOTAL DIFFERENTIAL MAINTENANCE COSTS/YEAR? .00

CONTROL SYSTEM SALVAGE VALUE AT END OF LIFE? .00

ECONOMIC LIFE OF SYSTEM? 10.00
OVERALL INTEREST RATE? 10.00

ANNUAL ENERGY COSTS

YEAR	BASE SYSTEM	CONTROLLED SYSTEM
1	101.37	4.58
2	101.37	4.64
3	101.37	4.86
4	101.37	5.09
5	101.37	5.33
6	101.37	4.58
7	101.37	4.64
8	101.37	4.86
9	101.37	5.09
10	101.37	5.33

TOTAL PRESENT WORTH(PW) COSTS AND
SAVINGS INVESTMENT RATIO (SIR) AT VARIOUS DIFFERENTIAL
ENERGY RATE INCREASES?

AT .0 % INCREASE/YEAR?

PW BASE?	622.85
PW CONTROLLED?	1229.87
SIR	.49

AT 3.0 % INCREASE/YEAR?

PW BASE?	718.71
PW CONTROLLED?	1234.55
SIR	.57

AT 6.0 % INCREASE/YEAR?

PW BASE?	831.51
PW CONTROLLED?	1240.07
SIR	.66

AT 9.0 % INCREASE/YEAR?

PW BASE?	964.33
PW CONTROLLED?	1246.57
SIR	.76

AT 12.0 % INCREASE/YEAR?

PW BASE?	1120.76
PW CONTROLLED?	1254.24
SIR	.89

AT 15.0 % INCREASE/YEAR?

PW BASE?	1304.98
PW CONTROLLED?	1263.29
SIR	1.03

Appendix A: Running the Program on the IBM Personal Computer

To run program CONTROLITE (CONLT) on the IBM Personal Computer, the following process is followed:

(if twin disk version)

1) Log onto drive A (default-drive)
2) Place program diskette in drive A
3) Place the Input/Output diskette in drive B
4) Type CONLT and hit return
5) Answer Input prompts with appropriate responses
6) Output will either be directed to the printer, or a user specified file, upon execution of the program and response to output prompt directives. If the output is written to a file, the user can obtain a listing of the file by typing, TYPE B: filename.

(if single disk version)

1) Log onto drive where program diskette resides
2) Input files are also to reside on same diskette as program
3) Type CONLT and hit return
4) Answer Input prompts with appropriate responses
5) Output will either be directed to printer, or a user specified file, upon execution of the program and response to output prompt directives. If the output is written to file, and the system is logged on Drive A, the user can obtain a listing of the file by typing, TYPE A: filename

To obtain a hard copy listing of output the user must hit the Ctrl-PrtSc Keys simultaneously before output is listed to monitor.

Appendix B: References

1. H.J. Bryan, R.D. Clear, J. Rosen, S. Selkowitz, "Quicklite I: New Procedure for Daylighting Design," Solar Age, Vol. 6, No. 8, August 1981, pp. 37-47.

2. H.J. Bryan, D.L. Krinkel, "Validation of the Microlite I Daylighting Model", Proceedings of the 1983 International Daylighting Conference, February, 1983, pp. 135-139.

3. S. Selkowitz, "Memo to Quicklite I Users: Availability of Quicklite I Basic Listings," Windows and Daylighting Program, Lawrence Berkeley Laboratory, November, 1981.

Appendix C : FINAL REPORT OF COMPLETED PROJECT

UNDER PURCHASE ORDER 4522110

for

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

by

LIGHTING TECHNOLOGIES INC.

INTRODUCTION

Lighting Technologies Inc. corrected and expanded the existing Controlite program which predicts energy savings due to various types of lighting control systems and strategies. The program was made suitable for distribution to the public domain so as to be useful and easily accessible for those involved in lighting design and energy analysis.

PURPOSE

The purpose of this project was to produce an integrated computer program which calculates daylight illuminances in a building space and computes the energy savings and cost-effectiveness for various types of lighting control systems and strategies.

TECHNICAL WORK

Task 1 - Correct Errors in Controlite

The reason for this task was to assess the existing model and program code of Controlite making a thorough investigation of its capabilities, and correct all a known as well as potential program errors.

The known program error concerning incorrect results in monthly variations was found and corrected. The problem was that of a ratio of (days used/days in a week) missing in the total energy and cost equations. Several program changes were incorporated so as to check for cases of mathematical instability due to the fourier series.

A complete description of the discovered errors, corrections, and verification of changes by test examples can be seen in the deliverables for Task 1.

Task 2 - Modify Controlite for 12 Day per Year Analysis

The reason for this task was to increase the capability and accuracy of the program by permitting energy savings analysis to be performed 12 times a year as a program option.

The increased capability allows for a closer modeling of the yearly daylighting contribution, as well as suppling the fourier series more data for a more accurate model of the yearly daylighting curve. With greater sampling of data this allows for monthly variations of daylighting where series interpolation using only four per year is not sufficient.

A complete description of the program changes and verification of changes by test examples can be seen in deliverables for Task 2.

Task 3 - Incorporate Quicklite

The reason for this task was to make program Controlite easier to use by allowing the user to calculate natural illuminance values at run time instead of using some other alternate method. This capability was to be added as an optional interface.

Quicklite, an existing daylight calculations program, was coupled to program Controlite for optional natural illuminance calculations. Quicklite employs a quick, yet accurate, model for calculation known as the daylight factor method.

A complete description of this program enhancement and verification of the neccessary program changes can be seen in the deliverables for Task 3.

Task 4 - Convert Controlite/Quicklite program to IBM Personal Computer

The reason for this task was to make the program Controlite easily accessible, or easily available. This was to be done by converting the program to run on a widely used personal computer.

Source code developed in tasks 1-3 was converted to run on the IBM Personal Computer. The program was converted such that all capabilities, user instructions, and output are identical to that of the VAX 11/780 version.

A complete description of this process and verification of the converted program can be seen in the deliverables for Task 5. These deliverables include documentation of the program.

Task 5a - Quicklite Program Validation

The reason for this task was to validate the mathematical model and program of Quicklite. Tests were to be run in order to determine the model's ability to predict natural illuminances under realistic conditions.

Test runs were produced under various conditions for a single day by Lighting Technologies. These test runs were compared with measurements performed by staff at LBL in a scale-model mockup facility representing the conditions used for calculation. This procedure verified the program's ability to model a realistic situation. A copy of the test runs can be seen in the deliverables for Task 5a.

Task 5b - Controlite Program Validation

The reason for this task was to validate the mathematical model and program of Controlite. Tests were to be run in order to determine the models ability to predict energy savings under realistic conditions.

Consultation was given by Lighting Technologies staff in experimental design to verify program and mathematical model. The scale-model mockup facility used for Task 5a was used again to acquire measured values to compare with the calculated values of Controlite. Quantities measured include natural illuminance values and power used to meet a criterion illuminance level. The natural illuminance information was used directly in the Controlite program to predict energy used and saved. A numerical integration over the period of the survey revealed a surprisingly high correlation between measured and predicted values.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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