TURBO-CHARGED LIGHTING DESIGN

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ABSTRACT

The task of the lighting designer has become very complex, involving thousands of choices for fixture types and hundreds of possible lamps. The designer who can consider the most combinations of these items guarantees each client the optimal lighting conditions and the best energy efficiency. This kind of professional service, however, is not available from the software design programs presently on the market. These programs generally let the designer analyze one room at a time, while providing perhaps three possible fixtures to choose from. Additional choices can be accessed from the software's data base, though at considerable expense in time and patience. This is a real hindrance when designing for a complex structure such as a hospital, which has many spaces with different task-specific lighting standards. The author was challenged by lighting-level requirements that spanned the range of possibilities, and was able to devise an accurate, expedient solution using a dBase language program. The result was a powerful tool integrating the entire gamut of design possibilities provided by the luminaire industry.

INTRODUCTION

A typical lighting design program consists of several diskettes full of data. The majority of the disk space is devoted to raw data on the many fixture types available. The balance of the space is given to the actual mechanics of the lighting.

The first problem to be solved in the design of a lighting program is the storage of the fixture data itself. Until quite recently a large volume of data could not be stored on a personal computer. At best it could be accessed by a time-consuming, tedious procedure. Consequently, electrical designers rarely investigated the quality of light specified for their projects. Rules of thumb and experience were the unspoken standard, and their broad generalizations were rarely questioned.

This need not be the case. In fact, it increasingly cannot be the case. City, state, and federal codes are becoming more prevalent, specifying exact criteria for lighting levels and electrical consumption. These authorities will not accept estimates and generalizations. As a result, the lighting designer spends an increasing amount of time fine-tuning lighting and luminaire characteristics to suit the design criteria.

Fortunately, new innovations in computer software make it easy to expedite these design problems. First, the advancement in data base applications permits the storage of tremendous quantities of data, so that it can be quickly and effectively accessed. Second, an entirely new language has been developed to manipulate this data, so that the ingenious programmer can build a versatile setup, not only to perform calculations, but to display and print out the data in a format acceptable to code and regulatory authorities.

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****** LIGHTING CALCULATIONS WORKSHEET *******

------------------PROJECT DATA --------------
      Project Name              [                    ]
      Project Location          [                    ]
      Project Number            [                    ]
-------------ROOM-BY-ROOM DEFAULTS -------------
            Number              [                    ]
            Function            [                    ]
            Work Surface        [                    ]
            Length              [                    ]
            Width               [                    ]
            Ceiling Height      [                    ]
---------------FIXTURE DATA -------------------
            Fixture Type        [                    ]
            Quantity            [                    ]
            Lamp Type           [                    ]
------------------CALCULATED VALUES -------------
            Room Cavity Ratio [                      ]
            Coef. of Utilization[                    ]
            Footcandles Calc  [                      ]
            Watts Total       [                      ]
***********************************************
```

FIGURE 1: Lighting Design Screen

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All this can be done on an inexpensive PC using a popular data base software package, dBase IV. The end user does not have to own dBase to use the design program. The application can be made into a stand-alone package using a run-time option available from dBase.

DESIGN OBJECTIVES

The completed lighting program first establishes several default values for a job that the lighting designer often performs: (1) Fixed values for the Lumen Depreciation Factor and the Maintenance/Dirt Factor; and (2) Fixed values for Floor, Ceiling and Roof Cavity Reflectances (e.g., 80/30/20). These inputs can later be modified on a room by room basis.

The working part of the program draws from three sources of information: (1) Stored records of coefficients of utilization for fixture types: (2) Data on lumens and watts for lamp types; and (3) Input values for room dimensions and reflectance. Each of these data sources are accessed from a design screen (See Figure 1)

A keystroke action by the user causes the calculations to be done, and the resultant footcandle value is displayed on the screen. Then the fixtures are changed until the necessary light level is obtained. The room and fixture data is then copied into a permanent file, and the screen made is ready for the next room lighting calculation.

Version 1.1 of dBase IV is used to do all of these things from a single computer screen, without having to call up other screens, or having to exit the program altogether to read new fixture data into the active data file. All the required information on the room is typed into the form by the user, including fixture type, fixture quantity, and lamp type. The designer simply enters all this data and presses a key on the terminal.

The computer then calculates the footcandle level and displays it on the screen. If the value is too low or too high, the lamp type, fixture type, or quantity can be changed and another value is calculated immediately, and displayed.

** LIGHTING CALCULATIONS WORKSHEETS ***

---------------- Room-By-Room Defaults ----------------	
Floor	[ ]
Ceiling Height	[ ]
Work Surface	[ ]
Lamp Type	[ ]
---------------- Room Data for Calcs ------------------	
Room	[Office]
Function	[Drafting]
Length	[20.0]
Width	[15.0]
Fix Qty	[7]
Fix Type	[4]
FC Required	[100]
----------------- Calculated Values -------------------	
C of U	[ ]
R.C.R.	[ ]
Tot Watts	[ ]

*************************** Fixture Menu ***************************			
--------- Lensed	-------------------------	Parabolic --------	
• 1	1 x 4L - 1L	11	1 x 4P - 1L
• 2	1 x 4L - 2L	12	1 x 4P - 2L
• 3	2 x 4L - 2L	13	2 x 4L - 2L
• 4	2 x 4L - 3L	14	2 x 4L - 3L
• 5	2 x 4L - 4L	15	2 x 4L - 4L
• 6	2 x 2L - 1U	16	2 x 2P - 1U
• 7	2 x 2L - 2U	17	2 x 2P - 1U
• 8	4 x 4L - 4L	18	4 x 4P - 4L
• 9	4 x 4L - 6L	19	4 x 4P - 6L
• 10	4 x 4L - 8L	20	4 x 4P - 8L
-------------------- Incandescents/Others ------------------			
• 21	RCSD - 075W 26	FLOOD - 050W	
• 22	RCSD - 100W 27	FLOOD - 100W	
• 23	RCSD - 150W 28	FLOOD - 150W	
• 24	RCSD - 200W 29	FLOOD - 200W	
• 25	RCSD - 250W 20	FLOOD - 250W	

FIGURE 2 A DESIGN SCREEN WITH AVAILABLE FIXTURE TYPES

This kind of flexibility is a great asset to the lighting designer, who has ready access to over one hundred fixture types and as many lamp types. Furthermore, careful organization of the data allows the user to quickly toggle (i.e. to change from one parameter to another by pressing a single key) from lensed-to-parabolic fixtures of the same type to see the affect on FC level; or to move between lens types, manufacturers of equivalent fixtures, and lamp types or manufacturers (e.g. from a fixture made by one manufacturer to the equivalent of another, or from a parabolic 3-lamp 2x4 to a lensed 3-lamp 2x4 luminaire, or from a 40-watt to a 34-watt energy-saving lamp in the same fixture).

As shown in Figure 2, the most commonly used fixtures are listed on the right half of the screen. The remaining fixtures are accessed by typing a numeric code in the "Fixture Type" blank on the form. A few prevalent lamp choices are also available. They can be changed and/or sequenced through while the cursor is in the "Lamp Type" position.

Once the best FC value is obtained another keystroke reads the room data into a project-specific data base file. Then the screen is cleared of values, and is ready for another calculation.

Additional features include data sharing, where certain values such as "Ceiling Height" and "Work Surface" keep the same values throughout the work session. These numbers do not have to be typed over and over again for each room. Ranges, default values, and error messages are specified for most values to make the program user-friendly and relatively error resistent.

The most versatile feature of the program is the data base that the program forms of all the inputs and calculations. This information can be viewed in tabular format (see Figure 3) and edited in that context too. Then if any subsequent calculations are needed, the values in the table are changed as needed, and the FC level is automatically calculated and inserted into the table. This is done by calling a batch file that performs the calculations on each record in the entire data file. Thousands of rooms can be reviewed, edited, and then analyzed in a matter of minutes!

An experienced lighting designer can even get by without ever using the design screen. All the data can be entered in this table instead, the designer making educated guesses on fixture quantities and type for a complete building. The computer will then perform the FC calculations on command, and even modify the data where required to produce the needed light levels.

ARRAY ARITHMETIC

The first task in building a dBase application is to create a data file on the fixtures. A simple screen, designed with the help of the program software, will read everything into a data file (See Figure 4). The lamp type and lumens - usually provided by the fixture manufacturers in their specification sheets - are typical values. They can be changed in the design process, however, as conditions require. Also, Figure 4 shows only one series of Room Cavity Ratios. The complete data set of RCRs is input using a similar format. The computer will interpolate between these standard values input among the reflectance ranges.

A good working fixture file, consisting of the most common fixtures used, is listed in Figure 2. Another, more specific set, is listed in Figure 5. In the latter case, note the inclusion of "Type" in the figure. This is a user-defined designation that applies to a specific job. It relates the fixtures to specific marks on the drawings, and can be printed out to generate a schedule of lights for the job.

In a simple case, the fixture data is read into a 10-column by 32-row array. The RCR data is arranged so that the RCR value of 4 for fixture type #21 is element [4,21]; the RCR of 5 for this fixture is element [5,21], etc. This makes it possible for the calculations to be performed quite easily using variables in array addresses (i.e. fix[xx,yy]), and for data on many fixture types to be stored in Ready Access Memory (RAM).

The only limit is the size of array that can be compiled by the software. dBase IV version 1.1 allows up to 1100 elements. This equates to a 10x110 fixture file (i.e. 110 fixtures at a given reflectance value).

The program also stores data on lamps, lumens, and watts for each fixture, so that in a 13x32 array, the lamp data is stored in the last two elements of each row of the matrix (elements [12,21] and [13,21] for fixture #12).

The RCR data, we have seen, is stored in slots that are equivalent to the number itself (i.e., all values for RCR =1 are in the first column; for RCR =2 in the second column, etc., corresponding to a matrix address of [1,x], [2,x], etc., x being the fixture type). This allows the program to access the coefficient of utilization data easily. That is, the program performs the following sequence of operations from the design screen:

1) Reads room data into public variables.

l = length
w = width
h = height
ws = work surface

2) Calculates the room cavity ratio.

$$rcr = 5*(h-ws)*\left[\frac{l + w}{l * w}\right]$$

3) Rounds this number to the nearest whole number

RCR = ROUND (rcr)

This generates a value that pinpoints a specific coefficient of utilization at a unique element in the array.

4) C of U = array element[RCR, fixture #]

The coefficient of utilization data is readily accessible, and subjected to the mathematical operations of footcandle level calculations. In fact, the program interpolates between the coefficient of utilization values provided by fixture manufacturers and this generates more accurate lighting calculations.

THE DATA STRUCTURE

To review what has been accomplished so far:

1) It is easy to add fixtures to the data base via the fixture data entry form.

2) This fixture information is read into a matrix in a specific way so that the array elements are related exactly to fixture characteristics.

3) The room information is used to compute an exact value for the coefficient of utilization.

4) The computer operator is able to choose from up to 100 fixture types which have been loaded into RAM. The C of U associated with the fixture type and the RCR is also readily accessible in the RAM.

ON-SCREEN CALCULATIONS

The lighting program uses all the data provided on the screen - room characteristics, fixture data, lamp type - and calculates the footcandle level when prompted. By the time Figure 2 is displayed on the screen, however, the computer has already done a lot of behind-the-scenes work.

First, the form itself was loaded into the active memory, RAM. Variable names have been assigned to each blank on the form. These variables correspond to positions in a data base file, e.g., the columns of Figure 3. This allows the program to use the inputs to calculate RCR, C of U and FC levels. It also simplifies the storage of data into a permanent file when instructed by the user.

Second, the program has read data into the fixture file. This information is read into an array which is then stored in RAM. This means that the RCR data of any fixture is immediately available to the program, as a system variable.

This RCR data, plus the variables from the screen - height, length, and width, - are used to calculate the room coefficient of utilization.

Finally, the program knows what to do when the "calculate" keystroke is hit. It first takes more values out of the lighting fixture data file, for the number of lamps, the lumens output, and the watts of the fixture. These numbers are located in specific positions in the array, (e.g. [11,x], [12,x], [13,x]), "x" being the fixture number) and are used to find the FC level as follows:

ROOM DATA					LUMINAIRE DATA				FOOTCANDLES	
ROOM #	NAME	LENGTH	WIDTH	HEIGHT	QUANTITY	TYPE	BULB	TYPE	REQ'D	CALC'D

FIGURE 3 THE BROWSE/EDIT SCREEN

1) Data is keyed to the fixture type, which has been read from the screen into the variable "x".

```
bulbs = array [11,x]
lumens = array [12,x]
watts = array [13,x]
```

2) These values are used in conjunction with the numbers from the design screen for length, width, and quantity of fixtures in the room.

3) The C of U is calculated as described above.

4) All these quantities are used in the equation:

FC = (lamps * lumens * quantity * CofU *.80)/ (length * width)

Where the 0.80 is a default value for the combination of lumen and dirt depreciation factors. This is itself a variable quantity that was initially set from a special screen for default values.

5) A value of FC is found and displayed on the screen along with the calculated values of RCR and CofU. The program then reverts to the edit mode.

6) The operator moves the cursor around the screen, changing fixture types or quantity, then prompts the computer to display the FC level under the new conditions.

7) Striking another special key at this point will read the data into the lighting file and clear the screen for the next calculation.

The designer has access to over one hundred fixture types (expandable indefinitely). The most useful ones are displayed on the screen. The balance are accessed via keyboard commands.

"DESIGNER" SOFTWARE

Future enhancements to the program described thus far include the ability to specify different lamp types in the fixtures. This increases the range of the lighting values possible for any given fixture, and also permits the user to consider the quality of light (e.g., the chromatic index) provided, especially by fluorescent fixtures.

For those who want to maximize energy efficiency, special lamps can be substituted in fixtures to determine the approximate footcandle level with the new lamps.

A second feature that can be designed into the program increases the number of fixtures that can be stored in RAM to be readily accessible to the user: a curve-fitting routine that generates a least-squares fit to the RCR data. This reduces the number of data points needed to fully describe the fixture from one hundred to less than ten.

For those fixtures which can be represented in this manner - and this includes almost all fluorescents, plus others with a uniform photometric data - the single equation format has two more advantages: (1) interpolation between RCR values is fast and accurate, and

```
******************** LIGHTING FIXTURE DATA INPUT FORM ********************

                    Description      [                    ]
                    Type             [                    ]
                    Bulb             [                    ]
                    Watts            [                    ]
                    Lumens           [                    ]
------------------------ Cavity Ratio Figure ------------------------------
                    >RCR = 1         [                    ]
                    >RCR = 2         [                    ]
                    >RCR = 3         [                    ]
                    >RCR = 4         [                    ]
                    >RCR = 5         [                    ]
                    >RCR = 6         [                    ]
                    >RCR = 7         [                    ]
                    >RCR = 8         [                    ]
                    >RCR = 9         [                    ]
                    >RCR = 10        [                    ]
```

FIGURE 4 FIXTURE DATA ENTRY FORM

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(2) extrapolation to conditions outside the given data set is accurately done. As such, few manufacturers provide information in room reflectances over 80%, and paint manufacturers designate reflectances for their products above this value for as many as half of all their paints.

Other curve-fitting routines can be easily written in the dBase programming language to represent a family of curves for which the least-squares fit is inadequate: the power and exponential curve-fitting functions. Each of the methods outputs coefficients on the correlation of the curve to the data, so the dBase program can be instructed to choose the method that provides the best fit.

A third possibility can be done on the faster PCs. The technique described earlier calculates the data only when a special key is hit by the user. dBase permits the user to cause a full calculation to be done after every key stroke. The effect of this on the existing routine is barely noticeable on a 20 mHz machine, and provides for a faster design sequence as the final values are always displayed real-time, as in a spreadsheet.

CODE	TYPE	DESCRIPTION	NOTES
1.	A	2x4 - 2L	
2.	B	2x4 - 3L	FL - Fluorescent
3.	C	2x4 - 4L	VP - Vandelproof
4.	D	2x2 - 2L	
5.	E	1x4 - 2L	
6.	F	4x4 - 6L	
7.	G	4x4 - 8L	
8.	H	1x4 - 2L	Wall Mtd. VP
9.	I	1x4 - 2L	Surf./Stem
10.	J	1x4 - 2L	Rec. FL
11.	K	4' Wall Mtd. FL - 2L	
12.	L	3' Wall Mtd FL - 2L	
13.	M	2x4 - 2L	
14.	N	2x4 - 6L	
15.	O	4' -PAT, Wall FL - 4L	
16.	P	150W INC	
17.	Q	100W INC	
18.	R	75W INC	
19.	S	150W INC	
20.	T	RD Rec - FL - 2X13W	
21.	U	Under floor INC 150W	
22.	V	Ext. Wall -HPS - 70W	
23.	W	Ext. Wall -HPS - 150W	
24.	X	Exit Unit	
25.	Y	Ext. Rec. RD -HPS - 70W	
26.	Z	Ext. Rec. RD -HPS - 150W	
27.	AA	Round Cylinder - 250W	
28.	BB	Round Cylinder - 250W	
29.	CC	Dark Room Unit	
30.	NL	Night Light, 25W	
31.	PL-1	Pole MTD - 190W, LPS	
32.	PL-2	POLE MTD, 2 - 190W, WLPS	

FIGURE 5 A JOB SPECIFIC FIXTURE FILE

For slower machines and bulkier programs, an option is to test all of the screen values before any calculation is done. This in turn can cause the routine to branch to a specific portion of the calculating program, and speeds up the response time considerably. It is also possible to track which values are changed by the user, and to further modify the calculation sequence to check for changes in these values first. And so, as a specific user becomes more adept at the design sequence, the computer is able to operate more effectively as well.

CONCLUSION

This paper introduces the lighting designer to a dBase program. The specific structure has been given and helpful formats were described for data entry and organization. These will be helpful later, when you begin to use the software. The key to the lighting design was to develop first a familiarity with organizing the types of data needed. Then, active matrices were created to store the necessary fixture data. Finally, access to the data base was done from a screen form which was also used to generate and store the calculated results. The many unique features and design aids are possible because the system is supported by a powerful data base management software.

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