The Technology of Lighting

ABSTRACT

Energy engineers performing audits need a method to evaluate lighting retrofits, and to determine the light levels that result. The computer program uses published coefficients of utilization and calculates room light levels by the zonal cavity method. Light levels for non-standard lamps in the fixtures are calculated by a direct ratio of lumens, before and after. The user inputs all data for each room, including existing fixture type, lamp type and required footcandles. The program then selects a lamp from a set designated by the user. The lamp chosen will provide light closest to the target footcandles, and at the lowest wattage. This determination is made automatically for every room in the file, then the cumulative annual energy savings is calculated. This value includes actual electricity cost savings, as well as savings from a reduced cooling load. The program is ideal for use in studying large, varied-use buildings and illustrates how substantial savings can be obtained by using two or more different lamps in a facility, rather than a single type throughout.

INTRODUCTION

Lighting retrofits are a common energy conservation project because they are inexpensive, easy to implement and have quick paybacks. The lighting levels available after the retrofit are seldom taken into consideration, however; other than by stating that," A 10% reduction in light levels is acceptable to the owner."

In actual practice even a 10% reduction in lighting may sometimes be unacceptable. In a school room for example, where present lighting is marginal, anything less would substantially degrade the lighting (and learning) environment. Conversely, other areas may be less affected by such a change, such as hallways, restrooms or lobby areas.

In either circumstance, the lighting designer rarely analyzes the lighting room-by-room. It's a tedious, time-consuming process that is difficult to accomplish using existing software. Also, building tenants are unwilling to maintain inventory on more than one lamp type, so lighting projects must be of a single lamp type or not at all.

Owners of larger buildings would do well to consider the alternative. The economics of using two or three lamp types can be compelling, especially when maintenance is reduced to an acceptable level. The former is accomplished by the computer program The latter is done by (1) using a single lamp type in each space and (2) color-coding the lamps for ease of maintenance and replacement by the engineering staff.

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A feature of the software is the ability to use a specific color of lamps for an entire wing, building or department. Lamps of equal color, but of different lumen rating, can be selected for such areas to provide exact lighting levels. Thus energy is conserved and quality of the lighting environment is maintained. Spaces that might benefit from special color lamps are lab areas, recreational or residential spaces.

Further advantages accrue from keeping on file all of the building luminaire data. As new lamps and technology become available they can be easily incorporated into the facility. As space usage and occupancy change, the new lighting requirements can be determined on the spot by the maintenance staff. As tenants change, their lighting needs can be catered to immediately.

Given the focus of the program, to specify fluorescent lamps for varied spaces in a facility, the program is limited to four foot length lamps. There are usually enough fixtures with these lamps to justify maintaining an inventory of two or more lamp types. There are many high-efficiency fluorescent lamps presently on the market that afford the lighting designer a wide range of energy-saving possibilities.

DATA ENTRY

Simple forms are used to enter data to the job file. The forms have prompts, help screens and error messages that warn of unusual or unacceptable data values. The fixture and lamp files are accessible from any project file.

Fixture data is entered by a simple screen for a single set of reflectances, 80-50-20 (wall-ceiling-floor). The design lamp and design lumens, used to ascertain the published coefficients of utilization, are also entered for each fixture. A subsequent screen will browse through all the fixtures on file and permit the user to identify select fixtures by customized type designations.

Lamp data is read to a permanent file from a second data entry screen. Specific values are required for initial lumens, lamp life, base type and ballast type. Again, another browse screen will display all the lamps on file so the user can identify select lamps by alphanumeric designators.

FIGURE 1 ASSIGNING LAMP IDENTITY TAGS

LAMP	ID	MFGR	LUMENS	WATTS
11	F40CW	GE	3150	40
22	F4022/SSP	SYLVANIA	2800	32
33	F40/D41/SSP	SYLVANIA	2925	32
44	F40CWTM33	SYLVANIA	2525	32
55	F40/D835/55P	SYLVANIA	3000	32
66	F40CW/55P	SYLVANIA	2750	32

The program is loaded with a selection of fixture and lamp data from several manufacturers. These data can be supplemented by the above method(s) as required. Normally, the user will have on file the favored luminaires and will enter the program and proceed directly to the building data entry form.

The **building data** is entered one room at a time, to include room dimensions, existing *lamp and fixture type* and required footcandle level. The lamp and fixture are identified by abbreviations previously entered. Ceiling height and work surface height are default valves that are automatically read into each record, but can be changed easily.

Other **default valves** are entered on a special form that, again, will seldom need modification by the user. This form is for electric rate, occupied hours/week, ceiling height, work surface height and the lumen maintenance/depreciation factor. Other values, discussed in the following section, will impose limits on the calculations. Such limitations may be imposed at the client's request.

FIGURE 2: DEFAULT PARAMETERS

Maintenance Factor	0.88%
Occupied hours/week	65 hours
Electricity Rate	0.087 $/kwh
Demand Elec. Change	$10.00/kw
Work Surface Height	2.50 feet
Ceiling Height	9.00 feet
Permitted FC Range	7 footcandles

CALCULATIONS

The data used for the luminaire footcandle distributions is stored in RAM by the computer. This greatly expedites the numerical analysis. The program numerically fits a line to the RCR data for each fixture as it is entered(using a least-square fit routine). This reduces from ten to two the numbers needed to represent fixture data. The affect on accuracy is negligible. This abbreviated method enables the program to access many more fixtures for the calculations, and speeds the calculations, which are iterated many hundreds of times with each run. This is possible because linear equations are used instead of the cumbersome file interpolation done using the manufacturers published data tables.

The lighting designer must be careful in the selection of lamps to be used for the calculations. Targeting ten lamps of varying lumens output allows a reasonable span from which to choose the lamp to match closest the required footcandle level. This selection is done automatically for every room in the project file. The new footcandle level and watts saved is then determined. The program also recognizes rooms that can have lamp(s) removed from the fixtures.

The software is designed to consider the different fixture geometries that exist. That is, an existing lamp will not be replaced with a lamp that requires a different kind of ballast. Nor will the program permit a lamp with one base type to be replaced by a lamp with an incompatible base.

In the **defaults screen** the user can limit the number of lamps in the final selection set; in this example, two. That is, the designer can identify ten lamps to consider for each room. The program will then iterate through the options for the entire building until the best two lamps are found for the greatest savings. Larger facilities managers may permit four or five lamp types. The additional trouble to the maintenance staff may keep smaller facilities from having an inventory of more than two lamps.

FIGURE 3: SAVINGS FOR TYPICAL OFFICE BUILDING

Building ID: Sam Houston

Lamps Selected:	Quantity:
#1	180
#3	22
#4	251
#5	15
#6	12

Savings

Watts/hr	2368 w.
Watts/yr	10617 kwh
Dollars	$1211.70*
No. lamps	5

* includes demand savings and cooling load savings.

The calculations output will identify the number of each lamp selected in the facility, plus the savings in metered electricity and the indirect savings to be realized from a reduced cooling load.

DATA REVIEW

Several **browse screens**, in which all the data is presented in a tabular format, are available to the user. One screen will list rooms with before and after lighting levels, plus a final column that lists the watts/hour saved in each room. Another screen itemizes by room the new lamp type and (if applicable) the potential of taking one lamp out of the fixture altogether.

The building data can also be accessed by a browse screen. This is helpful when performing a periodic update of the data base. New lighting levels, room dimensions or occupancy rates can be quickly entered and the calculations re-done immediately.

A full range of **output reports** are available. They itemize the savings potential, the room-by-room lamp types and the fixture and lamp data bases. A selection of printers and output configurations is available for printing out data on most common PC systems.

CONCLUSION

Lighting projects are a simple way to realize a quick, inexpensive energy conservation opportunity. If hastily done, though, they can result in a substandard living environment. It is important to verify the effect of lighting changes on crucial areas such as laboratories, classrooms, offices and reading spaces.

Use of a computer program to analyze a facility will help determine the actual footcandle levels in each space affected. Furthermore, the program permits the lighting designer to either save money or to improve upon an existing design. A better environment is the assured result.

Long term, having the entire facility on permanent file makes it easy to (1) take quick advantage of new energy-efficient lamps and (2) to modify the lighting environment to account for changes in space use or personnel.

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EXPERIMENT NO. 1

GIVEN: The coefficients of utilization matrix or a 4 x 4 fluorescent lensed fixture can be reduced to a set of equations with only eight variables - versus 150 in the matrix. These generate C of U's within 1% of the table values and automatically interpolate for RCR and wall roof and floor reflectances.

FIND:

1. Determine if the same process will work for other fixtures such as 2 x 2's and 2 x 4 fixtures.

2. Evaluate the variables in light of physical principles. For example Black Body radiation is the field of quantum mechanics that studies point sources of light. If the above analysis generates consistent results for many fixture types this may indicate a fundamental virtue of the light source.

PROCEDURE:

1. Validate the existing analysis of the 4 x 4 fixture (REF: attached table).

2. Input additional fixture data to the software that performs the matrix reduction tabulate results.

3. Study variables to discern any patterns evident.

4. If warranted by encouraging results set up a test room to measure accurately the C of U's in a control environment (or obtain same from the manufacturer) to compare with the calculated values from the equations.

APPLICATION: Investigation of Black Body radiation and the phenomena of light.

EXPERIMENT NO. 2

GIVEN: It has been proposed in the popular literature that several different light sources in a space, such as a task light, a down light and ambient daylight, will cause people to remain in that space longer.

FIND: A relationship between type of fixtures and the contribution of each to the overall light level, versus the time a test subject remains willingly in that room.

PROCEDURE:

1. Establish a test room that has two or more light sources, each dimmable independently. Exterior to this space must be a control area, with uniform lighting, such as by lensed 2 x 4 fluorescents.

2. Measure the light level (or calculate by a zonal cavity method) for each source independently, then the final level with all sources on.

3. Assign a task, such as a read, listen to music, etc., to the test subject, allowing freedom of movement in and out of the room.

4. Measure the time spent in the room, versus light levels, and correlate the data.

APPLICATION: Affecting students, employees, etc., to remain in a study hall or office longer; keeping some out of areas where they should not be.

EXPERIMENT NO. 3

GIVEN: A moderate light level in a space - e.g. "mood lighting" with soft, tasteful table lamps - will cause a subject to be more relaxed, open and comfortable than at harsh, higher light levels. This has been suggested by popular literature.

FIND: The relationship between the light level and the anxiety or openness of the test subject.

PROCEDURE:

1. Develop a series of questions to be answered by the subject under different lighting conditions: One room with industrial type fluorescent lighting, another more subdued and stylish.

2. Estimate the depth or "personalness" of the answers given - or simply the length of the written replies - under the given conditions.

3. Repeat the sessions several weeks apart, and under controlled circumstances, to compare the results.

4. Vary the light level, type of lamp, etc., to discern any noticeable effect.

APPLICATION: Police interrogation to obtain a more in-depth story from subjects, psychoanalysis, job interviews, instruction of students in a most effective environment.