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EVALUATION OF COMMERCIALLY AVAILABLE LIGHTING DESIGN SOFTWARE

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DISCLAIMER

ABSTRACT

For years the lighting industry has manually entered and manually performed calculations on the photometric data that is necessary for lighting designs. In the past few years many lighting manufacturers and private lighting design software companies have published computer programs to enter and perform these calculations. Sandia National Laboratories (SNL), and other interested organizations, are involved in outdoor lighting designs for Closed Circuit Television (CCTV) that require lighting design software programs. During the period when no commercial lighting design software programs existed, SNL first used a government agency's program and then developed an in-house program. The in-house program is very powerful but has limitations, so it is not feasible to distribute it to interested organizations. This program has been used extensively for many high security outdoor lighting design projects. There is still a demand for lighting design programs, so SNL has ordered several that are commercially available. These programs are being evaluated for two reasons: (1) to determine if their features are adequate to aid the user in lighting designs, and (2) to provide that information to SNL and other organizations. The information obtained in this paper is to be used to help an end user decide if a program is needed, and if so, to choose one. This paper presents the results of evaluations performed.

INTRODUCTION

SNL has been involved with designing outdoor lighting for high security perimeters for more than fourteen (14) years. The lighting provided was for exterior CCTV camera intrusion detection assessment. At the time, the CCTV cameras used a one-inch-format silicon-image-tube. The illumination requirements associated with these cameras (for a sodium vapor luminaire) for intrusion detection assessment are 1 footcandle minimum illumination and a maximum light-to-dark ratio of 6:1 in the camera's field of view.

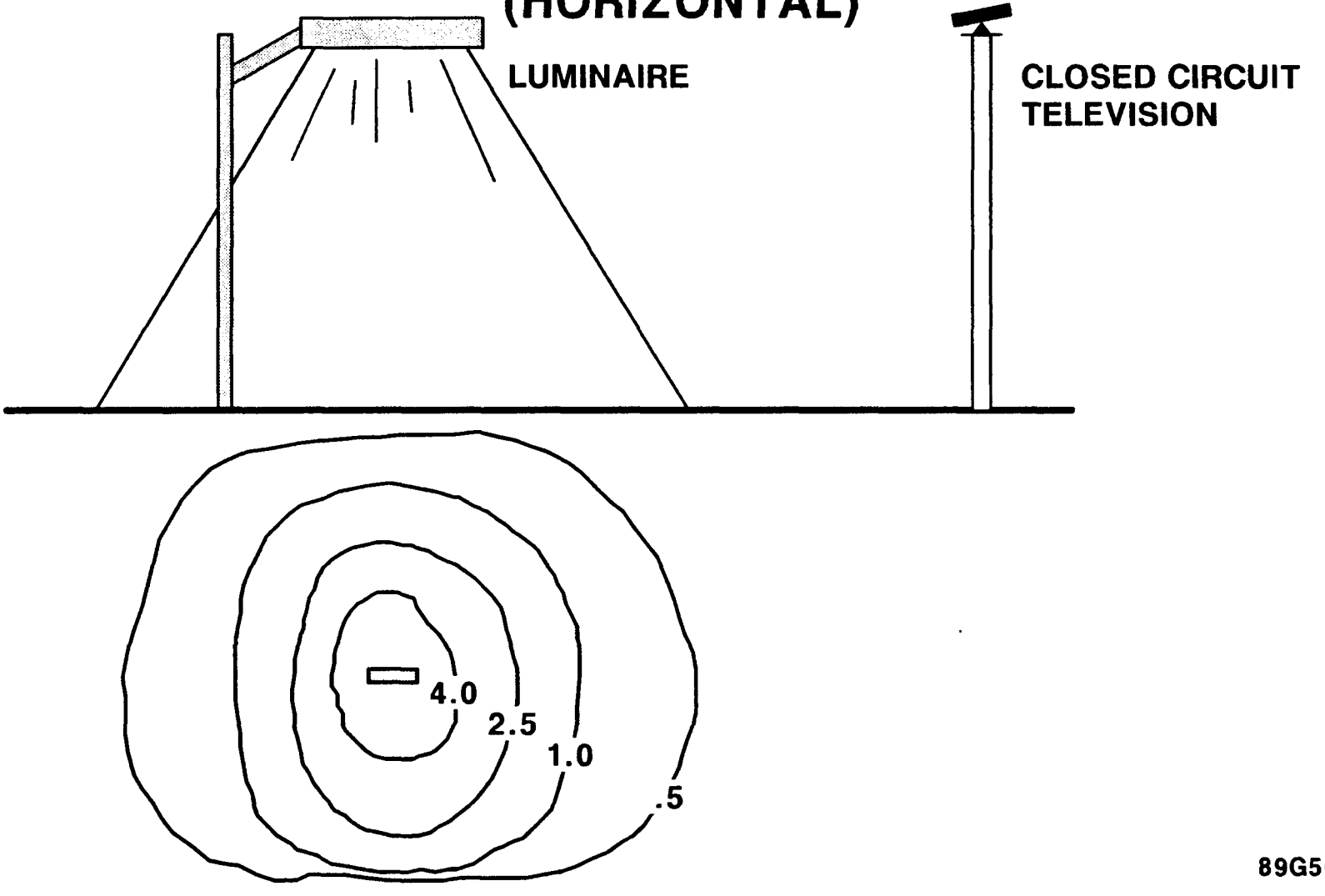
Prior to computer modeling, when SNL acquired a lighting project, an exterior testbed consisting of luminaires and a CCTV assessment system was

built. Figure 1 shows a luminaire installed next to a CCTV camera tower. The luminaire illuminance is shown by the pattern at the bottom of the figure. This pattern can be thought of as the footprint of the luminaire. The illuminance values are in footcandles (fc). Figure 2 shows the fc levels related to an x-y coordinate grid with the (0,0) coordinate being in the lower left hand corner. Each fc level shown on the grid at the bottom of the figure corresponds to a certain x-y coordinate (specified in feet) as defined by the x-y axis grid shown at the top of the figure. Ballpark estimates of fc levels were derived from lighting manufacturer's isolux diagrams. Then luminaires were rearranged as to type, mounting height, spacing between poles, etc., until the illuminance values met the video requirements. After a number of these projects, it became apparent that a better process be found. The testbed approach was too costly in time, equipment, and manpower. Computer modeling seemed to be the better process.

Unfortunately, SNL had no lighting design software program and, at that time, there were none commercially available. A short time later a program was borrowed from a government agency and used for a few years. This program was a slight improvement over the testbed approach. About five (5) years ago an in-house program was written. This program performed all the mathematical calculations previously done by hand. It also provided luminaire fc level print-outs in grid form and many other unique features. This is a very powerful program and has been used in many security perimeter lighting layout designs. Yet, this program was not distributed to interested organizations due to these primary factors: 1) the program was written solely for the HP 9000 series 200 computer (9836C); 2) there is no documentation (i.e., user's manual); 3) a user needs to be quite knowledgeable of lighting; 4) it cannot use standard format photometric data files; and 5) all photometric data files must be entered by hand.

SNL was left with a good lighting program, but few people could use it. Several other organizations have expressed an interest in obtaining their own lighting program, presenting us with two options - rewrite our program to be more compatible with other computer systems and

LUMINAIRE LIGHT PATTERN ON THE GROUND (HORIZONTAL)



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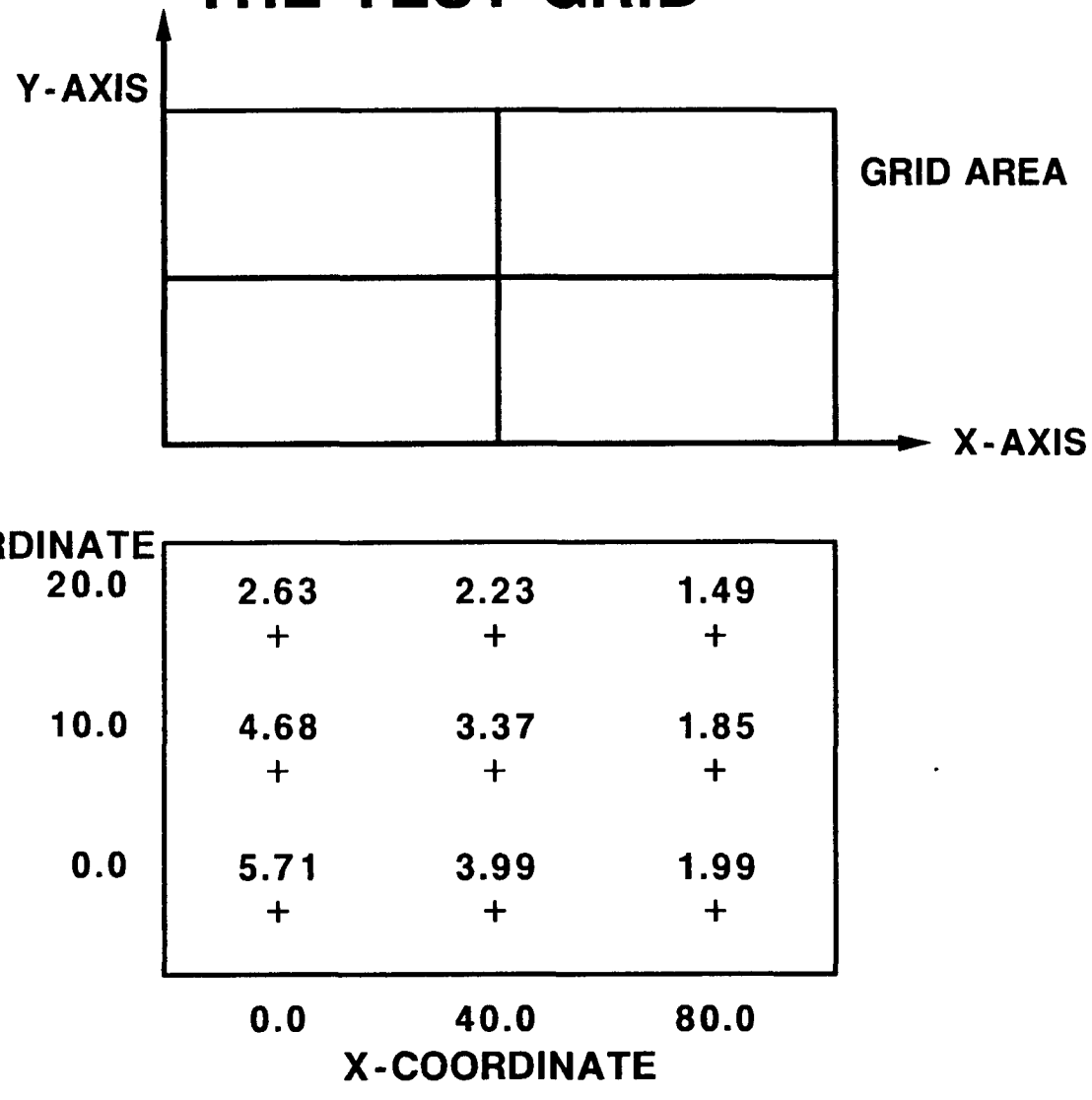
THE TEST GRID



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with a standard photometric data file format, or wait for commercially available lighting design programs to be developed by other companies. Due to time and manpower constraints, the decision was to pursue the commercially available lighting programs' option. So, commercial programs were sought, ordered, and then evaluated.

As a service to the lighting community, the Computer Committee of the Illuminating Engineering Society of North America (IESNA) publishes a list of commercially available lighting design programs (see Appendix A). They supplied SNL with this list. This was a thorough listing of indoor, outdoor, and indoor/outdoor programs. SNL was only interested in outdoor applications at this time, so only companies specifying outdoor or indoor/outdoor programs were contacted.

IESNA also provides a standardized format for lighting manufacturers' photometric data files (see Appendix B). They encourage all lighting manufacturers to publish their data in this format. IESNA also encourages all lighting design program manufacturers to write their programs to utilize the IESNA format for photometric data. The IESNA format will allow for universal use of <u>all</u> manufacturer's photometric data when <u>all</u> the lighting manufacturers publish their data in this format and <u>all</u> lighting design programs are written to accept this format. This will be a giant step towards standardization in the lighting industry.

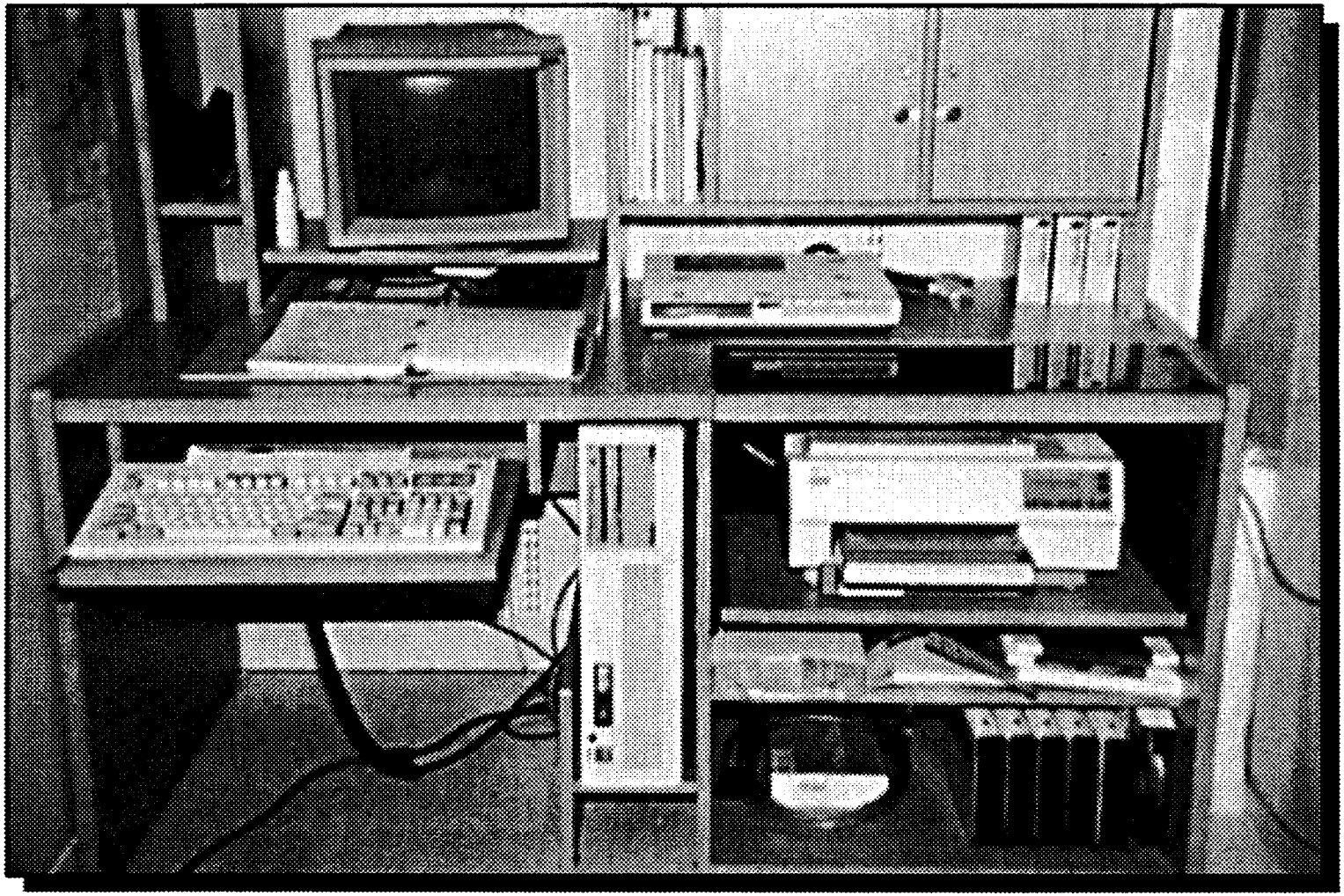
Therefore, two primary evaluation features are IBM personal computer compatibility and the ability to read IESNA formatted photometric data. The other primary evaluation features are program accuracy, user friendly programs, ability to adjust light loss factors, documentation, support and/or training, and updates.

All the features used to evaluate the lighting programs will be listed. The most important items will be explained. A listing of all the programs evaluated and tables showing how they fulfilled the evaluation features are included in this report.

EVALUATION EQUIPMENT

The computer system used during evaluations was an IBM PC/AT with a 30MB hard disk drive and 640KB of Random Access Memory (RAM) (Fig. 3). The Disk Operating System (DOS) was IBM version 3.30. Peripherals attached to the computer were a NEC Multisync color monitor and a HP Laserjet II printer. There was one high density 5 1/4" floppy disk drive. For SNL's purposes several lighting programs were installed on the IBM at the same time. Due to the installation instructions of

EVALUATION EQUIPMENT



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some of the lighting programs, most of the programs had to be installed directly onto the root drive rather than in separate sub-directories.

EVALUATION CRITERIA

PRIMARY FEATURES

Items considered primary features for evaluation were: IBM personal computer compatibility; to accept or be supplied with IESNA formatted photometric data files; program accuracy; user friendliness; the ability to adjust light loss factors; and to provide documentation, support and/or training, and program updates. The following paragraphs explain these features in more detail.

A program that can be installed on an IBM personal computer or IBM compatible personal computer could be used immediately in virtually every office and many homes in America. Therefore, all lighting programs evaluated should have been IBM personal computer compatible to be usable by a maximum number of end users. All of the programs were IBM compatible. Some programs come with 5-1/4" disks, some with 3-1/2" disks, and some with both sizes. Either or both sizes can be specified when ordering most programs.

In order to make end user's tasks much easier and help continue standardization of the photometric data file format in the lighting industry, programs having the ability to run IESNA formatted photometric data files were desired. Some lighting programs use only their own specially formatted data files supplied with the program. That is fine, but they should also accept IESNA formatted data files. If a program did not accept IESNA formatted data files, but came only with its own data files, it was still evaluated. However, a recommendation was made to the program manufacturer for a revised IESNA format version to be published. Unfortunately, when a lighting manufacturer publishes a program that only accepts their own photometric data format, the user is forced to obtain that program in order to evaluate any of that company's luminaires. The IESNA format would allow an end user access to an unlimited number of different brands of luminaires to assess for a project. Most of the programs evaluated ran the IESNA format for photometric data files.

Program accuracy was tested by checking for a degree of conformity of a measure to a standard. A luminaire available with IESNA formatted photometric data files was chosen as the standard. Footcandle levels in a x-y coordinate grid were

used for the measures. A print-out of the fc grid with a specific mounting height, spacing, tilt, orientation, x-y coordinates for luminaire placement, etc. was requested from the manufacturer of the standard. Exact duplicates of this grid, using the standard luminaire photometric data file, were printed out from the programs accepting IESNA formatted data. Specific x-y coordinates on the evaluation program's grid were chosen and compared with the same x-y coordinates on the standard luminaire's grid. The degree of conformity of the evaluated programs to the luminaire chosen as a standard was acceptable. Exact matches of fc levels, or within 1/100th of a fc, were seen with most of the programs. This accuracy check was for the mathematical formulas used to calculate illuminance levels from photometric data, not comparing program print-outs to actual exterior installations using the standard luminaire. Accuracy of programs accepting only their own data could not be checked.

All lighting programs evaluated had to be user friendly. This means presenting the program in a format that induces a user to just sit down and begin working with it. One way to ensure this is to have menu driven programs. If the program is in a user friendly form, it allows input and responses back and forth between program and user. This give and go is provided through menus and HELP screens. All programs were user friendly/menu driven and had HELP screens.

Light loss can be caused by a number of reasons. The light loss factor is a number between 0 and 1 (where 0 is no light and 1 is full light) by which all candela values are multiplied. The light loss of a luminaire can be caused by several reasons; such as: dirt accumulation depreciation, lamp lumen depreciation, ballast factor losses, or other adjustments in the amount of light output from a luminaire. All the evaluated programs allowed for adjustments to the light loss factor.

Providing documentation, support, and/or training is essential for complete understanding of a program. These factors also help to make a program user friendly. All evaluated programs had to provide not just adequate, but good, documentation in the form of a user's instruction manual. This is especially important if no training is available. Some programs do not need training due to their simplicity. But, several programs provide so many features that training is necessary. Training classes are discussed in more detail in the CONSIDERATIONS section. Support for the programs (telephone assistance and updates) is the mark of a reputable company. Support from local or district representatives of lighting

manufacturers for the lighting manufacturers' lighting design programs can also be a help. Private lighting software firms provide their own support for their programs. All programs evaluated had good documentation, support, and some had excellent training classes. Updates were received on a timely basis from program suppliers for program changes. Some programs had no changes, so have had no updates.

After receiving the lighting design programs and checking them for the primary features, such a wide variety of other features were available that it was felt these features should be mentioned (and described where necessary). These features will be listed as HELPFUL or OPTIONAL features.

HELPFUL FEATURES

Listed and briefly explained are more features examined during program evaluations.

1. Mass storage device - This is the ability to run a program from the hard disk drive and floppy drives. This can be critical depending on an individual's computer system. For example, receiving a program that only runs on a hard disk system while the user has only a floppy disk system means that the user cannot use the program. All the programs evaluated ran from either type of drive.

2. Math co-processor - All lighting programs should be used on a computer system with a math co-processor. This speeds up the large number of calculations involved in running a lighting program. Many of the programs evaluated will not run in a computer without a math co-processor; and the others recommend installing one to enhance program speed.

3. Program system configuration - This covers items such as computer and printer types supported, format for photometric data accepted, level of DOS required, RAM and disk drive space required, and math co-processor required. Most of the evaluated programs listed some form of a program system configuration.

4. Tilt - Tilt is the number of degrees above or below the horizontal luminaire position (usually 0°). Tilting of a luminaire was available on every program evaluated except one. This is a necessary feature in some projects and would eliminate use of that one program.

5. Masking - Masking is used to block out objects (e.g, buildings and posts) that are within an area of interest (e.g., security perimeter or parking lot). These objects are not desired to be displayed, yet they are physically present. The general shape of the object is desired to be shown. There is no illumination on the ground where these objects occur, so the program does not print fc levels on the grid at the coordinates of the object and in the general shape of the object. Masking also prevents the program from printing zeros within the masked area and eliminates using these zeros in the area calculations (e.g., min/max levels and ratios) (Fig. 4). All programs evaluated provided this feature.

OPTIONAL FEATURES

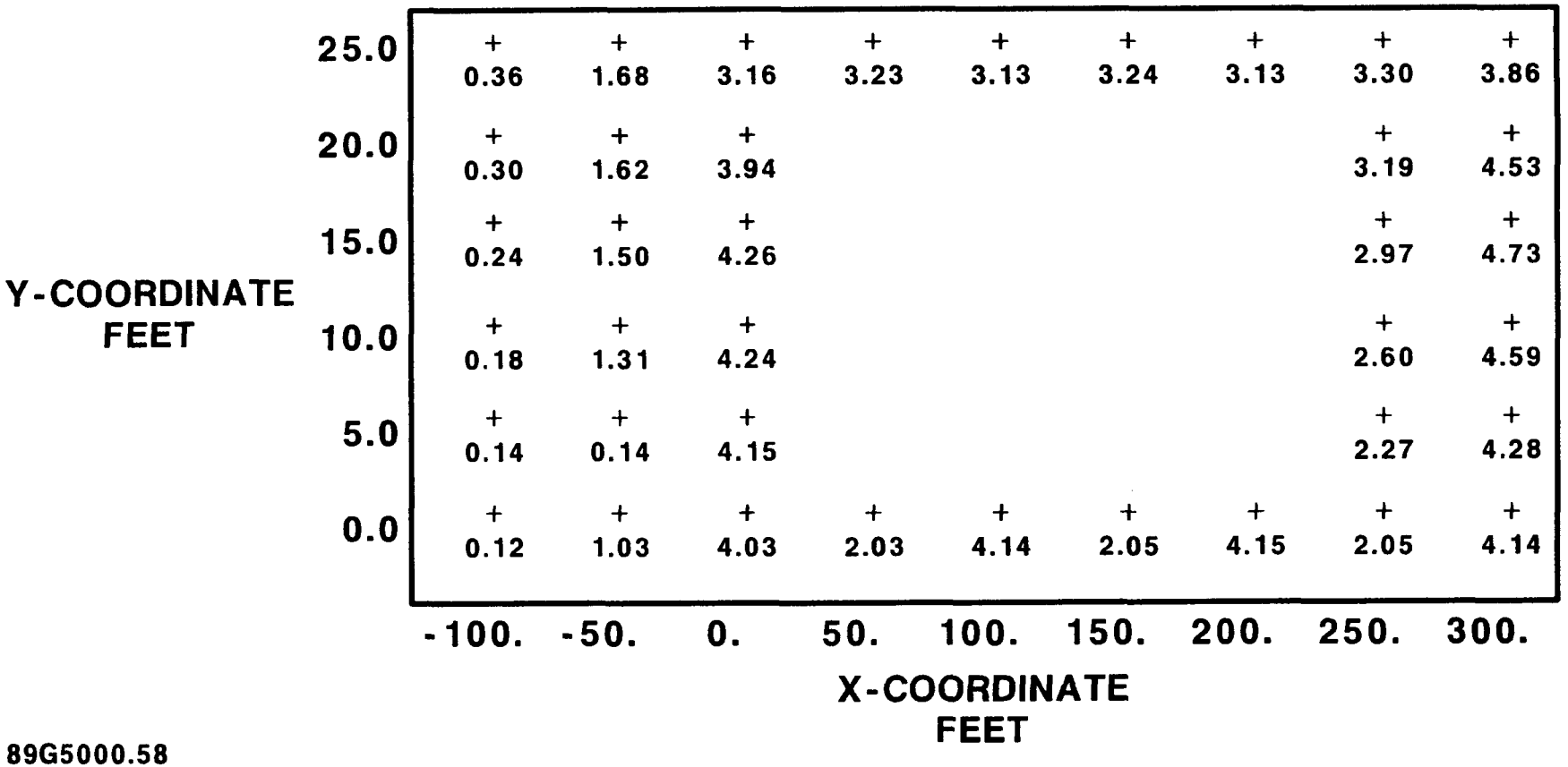
The following items are useful features that were included with some programs.

1. Template maker (prints luminaire footprints in hardcopy form without running the entire program. Footprints can be made to any scale, cut out, and then overlaid on the area of interest to achieve an idea of how many luminaires are needed).(Fig. 5)
2. Luminaire estimator (helpful tool to take a quick look at an area of interest to approximate the number of luminaires required, without running the entire program. Has a few limiters and is not quite as precise in its estimate as the template maker feature).
3. Hard copy of worksheet
4. Usable with a digitizer
5. Luminaire coordinates shown on x-y fc grid (Fig. 6)
6. User designed custom report headings
7. Allow IESNA photometric data files to be verified for correct format, or to be edited, or to add new files.
8. Program cost (a feature from the standpoint that some programs are free. Costs were from $0 to $1200).

PROGRAMS EVALUATED

The following is a list of the programs that have been evaluated to date. Some are provided by lighting manufacturers and some by private lighting design firms. An (*) beside a program name indicates that program was provided

MASKING
SHOWN ON X-Y FOOTCANDLE GRID



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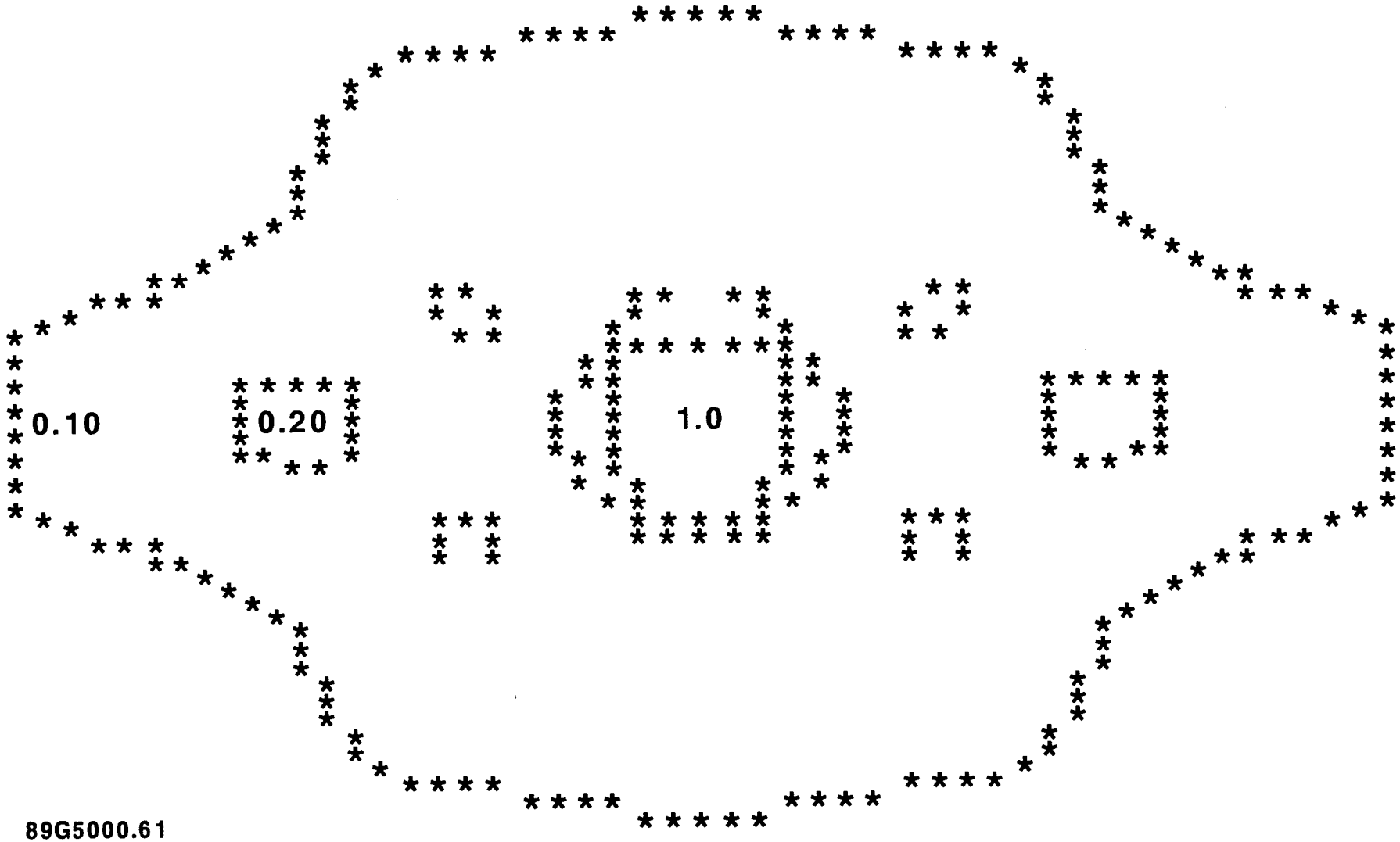
TEMPLATE MAKER



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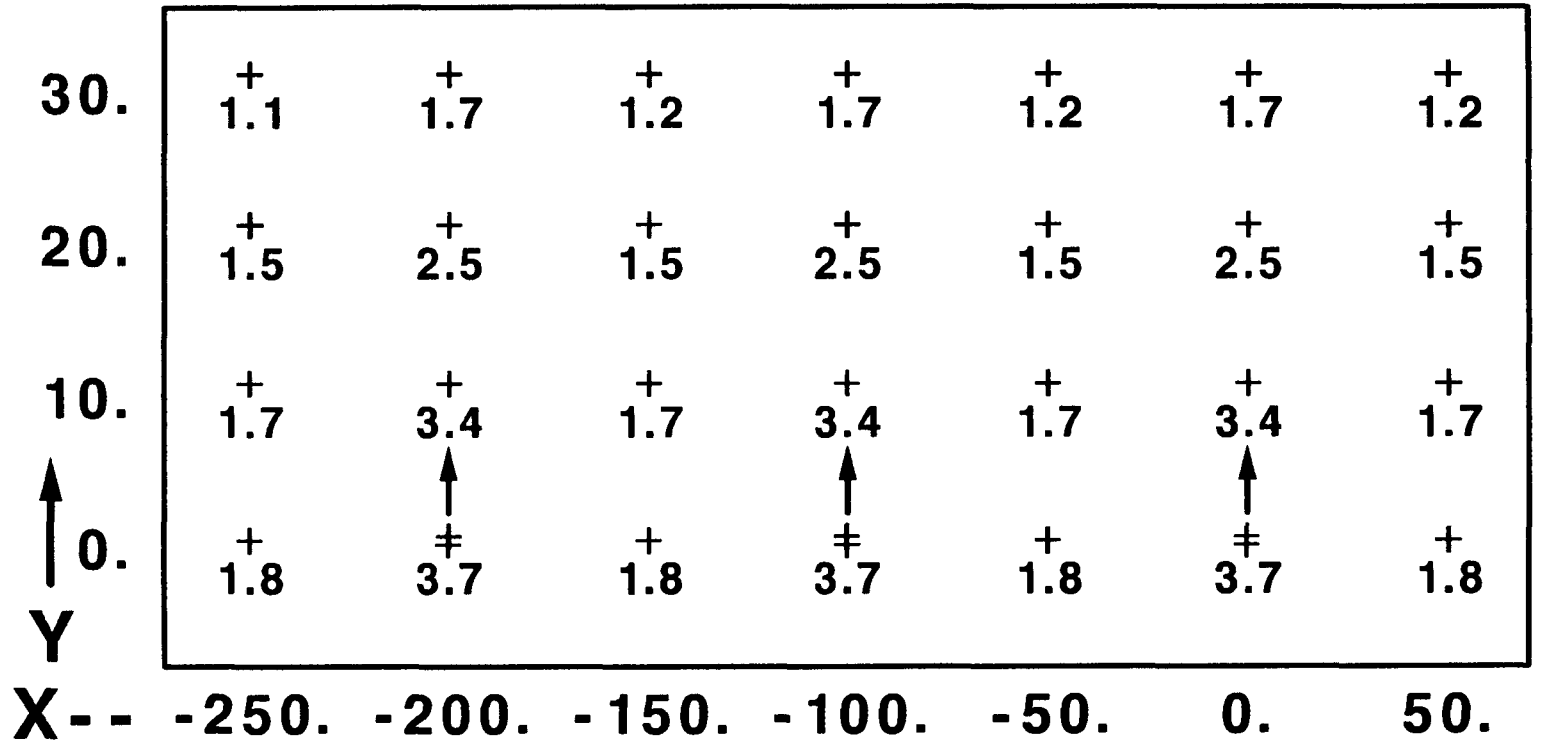
LUMINAIRE COORDINATES
SHOWN ON X-Y FOOTCANDLE GRID



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by a private firm.

PROGRAM	SOURCE
CALA	Holophane
EMCO LITE	Emco Environmental Lighting, Inc.
LUMEN POINT*	Lighting Technologies
LUX 88	Gardco Lighting
POINT*	Lighting Analysts, Inc.
SPAULDING LIGHTING APPLICATIONS PROGRAM	Spaulding Lighting, Inc.

PROGRAMS' EVALUATION RESULTS

Tables 1, 2, and 3 show the results of the evaluations of the lighting programs. Table 1 shows PRIMARY features. Table 2 shows HELPFUL features. Table 3 shows OPTIONAL features. There are a few features provided by a few of the evaluated programs that are not shown on the Tables. If a feature in which you are interested is not shown, contact the manufacturer of the program you are interested in to find out if that program offers that feature.

CONSIDERATIONS

By considering the following topics the user will save time and trouble.

"How often am I going to have a lighting design project?" If you rarely need a design, let the lighting manufacturers perform the computer run for you. All the lighting manufacturers I have dealt with will provide computer designs for you. There is usually no charge for this service. They will need a description of the area to be illuminated. If you know which luminaire you want to use, tell them. If you have no idea which luminaire to use, they can usually recommend one for you. The layouts for the project can be supplied to the manufacturers by describing them over the telephone, or by mail, or by fax. I have used this service several times and find it works well. The private lighting design software companies will also provide this service for you, but there will probably be a charge involved.

The hardest part of performing these evaluations was trying to obtain lighting manufacturers' photometric data files in IESNA or any format. There are two main ways to obtain the data. First, try to go through the lighting manufacturer's local or district representatives. I was successful with several companies this way. If this fails, call the Application Engineering Department at the lighting manufacturing company

EVALUATION RESULTS (PRIMARY FEATURES)

EVALUATION CRITERIA	PROGRAM NAME					
	CALA	EMCOLITE	LUMEN PT	LUX 88	POINT	SPAULDING
IBM COMPATIBLE	X	X	X	X	X	X
IES FORMAT	X		X	X	X	
PROGRAM ACCURACY	X		X	X	X	
LIGHT LOSS FACTORS	X	X	X	X	X	X
USER FRIENDLY	X	X	X	X	X	X
DOCUMENTATION	X	X	X	X	X	X
SUPPORT	X	X	X	X	X	X
TRAINING	X		X		X	
UPDATES	X	O	X	X	X	O

X = YES

O NO UPDATES DUE TO NO PROGRAM CHANGES

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EVALUATION RESULTS (HELPFUL FEATURES)

EVALUATION CRITERIA	PROGRAM NAME					
	CALA	EMCOLITE	LUMEN PT	LUX 88	POINT	SPAULDING
DISK DRIVE FLEXIBILITY	X	X	X	X	X	X
MATH CO-PROCESSOR	O	O	O	O	$	$
PROGRAM SYSTEM CONFIGURATION	X	X	X		X	X
TILT	X	X	X		X	X
MASKING	X	X	X	X	X	X

$ MUST HAVE TO RUN PROGRAM

O SUGGESTED TO HAVE, BUT NOT MANDATORY

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EVALUATION RESULTS (OPTIONAL FEATURES)

EVALUATION CRITERIA	PROGRAM NAME					
	CALA	EMCOLITE	LUMEN PT	LUX 88	POINT	SPAULDING
TEMPLATE MAKER					X	
LUMINAIRE ESTIMATOR	X					
WORKSHEET HARDCOPY		X	X		X	X
DIGITIZER	X				X	
LUMINAIRE COORDINATES		X		X		
CUSTOM HEADING	X	X	X		X	X
IES FORMAT VERIFICATION	X				X	
COST	595	FREE	1195	FREE	345	FREE

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you need data from and request it. Usually one of these methods works. Also, some of the private lighting design software developers can assist you. They work with lighting manufacturers frequently and can give you names and numbers for contacts or give you copies of the data. Users should request manufacturers' photometric data files in IESNA standardized format on disks.

Many of the evaluated lighting design programs specify an Epson or Epson compatible printer. I used a HP Laserjet II printer. For a few of the programs, in order to achieve a print-out, software causing the Laserjet II printer to emulate an Epson printer had to be installed. The software I used was LaserControl by Hewlett Packard. These print-outs are not as clear as ones printed on an Epson printer. If at all possible, use a printer supported by the lighting program.

The computer system used should have an adequate amount of free hard disk drive space and of RAM space. Most of these programs are large and the data files can be huge. Plenty of space is necessary, especially if the user installs all the photometric data on the hard disk. Free space is space not already allocated to other programs.

Training classes are worth attending. There is usually a fee, but it is not exorbitant. The classes last anywhere from 2-5 days, depending on the program. They give details on the program and usually provide some basic lighting background for the student.

To obtain their list of available computer lighting design programs, or other lighting information, write to:

Computer Committee
Illuminating Engineering Society of North America
345 East 47th Street
New York, NY 10017

IESNA also publishes a very informative monthly magazine called Lighting Design + Application. It is free with an IESNA membership and may be available to non-members. Contact IESNA for details.

SUMMARY

This paper is intended to provide the reader with enough information to decide: 1) Do I need a lighting design program? and, 2) Which program (or programs) best satisfies my needs? I discovered there are many good lighting design programs that are commercially available. As can be seen by the Tables, the features and costs of these programs

vary considerably. With the information presented in this paper, the user will be able to make program choice decisions based on their company's requirements.

If a user is still unsure of which program to purchase, there are demonstration programs available. The cost of a demonstration program is minimal (the ones I ordered ranged from free to $95). A demonstration program leads the user through a sample lighting design project using menus and worksheets and produces a sample printout. The user is able to obtain a feel for the program's features. These demonstration programs can be very helpful when trying to choose a complete program. Some programs are quite expensive, so a user needs to be sure of choosing the appropriate one(s).

FUTURE EVALUATIONS

There are many outdoor lighting design programs commercially available, and our evaluations are not complete. SNL intends to continue to evaluate available outdoor lighting design programs and document their features for interested organizations.

ACKNOWLEDGEMENTS

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APPENDIX A

LIST OF KNOWN COMMERCIALLY AVAILABLE LIGHTING DESIGN PROGRAMS

NOTE: (E) denotes programs evaluated
(R) denotes programs received, but not yet evaluated

PROGRAM		MANUFACTURER
AUTOLUX	(R)	Independent Testing Laboratories 3386 Longhorn Road Boulder, CO 80302 Bill Brackett (303)442-1255

CALA	(E)	HOLOPHANE 214 Oakwood Ave. Newark, OH 43055 Greg Subisak (614)345-9631
EMCO LITE	(E)	EMCO Environmental Lighting, Inc. 7300 50th St. Milan, Il 61264 Bob Gletty (309)799-3111
L-2	()1	Hauser's Lighting & Daylighting 128 Bell Ave. Piedmont, CA 94611 Greg Hauser (415)655-3158
LUMEN-POINT	(E)	Lighting Technologies 2540 Frontier, Suite 107 Boulder, CO 80310 Thomas Swanson (303)449-5791
LUX and LUME-STLT	(R)	Jolinko Enterprises 8 Lake Blvd. Vicksburg, MS 39180 Merle Keck (601)638-0484
LUX 88	(E)	GARDCO 2661 Alvarado St. San Leandro, CA 94577 Ken Fairbanks (415)357-6900 or 1-800-227-0758
MICRO-SITE-LITE	(R)2	Lighting Sciences, Inc. 7830 E. Evans Rd. Scottsdale, AZ 85260 Richard Heinisch (602)991-9260

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1 SNL and Mr. Hauser could not resolve disparities between our legal department and Mr. Hauser's attorney on the software use licensing agreement, so we were unable to order L-2.

2 Represented by Murray & Gillespie Computing Solutions
90 Nolan Ct., Unit 22
Markham, Ontario, Canada L3R4L9
(416)477-0260 or 1-800-387-4210

P-LIGHT	(R)	Richard Gehlbach 3321 Pepperhill Ct. Lexington, KY 40502 Richard Gehlbach (606)266-0531
PLANE	(R)	Illumination Computing Service, Inc. 523 Leda Lane Arcadia, CA 91006 Roy Jones (818)574-9695
POINT	(E)	Lighting Analysts, Inc. 10572 E. Park Mtn. Rd. Littleton, CO 80127 David Speer (303)972-8852
ROADWARE	(R)	ELITE Software Development, Inc. 4444 Carter Creek Pkwy. Bryan, TX 77802 Tim Wilcox (918)585-1826
SPAULDING LIGHTING APPLICATIONS PROGRAM	(E)	Spaulding Lighting, Inc. 1736 Dreman Ave. Cincinnati, OH 45223 Vicki Weems (513)541-3486

APPENDIX B

THE STANDARD IESNA PHOTOMETRIC FILE

The Illuminating Engineering Society of North America has developed a standard format for the exchange of photometric data. The specifications for this file are shown in this section.

The standard photometric file is organized in the following manner:
(Each line marked with an asterisk must begin a new line. Descriptions enclosed in "<" and ">" refer to the actual data stored on that line. All data is in standard ASCII format).

```
* <label line 1>
* <label line 2>
*      .
*      .
```

```
* <label line n>
* TILT=<file-spec> or <INCLUDE> or <NONE>
The next four lines appear only if TILT=INCLUDE
*     <lamp to luminaire geometry>
*     <# of pairs of angles and multiplying
         factors>
*     <angles>
*     <multiplying factors>
* <# of lamps> <lumens/lamp> <multiplier>
  <# of vertical angles> <# of horizontal angles>
  <photometric type> <units type> <width> <length>
   <height>
* <ballast factor> <ballast lamp photometric
    factor> <input watts>
* <vertical angles>
* <horizontal angles>
* <candela values for all vertical angles at 1st
    horizontal angle>
* <candela values for all vertical angles at
    second horizontal angle>
*               .
*               .
* <candela values for all vertical angles at last
    horizontal angle>
```

Each of the items listed above are defined and input as follows:

<label line> - Line of descriptive text that describes the luminaire in the file. Each label line may contain up to 80 characters of information.

TILT=<file-spec> - This line directs an analysis program to a file which contains data describing how the luminaire/lamp output varies as a function of the tilt angle. <file-spec> is the name of the file which contains this information. This name may be composed of up to 75 characters.

TILT=INCLUDE should be used if the angles and multiplying factors are included as part of the complete photometric file. The format for this information is the same whether it is in a separate file or included as part of the photometric file, and is shown below:

<lamp to luminaire geometry> - This indicates the orientation of the lamp within the luminaire, and should be the value 1, 2, or 3, according to the following schedule:

1 When the luminaire is aimed straight down, the lamp is either vertical base up or vertical base down.

2 When the luminaire is aimed straight down, the lamp is horizontal, but when the lamp is tilted in the 0 degree horizontal plane, the lamp tends to a base up or base down condition as a result of the luminaire tilt.

3 When the luminaire is aimed straight down, the lamp is horizontal and remains horizontal when the luminaire is tilted up in the 0 degree horizontal plane.

<# of pairs of angles and multiplying factors> - The total number of pairs of angles and corresponding multiplying factor.

<angles> - The angles should be listed in increasing order, and should go from 0 to 90 degrees or from 0 to 180 degrees, inclusive. 0 degrees corresponds to the multiplying factor to be used when the luminaire is aimed straight down.

<multiplying factors> - The multiplying factors should be listed in order corresponding with the angles given in the line above.

NOTE: the phrase 'TILT=' must begin in column 1 and contain no blank characters. This is important since this phrase is used to signify the end of the label information. If the out put of the luminaire/lamp combination does not vary as a function of the tilt angle, then TILT=NONE should appear in the file.

<# of lamps> - This is an integer equal to the number of lamps in the luminaire.

<lumens/lamp> - This is an integer equal to the number of rated lumens per lamp on which the photometry is based.

<multiplier> - This is a factor which must be applied to all candela values in the file. It will usually be equal to 1.

<# of vertical angles> - This number is an integer equal to the number of vertical angles in the photometric report.

<# of horizontal angles> - This number is an integer equal to the number of horizontal angles in the photometric report.

<photometric type> - This number is an integer indicating the type of photometry

which exists for the luminaire being described. A '1' corresponds to type "A" photometry, and a '2' corresponds to type "B" photometry.

<units type> - This is an integer indicating the type of units which are used in the report. A '1' is used if the units are given in feet, and a '2' is used if the units are given in meters.

<width> - This number is the distance across the luminous opening of the luminaire in the 90-270 degree plane.

<length> - This is the distance across the luminous opening of the luminaire in the 0-180 degree photometric plane of the luminaire.

<height> - This distance is the height of the luminous opening of the luminaire.

<ballast factor> - This factor is a loss factor due to the difference between the operating ballast and the standard (reference) ballasting specified for rating lamp lumens.

<ballast lamp photometric factor> - This factor is the loss factor due to the difference of using a given ballast and lamp type under photometric test conditions to that of the same luminaire with the ballast and lamp type used to generate a photometric report.

<total input watts> - This is the value of the total watts input to the luminaire, including ballast watts.

<vertical angles> - The vertical angles that are present in the photometric report should be listed on the appropriate line in the file, in increasing order. For type "A" photometry, the first value must be either 0 or 90 degrees, and the last value must be either 90 or 180 degrees. For type "B" photometry, all angles must be between -90 and 90 degrees, inclusive. If the first value is equal to zero, symmetry will be assumed to exist between the top and bottom half of the luminaire.

<horizontal angles> - The horizontal angles that are present in the photometric report should be listed on the appropriate

line in the file, in increasing order. For type "A" photometry, the first value must always be either 0 or 90 degrees, and the last value must be either 0, 90, 180, or 360 degrees. For type "B" photometry, all angles must be between -90 and 90 degrees, inclusive. If the first angle is equal to zero, then symmetry will be assumed to exist between the left and the right half field of the luminaire's photometry.

<candela values for all vertical angles at Nth horizontal angle> - This is a list of the candela values in each vertical plane of photometry. The candela values for each vertical angle are listed for successive horizontal angles. The order of the angles must be in increasing order, exactly as the angles appear in the previous lines of the file.

There are a few simple rules which must be followed in constructing a standard photometric file. These are as follows:
(1) The individual values on any one line should be separated by a space or a comma. (2) Any of the data lines specified above may be continued on an additional line (or lines), if necessary.
(3) No line is permitted to exceed 132 characters.
(4) In the case where more than one luminaire is present in a standard format file, the first label line of any subsequent luminaire should immediately follow the last line of candela values for the previous luminaire.

An example file is shown below.

```
1' X 4' TEST TROFFER
ADDITIONAL SPECIFICATION DATA
FOR THE LUMINAIRE WOULD
GO IN THESE LINES
TILT=NONE
2 3150 1.0 11 3 1 1 .92 3.83 0.
1. 1. 78
0 5 15 25 35 45 55 65 75 85 90
0 45 90
1720 1714 1643 1506 1295 909 506 253 106 34 0
1720 1701 1647 1543 1350 909 383 150 121 43 0
1720 1695 1645 1543 1342 837 503 222 104 29 0
```

REFERENCES

1. D. A. Smith, "An Exterior Lighting Design Program", Contractor Report, (February, 1986), SAND85-7245

2. U. S. Department of Transportation, "Roadway Lighting Handbook Addendum to Chapter Six", (September, 1983), Addendum to Implementation Package 78-15

3. Michael Z. Cahana, "The Use of Computers by Lighting Designers, Survey and Suggestions", (June, 1989), Lighting Design + Application Magazine

4. Robert Chasse', "The Role of the Computer in Lighting Design", (June, 1989), Lighting Design + Application Magazine

5. Illuminating Engineering Society of North America, Computer Committee