

A SURVEY OF COMPUTER APPLICATIONS IN

LIGHTING

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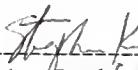
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1.0 FACTORS AFFECTING LIGHTING

1.1 Introduction

Cushman and Crist (1983) define light as the stimulus for vision, the primary sensory channel for receiving information about our environment. Our ability to perform tasks depends, to some extent, on the quality and quantity of the light that illuminates them. Lighting may also affect the way we feel and perceive our environment. This discussion begins with some basic definitions of terms associated with lighting.

1.2 DEFINITIONS

The fundamental unit in photometry (branch of metrology that is concerned with the measurement of light) is luminous flux, which is measured in lumens. One lumen (lm) is equal to 1 W for light with a wavelength of 555 nm as defined by IES lighting handbook. In addition one should also be familiar with two other photometric concepts - illuminance and luminance. The following are some important lighting terms as defined by the IES Lighting Handbook 1981 reference volume.

1.2.1 Illuminance : Illuminance, also called illumination is a measure of the amount of light from ambient and local sources that falls on a surface. In the SI system of measurement units, illuminance is measured in lux.

One lux (lx) is equal to 1 lm/m sq of illuminated surface area. Illumination may also be measured in footcandles (fc) where 1 fc is equal to one lm/ foot sq.

1.2.2 Luminance : Luminance is a measure of the physical intensity of light. Often used interchangeably with the term brightness; brightness is actually a measure of the intensity of the sensation perceived by the observer. Luminance, or reflected luminous flux in the old U.S. system is lumens /sq foot called footlamberts (fL). However in the S.I system luminance is measured in candellas/sq mt. Since candellas involve a spherical surface, the value 3.141 must be included for conversion to flat surfaces.

1.2.3 Reflectance : Reflectance is the percentage of light reflected from a surface. Typical reflectances vary from 80 - 90 % for mirrored glass, to 3 - 5 % for black paint. There is no unit of measurement for reflectance.

1.2.4 Wavelength : Wavelength is the distance between successive waves (a "side view" of light). Wavelength determines the color hue. Saturation is the concentration of the dominant wavelength, or the degree to which the dominant wavelength predominates in a stimulus. Of the 60 octaves of electromagnetic radiation, the human eye detects radiation in the range from 380 to 760 nanometers. Nanometers are the SI unit of measurement for wavelength.

1.2.5 Polarization : Polarization is the transverse vibrations of the wave (an "end view" of light). Most light is a mixture. Horizontally polarized light reflected from a surface causes glare.

1.2.6 Luminance exitance The density of luminous flux leaving a surface at a point. This was formerly defined as luminous exitance.

1.2.7 Equivalent Sphere Illumination (ESI) The level of sphere illumination which would produce task visibility equivalent to that produced by a specific lighting environment.

1.2.8 Coeffecient of Utilization, CU The ratio of the luminous flux (lumens) from a luminaire calculated as received on the work plane to the luminous flux emitted by the luminaires lamps alone.

1.2.9 Visual Comfort Probability, VCP This is defined as the rating of a lighting system expressed as a per cent of people who, when viewing from a specified location and in a specified direction, will be expected to find it acceptable in terms of discomfort glare.

1.2.10 Flux transfer theory This is a method of calculating the illuminance in a room by taking into

account the interreflection of the light flux from the room surfaces based on the average flux transfer between surfaces.

1.3 EFFECTS OF LIGHTING ON BEHAVIOR

Numerous studies have been performed to determine relationships between lighting and behavior. This section highlights some of the major effects of illumination and performance, in office and industrial environments.

1.31 Task characteristics: The visual difficulty of a task is closely related to the size of the smallest critical element and the contrast between the task and background. Weston (1945, 1962) showed that performance improves with illuminance, but the incremental benefit diminishes with each subsequent increase. Beyond a certain point, further increases in illumination are not beneficial.

1.32 Office tasks Barnaby (1980) and Hughes and McMillan (1978) have shown some improvement in productivity with increased illumination. Improvements in performance were greater for visually demanding tasks for workers above 45 years. Improvements for younger workers and less visually demanding tasks were much smaller.

1.33 Industrial tasks McCormick (1970) summarized the results of surveys showing an increase in productivity for 15 industrial tasks following an increase in illumination. The tasks included a wide variety of activities such as metal bearing manufacturing, steel machining and letter sorting. In most instances the increase in work output was modest ; less than 15 % for a 2 to 10 fold increase in illumination.

1.4 GENERAL LIGHTING

Atkinson (1970) states that the human eye is very adaptable. If it worked over only a limited range of lighting conditions, and did not work outside that range we would all realise that suitable lighting is essential. But as it is eyes work after a fashion in almost any lighting conditions likely to be met. We evolved as outdoor animals and our visual need then was for fairly casual viewing of large objects at some distance in daylight. It is only recently , biologically speaking, that we have come indoors into much less light and concerned ourselves with close attention to fine detail. The eye has not changed but visual jobs and visual conditions have. If visual difficulties are not removed then the work progresses more slowly and inaccurately.

1.5 QUANTITY OF LIGHT

Having enough light is the easiest solution to most difficulties. It makes detail look larger and clearer at the usual viewing distance. It particularly compensates for poor contrasts. The minimum illumination values recommended by the Illuminating Engineering Society for various processes and occupations are calculated to provide the conditions for something better than 90 % of maximum visual performance of the concerned job. The recommended levels of illuminations for indoor industrial lighting (1983) is shown in Table 1.0. This standard is considered to be justified at today's low cost of lighting in relation to other business and production costs. Naturally a lower standard of lighting can be used which risks slower work and more mistakes. It is a question of balancing the cost of lighting against a waste of human effort, loss of time and material which occurs when there is not enough of it. The I.E.S. recommendations are a good basic guide but should be exceeded if the situation demands. However the quantity of light is only one of the things necessary for the lighting to be successful for the job.

1.5.1 Sources The ideal illumination source would be free, give the desired amount of light on demand, and have a high quality as reported by Konz (1986). Although

Table 1.

Recommended Target Maintained Illuminance (lux) for Interior Industrial Lighting (IES 1983)

REFERENCE WORK PLANE General lighting	ACTIVITY	CATEGORY	Illuminance (lux)		
			2000	11000	20000
Public spaces with dark surroundings	A	20	70	50	
Simple orientation for short temporary visits	B	50	75	100	
Working spaces where visual tasks are occasionally performed.	C	100	150	200	
REFERENCE WORK PLANE Illuminance on task	TYPE OF ACTIVITY				
Performance of visual tasks of high contrast	D	200	300	500	
Performance of visual tasks of medium contrast	E	500	750	1000	
Performance of visual tasks of very small size	F	1000	1500	2000	
REFERENCE WORK PLANE Illuminance on a task, obtained by a combination of general and local lighting.	TYPE OF ACTIVITY				
Performance of visual tasks of low contrast and very small size over a prolonged period.	G	2000	3000	5000	
Performance of a prolonged and exacting visual task	H	5000	7500	10000	
Performance of very special tasks of extremely low contrast and small size.	I	10000	15000	20000	

Table 2

Office Tasks of Illuminance Categories	
Illuminance Category	General Task/Activity
B	Copied tasks, General public areas.
C	Drafting, EDP tasks, General and public.
D	Copied tasks, EDP tasks, General and public, handwritten and printed tasks.
E	Copied tasks, Drafting tasks.
F	Copied tasks, Drafting tasks, general and public, graphic design and material, hand - written tasks.

Table 3

Factors for Illuminance Table.

**For Illuminance Categories A, B, C & General lighting
Throughout Spaces)**

		Factor	
<u>Variable</u>	± 1	0	± 1
Occupant ages, year	under 40	40-45	over 55
Average weighted room surface reflectance (%)	over 70	30-70	under 30

For Illuminance Categories D,E,F,G,H,I (on Task)

Workers ages,			
year	under 40	40-55	over 55
Speed and /or accuracy	not important	Important	Critical
Task background reflectance	over 70	30-70	Under 30

sunlight can act as a supplement for artificial in some cases, there may be problems with sunlight as an illumination source. Thus the choice is generally among artificial sources. The lamp to use depends on cost, convenience, and color.

Cost is primarily the cost of energy (about 90 %) with about 10 % for the fixture, lamp, and cost of replacing the lamp. Lumen output decreases with age so for cost calculations it is better to use lumens/watt rather than initial. Lumens/watt are higher for larger bulbs, often the advantage is over 25 %. When there is a power interruption, there is a delay before lamps for sodium, mercury, and metal halide lamps; this may require supplementary fluorescent or incandescent lighting for emergencies . Color of low pressure and high pressure lamps are poor. Metal halide lamps give good color (disriminate shades of color), thus they are often mingled with HPS in high bays to get high lumens/watt and acceptable color. Fluorescent lamps give good color rendition and allow you to select the color.

1.5.2 Luminaires (Fixtures) Luminaires can be put into a wide variety of fixtures. A fixture will release 50 - 80 % of the light from the lamp to the room. If a fixtures

coefficient of utilization is .70, it means 70 % of the lamp light inside the fixture is distributed to the work plane. The light distribution from a fixture (up vs down) is in five categories : direct (90 % down), semidirect (90 % - 60 %), semidirect (90 - 60 % down), general diffuse (60 - 40 %), semi-indirect (40 - 10 % down), and indirect (10 - 0 %). Direct and semidirect are most used. Some uplight tends to be the best since the light on the ceiling reduces brightness contrast and non direct luminaires tend to stay cleaner. The downward component is further described by " beam spread ", wider spreads give more overlapping (better illumination on vertical surfaces and less dependence on a single lamp). The shielding angle which is angle between a horizontal line and the line of sight at which the source becomes visible should be greater than 25 degrees, preferably approaching 45.

1.6 QUALITY OF LIGHT Quality in lighting is at least as important as satisfactory quantity. The manner of achieving this is not as easy to specify. Some of the chief requirements are :

1. Absence of direct glare
2. Absence of reflected glare.
3. Agreeable modelling.
4. Good Esthetics.

1.6.1 Glare Kaufman and Haynes (1981) define glare as the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility. Glare can be either direct or reflected (indirect). Direct glare may be caused by one or more bright sources of light in the visual field. Examples of direct glare include sunlight and incandescent bulbs. Reflected glare on the other hand, is caused by light reflected from an object or objects that an observer is viewing.

1.6.2 Direct Glare A common saying used to be " if there is plenty of light there is plenty of glare too". This used to have justification but the position now has been entirely altered. Atkinson (1970) reported that direct glare from lighting fittings may hinder work by making it difficult to see. But whether it does this or not , it certainly makes the workplace more unpleasant by the visual discomfort it causes. Direct glare causes headaches, dissatisfaction and absenteeism. Complaints about the workplace are infectious. Discomfort from glare is not a function only of lamps or fittings used. It is a function of the environment and installation. Now fairly simple means have been found to determine how much glare a proposed installation will produce in a given

room. This can be compared to the acceptable amount of glare. Cushman and Crist (1983) recommend covering windows with drapes or blinds to overcome direct glare. Einhorn (1970) describes another approach which is oriented lighting. Another source of direct glare is lights, especially point sources with dark backgrounds. A study by the IES (1970) showed that 24 % of the people were comfortable with a 21 % shielded luminaire while 90 % were comfortable with it shielded at 33 %. For equal performance, calculations showed that 21 degree unit would require 28 % more light on the task than the 33 degree unit. Another source of direct glare is incandescent objects. Sliney and Wolbarsht (1980) describe the safety problems of lasers, bright lights, welding arcs, and hot metal. They recommend specialized glasses for this type of source.

1.4.3 Reflected Glare Indirect glare is usually caused by high luminance from a source. Reflected glare is horizontally polarized light. Glare from shiny, wet or polished working surfaces is, in most cases, a real handicap to production since it masks whatever one is trying to see on the surface.(a blemish, scale mark etc). Glare is usually blamed on the lighting because it is a reflection of the lamps or fittings which causes it. Large area fittings of low brightness, as seen from below,

cause less reflected glare than small bright fittings. One approach is to decrease incoming light so less is reflected. Lion (1964, 1968) reported better inspection performance, when line sources (fluorescent) were used instead of point sources (incandescent). Blackwell (1963) recommended filtering the light source with a multilayer polarizer to minimize the horizontal reflection. Objects will be seen better if the ceiling itself is white and well lighted. But changing the lighting is hardly a complete cure. Changing the position of work or worker in relation to the lights can be effective. The real answer is not to have glossy surfaces, or, if possible, to dull them temporarily by a color wash or other medium which can be removed later if necessary (Applied Ergonomics Handbook, 1970). Another possibility is to filter at the eye with sunglasses. Bennett and Mehan (1973) reported that polarized sunglasses filter horizontally polarized light and improve both visual acuity and comfort.

1.6.4 Agreeable modelling It is possible to sharpen or to blur the form and surface texture of an object by changing the direction of light falling on it. The effect is generally known as modelling (Einhorn 1970). It is used to improve the visibility of the details of some tasks, particularly in industrial processes. Where it is necessary, the modelling light should be provided in

addition to the general lighting in the room. The light sources should be specially located in relation to the work.

1.6.5 Esthetics The amount of light not only facilitates visibility of a task, it contributes in other ways to the visual quality of the space. Flynn (1977, 1979) did key studies showing that light must be seen as a form of communication, evoking perceptual response as well as visual performance response. In general, esthetic lighting should consider the design of shadows and design of light. Gordan (1987) emphasized assymmetry and variability in the amount of light.

2.0 DEVELOPMENT OF COMPUTER SOFTWARE FOR LIGHTING

2.1 INTRODUCTION

Two major issues in lighting design are quality and quantity of light. The microcomputer is useful in solving problems in each of these areas. The lighting design concept must be illustrated and accompanied by calculations both of which can help turn a proposal into reality (Lord, 1987). Designers need to determine the amount of illumination received at a work plane and the wattage of a lighting installation. Designers and clients need to know ahead of time the economic and aesthetic effects of using alternate light sources, or sources from different manufacturers. Architects and interior designers need to know how the space will appear when lighted as designed, so they can make timely and economical changes when necessary. They will appreciate any tool that brings increased accuracy, ease of computation and clear graphic representation to this process. The micro-computer offers this potential to every lighting designer (Hibbs, 1986).

Mainframe computer programs for lighting calculations have been around for many years. These leviathans were useful to the largest lighting and design organizations, but were expensive , required specialized skills to run,

and were available to only a few lighting designers.

Over the last few years a new generation of lighting programs for micro-computers have been developed, some based on some of the earlier mainframe versions. Standardized micro-computer hardware, notably the introduction of a virtual I.B.M standard, played an important part in making new programs practical. Lighting manufacturers also spurred the development of software by agreeing to an I.E.S standard, computer-readable format for luminaire photometric data. Many manufacturers now make this photometric data available to designers on floppy diskettes.

The range of capabilities of micro-computer hardware and current software packages is quite broad and is expanding at a rapid pace. The I.E.S. computer committee compiles and publishes a list of available computer software programs, yearly. Something is there for every one in almost any price range.

Some lighting analysis software programs are in the public domain, and are freely available, but have limited applicability. Others are inexpensive but are of limited reliability. Some of the fully blown, user friendly and robust micro-computer programs can cost more than \$2500. Each type of software satisfies a need in the world of

lighting design. Some of the less expensive programs used for educational purposes can give beginning designers a rough idea of the consequences of some lighting design. The more expensive programs are reserved for the more experienced professionals who demand the best possible results.

Documentation is often very poor or unavailable. In all cases ultimate responsibility for the accuracy of the results obtained with any program rests with the designer or lighting consultant (Lemons, 1986). The software vendor has little or no control over data entry or the many ways it is possible to use the programs. Often programs are written for generic room shapes, locations, and window and luminaire sizes. The design of unusual shapes, such as curved walls or arched windows, requires that approximations be made on the keyboard. The subsequent output then is only an approximation of expected conditions. Most programs are written for the IBM PC/XT,AT, or lookalike computers. This family of computers seems to be chosen most often by people in the scientific and engineering communities.

Many people are drawn to the Apple Macintosh, partly for its user-friendly operating system, partly for its attractive high resolution screen display. A few energy related programs are available for the Macintosh, and the

list probably will grow.

In addition to a microcomputer and monitor, a dot matrix printer is needed to print out results. These printers are commonly used today. As previously mentioned large mainframe computers have been used for the last ten years to store photometric data and perform design analysis. While much of the work was research oriented, practicing designers were able to access mainframe systems on a time share basis. The disadvantages of this system were the long turn around times and the expense. In many cases the cost per iteration was large in proportion to the lighting design budget. Lord (1987) reports that there were major limitations in the ability of computers to model real situations such as winding roads and offices with movable partitions. The next step was the development of computer programs by manufacturers of lighting equipment. These were made and available to designers on a no cost basis. A major limitation was the restriction to comparisons of only the product produced by the company offering the software. Thus the major problem was the proprietary nature of the systems. That meant the software packages could be used only with company provided photometric diskettes. These systems did allow the designer to ask "what if" questions and make some trade off analysis without the need for manual calculations.

The major advance in bringing computers to the designer was development of the microcomputer and user-friendly software. Rapid price reductions, due to increased competition brought microcomputers within reach of most design professionals. In the area of design and analysis, custom programs are available to analyze photometric performance, illuminance, maintenance options, and economics.

Most lighting designs do not require the computer as a design aid. This may be due to the small size of the job, the fact that computation of the solution is reasonably quick and direct. Designs requiring computer assistance typically involve new techniques, complex aiming, daylight as a design element, or where specific documentation is desired by the client. The dilemma faced by the designer is when to bring computers into his practice. There is no one solution to the problem. In fact as a practice develops, its requirements for computer support also evolve.

2.2 IMPORTANT CRITERIA FOR SOFTWARE

Leite (1986) writes about the three main criteria for a designer. For the designer, the three main criteria are :

Flexibility : Any system or option selected should be capable of expansion to meet future needs.

Operability: The complexity of the system should be within the ability of the staff to operate. It should not rely on a single operator.

Cost : The system selected must provide sufficient benefits to recover the costs to purchase and support it. This usually is seen through increased productivity or added capabilities.

2.3 APPLICATIONS OF TYPES OF SOFTWARE

To assist in the evaluation of the foregoing criteria, an examination of the potential applications of software which are commercially available and are of interest to a lighting designer follows.

2.3.1 Graphics packages These packages have capabilities that range from simple graphs to topographic plots such as isolux and isocandela charts. Often graphics capabilities are incorporated into spreadsheet software. Certain packages allow drafting capability and multicolored plots. A sophisticated graphics package represents a major investment for a design firm. This is particularly true when the cost of a special plotter is included. Lighting design applications for a graphics package include photometric plots tailored to an installation being designed, drafting of the design itself, and rendering of

the design.

2.3.2 Database Database software is used to store and manipulate large volumes of data. It also can produce reports and perform limited mathematical and statistical operations. A major capability of database programs is the ability to sort the stored data. For the lighting designer database programs can store photometric data, catalogue information and client data. For applications other than report generation , the information is transferred to other software packages such as the spread sheet program.

Thus far this dicussion has centered on generic software which can be used to perform most of the calculations and produce the reports required to execute any lighting design. Because the programs are for general applications, some expertise is required to set up the problem in the computer. A second type of program available to lighting designers is the lighting application package. These programs have been designed to solve specific types of lighting problems, and are used as design and analysis tools. Programs of this type tend to be " user friendly ". They lead the user through the set up process and data entry steps. Their report format is preprogrammed so that the user need only select desired options.

Lighting application programs that have been developed include general design problems, indoor lighting analysis, outdoor lighting analysis, lighting controls, energy consumption and economic analysis. The next part of this report deals with some of these programs.

3.0 DIFFERENT CATEGORIES OF LIGHTING SOFTWARE

3.1 CLASSIFICATION OF LIGHTING PROGRAMS

This section classifies lighting application programs into categories. Leite (1986) classifies programs as those available for luminaire design, outdoor lighting programs, indoor lighting programs, and economic analysis programs.

3.2 LUMINAIRE DESIGN

The design of a luminaire and the selection of the light source to be employed for a given application depends upon many factors (IES Lighting handbook, 1981). In addition to the illumination aspects such as luminance, glare, uniformity, illuminance, etc., consideration also should be given to appearance, color of light, heating effect, efficiency, life and economics.

Computer programs for microcomputers are available which allow the analysis and design of luminaires. These are aimed chiefly at the optical system; programs are able to design both reflectors and lenses, and combinations of both. Lewin (1986) states that luminaire design programs fall into six separate types, depending on the general form of the optical system.

3.2.1 Axially symmetric reflector programs The program assumes the lamp axis lies along the reflector axis, and that the distribution of light produced will be identical in all planes. With newer and more sophisticated programs, however, axial symmetry is not assumed. Factors such as arc tube supports within the lamp and nonsymmetric filaments can be handled, giving an accurate performance prediction of real world lamps and reflectors. In a computer output on a plotter, ray paths are traced, and bare lamp intensity distribution is considered, as is reflector surface finish. The resultant luminous intensity pattern and efficiency are determined. Figure 1 illustrates an example of a program output produced on a computer driven multicolor plotter. The resultant luminous intensity pattern and efficiencies are determined.

3.2.2 Trough shaped reflector programs Such programs assume a constant cross section. Multiple lamps can be handled, which often is important in interior luminaire design. Blockage of one lamp by the other is taken into account, as well as multiple reflections of individual rays. The reflector is built interactively on the computer screen as stated by Lewin (1986); see Figure 2. Lewin (1986) stated that the designer has the ability to change reflector shape, insert new reflector sections, and move the lamps. At any time, desired the candlepower

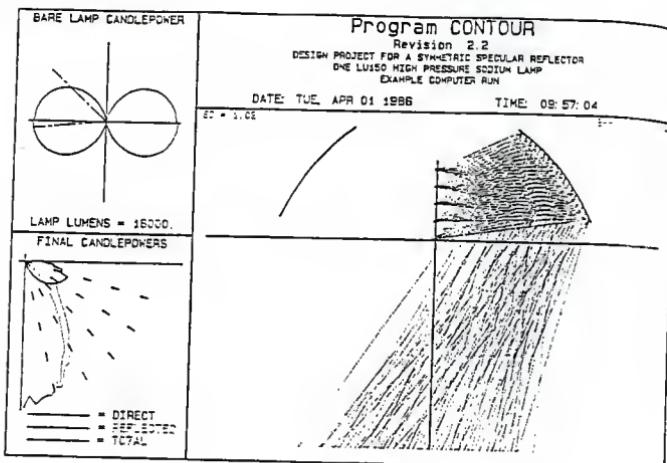


Figure 1. Graphics output from an axially symmetric program.

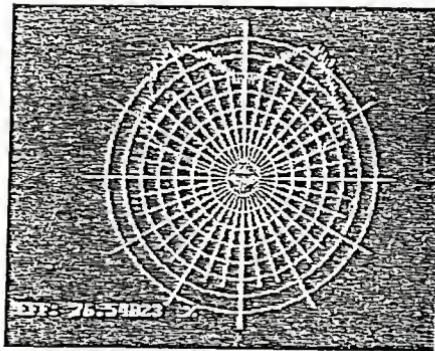


Figure 2. Video display during an interactive reflector design.

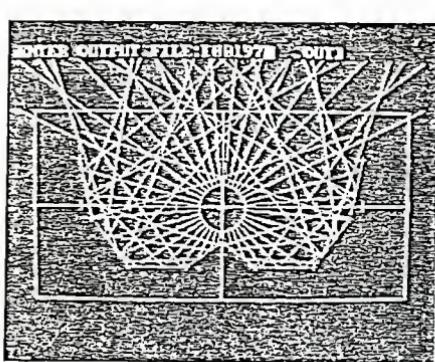


Figure 3. Video display of candlepower distribution during interactive optical design.

distribution curve can be displayed on the screen; refer Figure 3. Lewin (1986) also states that the design proceeds until a satisfactory candlepower and efficiency is obtained, and the information is transferred to any plotter, as shown in Figure 4. The computer aided design system then can produce manufacturing drawings.

3.2.3 Three dimensional asymmetric reflector programs

Such programs assume no axis of symmetry and can be used, for instance in street lighting reflector design where intricate profiles are common. The computer must record the complex inter-reflectances which may take place within such reflectors and accurately predict final intensities and coefficients.

3.2.4 Multiple reflector system programs

Programs to handle reflector systems consisting of multiple reflector elements require highly sophisticated mathematical routines and large computers. Applications are in the medical field, aerospace and defense systems, often where a dichroic reflector element must be used to remove ultraviolet and or infrared radiation. The development of such software for micro-computers can be expected as speed sophistication of micro - computer equipment increases.

3.2.5 Refractor design programs

Refractor or lens programs require the ability to handle refraction, internal reflection, transmission loss, and multiple refracting

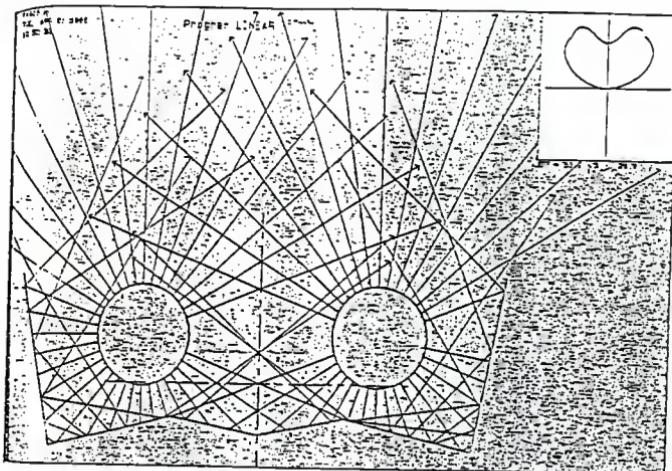


Figure 4. Pen plotter output from a computer aided design system for reflector design.

surfaces. Frequently, rays strike several surfaces, particularly when internal reflections occur thereby undergoing a series of optical effects. Program capabilities must include multiple lamps and keep track of refraction and reflection effects taking place in the refractor. The output will reveal a graphical illustration of the paths and the computer records luminous intensities (Lewin 1986); see Figure 5. A computer also produces coefficients and isolux diagrams.

3.2.6 Interior lens programs Perhaps the most common of programs, these programs analyze and design lenses, for use in fluorescent indoor luminaires. Rays on the top surface of the lens may internally reflect a number of times prior to being emitted and large amounts of computer capability may be needed.

3.3 LIGHTING SYSTEM DESIGN BY COMPUTER

The development of computer software began in 1971 when Holophane brought out a mainframe program for commercial and industrial layouts. Since then major advances have been made with all forms of lighting design performed with great speed and accuracy. Such programs are available for indoor and outdoor lighting analysis.

3.3.1 Outdoor lighting programs The basic equipment required for such programs is the same, a personal

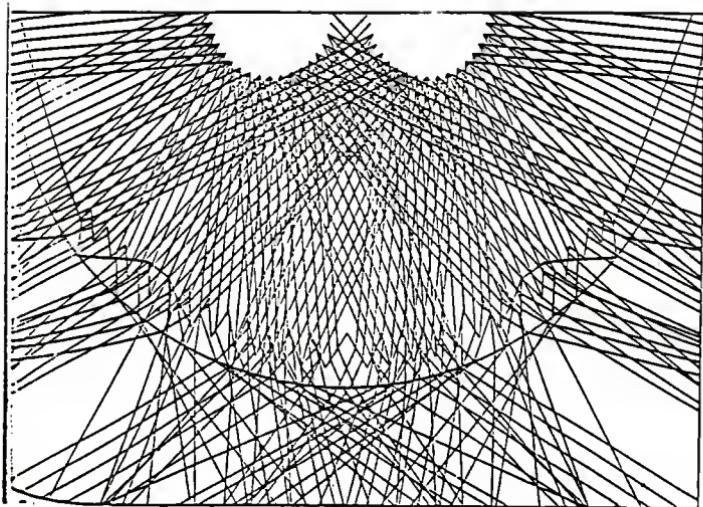


Figure 5. CAD system output from a refractor design program.

computer. Most programs are installed on a hard disk drive, and supplied with photometric disks containing luminaires of interest. These programs, depending on the manufacturer, perform some of the following functions : sports facility lighting, street lighting, or area lighting applications.

Once the input file containing details of the lighting design of interest is constructed, the main program is run. The computer reads the appropriate photometric data, performs computations and supplies the output. Examples of quantities which can be calculated are horizontal illuminance, vertical illuminance, illuminance on sloping planes, and veiling illuminance.

Considerable complexity may be introduced into the design , taking into account multiple luminaires in a single installation (usually up to 500 luminaires), multiple area calculations, and shadows due to obstructions such as buildings and bridges. Luminaires selected for calculations can be tilted, rotated, and positioned for optimal conditions.

Recent developments in numerical analysis allow the generation of optimal lighting designs. If, for example, a roadway system is to be designed to meet a variety of illuminance and luminance requirements, then such data is

provided to the computer. By omitting input for the spacing of lighting poles, the computer recognizes that it is being requested to perform the lighting design. Luminaires are located at the maximum spacing allowable to meet the specified criteria, providing the optimum design for the greatest economy.

3.3.2 Indoor lighting programs These programs also require the same basic equipment as outdoor lighting programs. Indoor lighting programs usually are capable (depending on the program) of multiple luminaire types within the cavity. They also will calculate point by point illuminance, luminance, ESI footcandles or lux. Most software allow the users to model point, line, or area sources, and determine the effect of that luminaire source. Some programs are equipped with an enhanced graphics option, which can generate perspective views of rooms with shaded plots, emphasizing areas which fall above or below the required luminance and illuminance levels.

3.4 Economic analysis In the lighting industry effective design must do more than meet the illuminance requirements. It must incorporate sound economic principles as well. As a result, increasing numbers of lighting professionals are now presenting clients with accurate lighting cost projections, along with detailed

analyses of comparable systems. Most programs feature easy data input, flexible calculations and graphics capabilities. These software packages are capable of rapid comparisons among alternatives on an average footcandle or life cycle cost basis. While determining average footcandles, programs apply the zonal cavity system to almost any room configuration. As a whole, programs of different manufacturers offer comparisons between a "base" or existing lighting condition against upto three alternatives simultaneously. Such a provision saves additional hours in project time.

Some programs can account for cost escalation factors in energy, labor and materials. Tax benefits of lighting system depreciation also can be calculated. Users may perform initial and effective annual cost, present worth, rate of return and yearly cash flow calculations. Another unique feature of some programs is that they can perform selected maintenance calculations for group, spot or lamp replacement.

Now that an overview has been given, dealing with types of programs, the next section will review some of the more important software.

4.0 VARIOUS SOFTWARE PACKAGES AND FUNCTIONS

4.1 INTRODUCTION

This part of the report will deal with some of the more important software available on the market. The lighting designer has several software packages available, performing various functions. Some packages can do a combination of functions such as the design of a lighting system and the analysis. We will now elaborate on some of these programs.

4.2 FIELD

4.2.1 Program overview After three years of extensive research and development, Lighting Technologies released FIELD, a PC based luminaire design and analysis program [FIELD 1988]. The program uses three dimensional modelling and real directional reflectance characteristics of luminaire materials. FIELD is an acronym for Finite Element Luminaire Design, and the program may revolutionize the design and testing cycle currently employed by luminaire designers and manufacturers. FIELD brings the ability to synthesize photometric data to the desktop computer of a luminaire designer.

The designer can accurately construct a three dimensional model of a luminaire, and generate photometric information ranging from summaries to elaborate reports.

The data options include the conventional far field photometric report, as well as features such as near field photometric data, identification of luminaires primary flux paths, calculation of illuminances at points on an arbitrarily positioned plane, mapping of luminaire surface luminances and the generation of three dimensional color images of the modeled luminaire. The power of FIELD lies in its ability to simplify and expedite the design process.

FIELD replaces the existing luminaire design and testing cycle (ray tracing calculations, construction and alteration of prototypes, and photometric testing) with a fast and accurate computer simulation. With FIELD, the designer can complete the entire design and analysis process in a fraction of the time it presently takes to bring a luminaire into production or alter an existing one. The result is increased design productivity and reduced development costs. FIELD accurately predicts the luminaires photometric performance without the need to physically construct and test a prototype. A three dimensional geometric model of a luminaire is constructed using CADKEY, a computer aided design program.

Upon construction of the luminaire model, the designer assigns material types to the various surfaces that comprise the luminaire. The photometric behavior of

the surfaces is described by real, measured directional reflectance characteristics. A library of these characteristics has been measured and compiled by Lighting Technologies. After assignment of luminaire material characteristics, FIELD will generate photometric information for the modeled luminaire with unparalleled accuracy. The photometric information generated by FIELD may be used with Lighting Technologies indoor and outdoor lighting analysis programs, (Lumen Micro and Lumen-Point) to evaluate the simulated luminaires performance without building a prototype or mocking up a room.

4.2.1 System requirements The program is operational on the IBM PC/XT, AT, or PC/2 systems. With the advent of the video graphics adapter and the PC/2 systems, a full color perspective image of the design can be achieved with no additional expense. The VGA has the ability to display 256 colors simultaneously at a resolution of 320 * 200 pixels.

4.3 CAD-LITE (Luminaire reflector design program)

4.3.1 Program overview This program was recently developed by Lighting Services Incorporated (CAD LITE 1988). The program with digitizer capability is now available, using the GTCO Digipad series with 16 button cursor. The advanced version includes a file containing the

transmittance characteristics of the KSH12 lens. The candlepower distribution as emitted by the lens is computed. Other lens files can be supplied at extra cost by Lighting Services Inc. A dimensioned X - Y pen plotter outputs provide scaled shop drawings for use by the production shop. A graph may also be drawn depicting the brightness pattern across the lens. An illuminance footcandle table can be produced for a plane at any distance from the luminaire. The program permits the entry and analysis of the reflectance characteristics of different types of reflector materials. The chamber or shape into which the reflector shape is built may be of any desired shape. The new Turbo release of CAD-LITE processes three times faster than the previous version.

The program can be used to handle axially symmetric reflectors and cross section of asymmetric reflectors. For axially symmetric systems such as industrial reflectors, downlights, and floodlights a vertical section is displayed and the complete three dimensional reflector is computed. The axial lamp can be moved up and down to determine the effect of beam spread and spacing to mounting height ratios. Reflector curvature can be altered at will to provide the optimum light distribution and efficiency. The lamp can be tilted and the shifted candlepower in that plane will be computed.

For trough reflectors, any form of trough profile can be specified. This need be only bi-symmetric, assymetric troughs and unusual shapes can be generated. Lamp locations can be moved in seconds to change beam angles, spreads and efficiencies for complete analysis of all design possibilities.

4.3.2 System requirements This program runs on any IBM PC/XT/AT or compatible system. A 640K memory is required. Other requirements are a hard disk drive and DOS operating system. A 8087 or 80287 math co-processor is recommended although not mandatory.

4.4 CALA

4.4.1 Program overview CALA is an acronym for computer aided lighting analysis, the most recent release is version 6.5. The program was written by John Hibbs (Lord 1987). CALA is suitable for any electrical lighting analysis, including roadway lighting, indoor area lighting, and indoor or outdoor sports lighting or industrial lighting. Any luminaire layout can be entered and the illumination values for vertical or horizontal surfaces will be calculated. A special feature allows the input of sketches in three dimensions so that unusual shapes can be analyzed. Users can select points, lines, or areas for analysis, up to 4000 points, 200 line segments, or 2000 panels. Data may be entered using a

digitizer or the keyboard. Feedback from CALA is in three dimensional wire frame perspective views of the design layout. The program supports either a monochrome or color graphics adapter, with printed output going to the Epson printer. Documentation for the program is complete and well written. Installation is possible with the help of an "install" batch file to transfer the program onto a hard disk. CALA can be run with a two diskette drive system, but quicker results are obtained using the hard disk. During installation, the program creates subdirectories for photometric data files. Photometric data for Holophane manufactured luminaires is available on 12 diskettes. Photometric data in the IES format can be used with CALA. CALA saves information automatically at predetermined points in the program. Although this feature works well some designers prefer a manual override to make sure of file saving.

4.4.2 Calculation method CALA is a point program. Up to 50 help screens and 200 messages help keep the user track throughout a complete session. A deep understanding of the program is essential for accurate and sophisticated results. When rerunning a project, only the new data is required to be entered. CALA also has a quick calculation routine; as well as a refined analysis and presentation of lighting designs to give designers an accurate picture of the final

effect. The drawback of such precision is that it requires extra time in setting up the analysis and in calculating the results. Some benefits of investing in CALA are its high caliber technical support and the company's plan for future expansion. Holophane (company which markets CALA) is currently contemplating including a simple analysis in its next version.

4.4.3 System requirements Requires an IBM PC/XT , AT or compatible with a 3087 or 80287 Math coprocessor. The system also requires an IBM color graphics board. It requires a hard disk with at least one 360K or 1.2MB floppy disk drive, or two 360K or 1.2MB floppy disk drives is required. A hard disk drive is recommended. The printer used is a Epson FX, LQ or compatible printer.

4.5 ICON/ECON

4.5.1 Program overview Troxell (1993) describes the ICON/ECON program as a straight program which is based on the zonal cavity method of calculation. It is an easy and user friendly program. The package can be used to ask several " what if " questions by changing fixture quantities and ballast and lamp combinations. The input data can be modified. In addition there are two point source programs, ICON II (indoor) and ICON II (outdoor).

4.5.2 ICON II (indoor) This is a full blown indoor lighting design program for the experienced lighting

designer. One should learn the program to reap the benefits that it can give to the designer. It is capable of multiple luminaire types within the cavity and will calculate point by point illuminance (horizontal) footcandles or lux, illuminance with IES body shadow factor, Lighting Effectiveness Factor, and Visual Comfort Probability. The new user is recommended to use the QAI subprogram to construct the data files required for the program to use for application. The more experienced user can use EDLIN from DOS or any text editor or word processor that will give an ASCII text file. It is also required to run a subprogram called SEARCH , as well as obtaining a listing of data files listing the company's luminaires.

4.5.3 ICON II (outdoor) This is the outdoor program for the three program set. The program is complete and well written. It comes out with a set of work sheets to be used in the laying out of luminaires, pole heights, and locations. As in the ICON Indoor, either a text editor or a subprogram called QAO must be used. The program can be used for designing sports lighting, street lighting, flood lighting and area lighting. It has all the requirements one would need in a program, including meter elevation at different elevations, and masking horizontal and vertical target planes. QAI and QAO lead the user through some of

the more difficult tasks presented. However there is no menu driven interphase, which would make operation a lot easier.

4.6 SPAULDING LIGHTING

4.6.1 Program overview This program can be used for both indoor and outdoor lighting (Spaulding Lighting, 1988). This software is proprietary, that is it will run only on Spaulding supplied photometrics. Some features of this program is that it will calculate both horizontal and vertical footcandles, and will printout to any scale required. The program is capable of up to 5 different fixture types at one time and will include upto 500 luminaires per layout. The user also can specify up to 9 obstructions per layout and 30 masked areas. Since Spaulding makes an extensive collection of floodlights, the program will allow the user to input aiming points and will do sportslighting and facade lighting as required.

4.6.2 System requirements This program is designed to be used on an IBM compatible computer with at least 512K RAM memory. It can be used from 2 floppy drives but is much easier if installed on a hard disk. If installed on the hard disk, it requires 1.2 MB storage space. A math coprocessor is required to run the program, with DOS version 3.1 or better.

4.7 MICRO - EYE - LITE

4.7.1 **Program overview** This powerful indoor lighting application program handles almost every conceivable type of lighting system, including florescent, HID and incandescent, asymmetric and symmetric distributions, and a mix of downlights and uplights (MICRO-EYE-LITE, 1988). In addition to traditional footcandle or lux illuminance tables, designs can be investigated using exitance and task luminance patterns, visual comfort, contrast rendering, as well as relative visual performance. Sloped ceilings and certain irregularly shaped rooms may be analyzed as well as rectangular rooms having reflective room surface inserts. The program also calculates the full point by point flux transfer interreflectance calculations, and provides the option of using the room position multiplier method.

Room layout data is entered screen by screen, using a user friendly data input program complete with " help " screens. Data preparation as well as job submission and reporting are all controlled by the main menu, a feature which assists all users. The program has output capabilities which include point by point tables of horizontal illuminance, vertical illuminance, illuminance on a slope plane, task illuminance, and task background illuminance. Other factors which can be calculated are

the luminance of the walls, contrast rendering factor, equivalent sphere illuminance, visual comfort probability, and the relative visual performance. The program also incorporates upto 200 luminaires per run. Five different luminaire types per run can be studied.

The package uses luminaire photometric data available not only from the program developers but also numerous manufacturers. The plotting option gives iso-plot output for most printer types. Contour levels can be selected automatically by the user. If desired, all areas above or below a certain level can be shaded.

4.7.2 System requirements The program is intended to be used on an IBM compatible computer with at least 512K RAM memory. It can be used from 2 floppy drives, but it is much easier and faster if installed on the hard drive. If installed to the hard drive, it takes up 1.2 MB storage space. A Math-Coprocessor is required to run the program. DOS version 3.1 or better is necessary.

4.8 LUM-H

4.8.1 Program overview This program has some of the best screen displays as mentioned by Troxell (1987). The screens are extremely attractive and user friendly. The product has no manual and requires only a basic knowledge to run. There is a Read.Me file to explain the use of the

keys. This information is repeated in the menu line on the bottom of the screen.

The program consists of several modules. These modules are illumination calculations, cost analysis, lighting tables, and coefficient tables. The illumination calculations module takes the work out of zonal cavity calculations and delivers a printout if necessary.

4.8.2 Calculation method It is possible to calculate fixture quantity or illuminance levels for a predetermined fixture quantity with the program. You can ask "what if" with the lamp quantity or reflectance. Its page back option can make changes and obtain quick results. Also this section of the program provides results on an area per luminaire calculation. It contains a file handling utility for storage of calculations and recalling for future use. The only shortcoming of the program is that does not provide spacing data for fixture quantities for proportional spacing or even calculate number of rows or fixtures per row. This feature is handy for those using a CAD system.

The cost analysis is pretty basic, and suitable for comparisons of three systems. This program is a manufacturer supported product and the cost is low. The Co-efficient table generator is impressive. The zonal

flux or candelas have to be input to get a neatly printed set of coefficient tables, including wall and ceiling cavity exitance. All this is in accord with IES standard procedures. There is also a footcandle and energy selector module that will print a set of tables that indicate for each room cavity ratio (RCR), square footage per fixture, and watts per square foot. The software needs a file storage routine. This program will run any fixtures photometry, not just Globe Lighting's (the company which manufactures this program).

4.8.3 System requirements This program can be run on an IBM PC/XT, AT or any compatible system. Other requirements are MS-DOS, with 256K or more with 1 or 2 floppys or hard disk.

4.9 POINT

4.9.1 Program overview Point is a general purpose, point by point lighting calculation program from Lighting Analysts. It is simple enough to run for those who might use it for a month (Lord 1987) yet sophisticated enough to satisfy frequent users, from consulting engineers to manufacturers.

Although some lighting manufacturers offer complimentary software that works only with their photometric data, Point is a reasonably priced package

which will work with any Illuminating Engineering Society (IES) standard photometric data. It is organized around a worksheet display so entering data into point is straightforward. Online help is readily available, and from the main menu, a user can branch to any of the following options : create or change a worksheet, create or change a photometric file, create a title block, replot a grey scale plot.

4.9.2 Calculation method The program is capable of printing point by point graphics to any scale up to 50 inches wide by 30 inches long with a user definable grey scale illuminance grid. It accommodates horizontal, vertical, or tilted planes of analysis with any lightmeter orientation. The major advantage of the program is the ability to define most of the variables in lighting analysis. Included with Point is a utility program, Phodir, that allows the manipulation of standard IES photometric files. Users who desire a grey scale printout must have a printer that can print IBM graphic characters. Most printers have this capability.

Lighting Analysts has scheduled two add - on module for release in the near future. This will allow users to show shadowing and obstructions as well as luminaire locations and aiming angles (Lord 1987).

4.9.3 System requirements Requires an IBM PC/XT/AT or

compatible with an 8087 or 80287 math coprocessor and a dot matrix printer with graphic capabilities. A hard disk is recommended by the manufacturers.

4.10 SOFT/LIGHT

4.10.1 Program overview Soft light is a software package which is not available on the open market. At present Soft /Light is in its second generation, the first version was released in 1985. Version 2 became available early in 1987. The program contains a database with over 300 Benjamin Lighting products represented. The program can do calculations on any fixtures in the database (SOFT LIGHT 1988).

4.10.2 Calculation method Soft Light consists of four basic programs. The first will generate a listing of candlepower data, coefficients of utilization and fixture efficiency. The second program is an implementation of the zonal cavity method, and will calculate the number of fixtures or footcandle levels for a given area. This program will automatically calculate the coefficient of utilization for a particular fixture, eliminating the need for CU tables. Program three is a point by point program which gives footcandle levels at discrete points within a room. It makes use of the inverse square law and can calculate the contribution from up to 300 fixtures for

each point. This program will also estimate the reflected component for each point of interest. The last program is another implementation of the inverse square law but generates the footcandles for vertical walls or surfaces.

4.10.3 System requirements Soft Light will run on any computer which will run MS-DOS with either two diskette drives, or a single diskette and a hard disk. A printer also is required. The programs, when running, use less than 128K of RAM. Due to the size of the database 1.2 Meg of hard disk space is required.

4.11 LUMEN MICRO

4.11.1 Program overview Lumen Micro is a comprehensive computational system for point indoor lighting calculations which accurately models the characteristics of almost any lighting system (LUMEN MICRO, 1987). Some of the major capabilities include the calculation of Equivalent sphere illumination (ESI), Relative visual performance (RVP), horizontal and vertical illuminance on a horizontal plane at a rectangular array of up to 20 X 20 points. The program is also capable of calculating room surface exitances and illuminances on any room surface. A mixed luminaire system can also be analysed. Rectangular areas with different reflectances can be input on any wall surface, and their effects accounted for.

Contour plotting is available for all calculated values. The user can specify contour values to be used, and can generate plots on a printer. An iso-contour line plot can be produced with up to 15 different user defined contour lines. These line plots can be produced with "criterion shading" where any area which falls above or below a specified criterion value will be shaded on the printed plot. Full grey scale shaded renderings in place of iso-contour lines are useful for studying the exitance patterns on the room surfaces.

4.11.2 System requirements To insure proper program operation an IBM PC/XT, AT or compatible system is required. An expanded memory of 256K with DOS version 2.0 or 320K with DOS version 3.0 is essential. Other requirements include a parallel printer port, 80 column monitor, 8087 math coprocessor and an Epson or Epson compatible printer.

4.12 LUMEN POINT

4.12.1 Program overview Ease of data input, superior calculations and graphics capabilities make Lumen Point one of the most advanced outdoor analysis software packages on the market today (LUMEN POINT, 1988). Lumen Point allows the complete design and analysis of outdoor lighting systems from simple to the most complex. This

includes predicting the performance of roadway or sports lighting projects, running comparisons on floodlighting or general area lighting systems. Lumen Point saves hours of trouble by virtue of a highly evolved data entry system. It features an online help system to guide even the most inexperienced user through the system functions. Lumen Point's self-documenting worksheet also provides an effective format for assembling and organizing data. Since the worksheets can be saved, the same information never needs to be input twice. This feature allows ideas to be modified to perfection even on short notice.

If it is necessary to predict the effect of a group of lights, data concerning these luminaires can be entered in groups, minimizing the amount of information needed to describe an entire system. Planes of symmetry can also be specified to reduce the amount of data input for large projects such as sports complexes where luminaire locations and aiming are often symmetric.

4.12.2 Calculation method Since outdoor lighting systems vary from the simple to the complex - Lumen Point provides the software flexibility to match, with the power to do more calculations on any given run in either footcandles or lux. The program enables the calculations on multiple grids, each of which can be up to 50 by 50 points. Depending on the type of information you need, these grids

can be either horizontal, vertical or sloped. In a tennis court design for instance, the calculation of vertical illuminances will take precedence, whereas in an analysis of a stadium, the aisle is normally accommodated on a sloping grid. Illumination values can also be determined at any arbitrary orientation, including lighting for all points directed towards a single location. To increase productivity , this software can perform calculations for up to five different grids simultaneously.

Lumen point also enables you to calculate the effect of different lighting systems by specifying either aiming angles or aiming points. Up to eight different luminaire types can be analyzed in a single run. Utilization of Lumen data photometric database will reduce project time even further. Lumen Point can be used to analyze special interior lighting applications, such as industrial, track and display lighting. Using Lumen Point iso contour or gray scale shaded plots can be produced for any analysis grid with 15 different specified contour values. This feature can provide dramatic aerial views of site lighting projects at night, as well as graphics for indoor lighting applications.

Iso contour plots can also be generated with criteria shading, to isolate areas which fall above or below specified illumination values. These areas are shaded

automatically on reports. Criterion shading is particularly effective for outdoor lighting applications, where often there are minimum footcandle or lux requirements.

4.12.3 System requirements Lumen Point runs on IBM personal computers, PC/XT, AT or any fully compatible hardware configured as shown below :

1. A system unit with 2 diskette drives or 1 diskette drive and a hard disk.
2. Expanded memory to 256K with DOS version 2.0 or 2.1; 320K with DOS version 3.0.
3. 80 column monitor.
4. Epson dot matrix printer.
5. 8087 numerical coprocessor.

4.13 EMCOLITE

4.13.1 Program Overview Emcolite is a simple outdoor lighting program from Emco Environmental Lighting. In contrast to the comprehensive and complex nature of CALA, Emcolite is a simple yet powerful program. Emcolite offers a sophisticated range of functions (EMCOLITE 1988). Some of the more important is the ability to mask out unwanted areas and to tilt fixtures above or below the horizontal. The program also has an editing feature, simple and quick, which allows design components such as poles, luminaires, lamp size or tilt to be changed,

analyzed, and recalculated in a matter of minutes. One drawback is that only EMCO luminaires may be used in the lighting analysis. The manual is easy to understand and the experienced user familiar with DOS and lighting principles can generate useful results with the program.

4.13.2 Calculation method This program allows point by point scaled results of the outdoor lighting analysis. These results can be viewed on the screen (in high resolution color on color monitors), or sent to the printer. The print out scale can be specified to match a plot plan. In addition the program calculates the maximum, minimum, and average footcandle levels.

4.14 MICRO - SITE - LITE

4.14.1 Program overview This is an outdoor lighting design applications program. By using a digitizer the lighting layout site plan features, such as the location and orientations of luminaires, obstructions, curb lines can be entered directly from blueprints using the GTCO Digipad Series 16-button digitizers. The GRAPHER option of the program displays the lighting layout site feature plans and they are superimposed on the point by point analysis reports. The luminance and illuminance contour lines are included. The MICRO SITE - PLOT option is similar to the GRAPHER except that it produces a 6 color "

plan view "site layout with luminance and illuminance contour lines as explained by MICRO-SITE-LITE (1988).

A new Main Menu permits users to scroll output report files page by page on the screen, and provides a secondary menu to include the MICRO-SITE-PLOT and GRAPHER plotting options. Enhancements have been made to the interactive "help" screens of the MSLIN input programs. The .INP file has been eliminated , so that the layout data file may be modified now by using a system editor as well as by using the MSLIN data entry program.

Photometric data files in the IES Format on diskettes are available as a photometric data base service from Murray and Gillespie Computer Solutions Inc for American Electric, Gardco and General Electric outdoor and industrial luminaires.

Output capabilities include horizontal illuminance, pavement luminance (various pavement types), veiling luminance (disability glare), vertical and slope plane illuminance. Upto 500 luminaires per run are allowed, with 5 different luminaire types per run. The luminaire can assume any location, tilt angle or orientation.

Plotting capabilities range from simple contour plots to iso plots for various values of illuminance, pavement or veiling luminance. Contour levels can be selected

automatically, or by the user.

4.14.2 System requirements The program can run on IBM PC/XT/AT or compatible system. Also required is a Hewlett-Packard 7440 plotter and compatible series pen plotters for the MICRO-SITE-PLOT option.

4.15 ISOPPOINT OUTDOOR DESIGN

4.15.1 Program overview Isopoint, is a program that creates isofootcandle design templates for outdoor area lighting. Isopoint manufacturers (1988) state that it was written as a marketing tool with manufacturers in mind. The program can be customized and licensed to any lighting manufacturer, who can then distribute it to specifiers of their particular luminaires.

4.15.2 Calculation method Lighting designers and specifiers can also purchase Isopoint in a generic version, and use it to compare alternate luminaires using IES format data from different manufacturers. Until Isopoint, such templates were produced by pen plotters or by hand. Isopoint allows designers to produce large numbers of templates using a generic PC and a dot matrix printer. Both Isopoint and Point come with complete documentation, the disadvantage is that it must be printed before the program. The excellence of the program is that it was written by lighting designers and not software

developers, for their own practice.

4.15.3 System requirements This program requires the same basic equipment as the Point program. The main equipment is the IBM PC/XT/AT or compatible with an 8087 or 80287 math coprocessor.

4.16 SOLAR S

4.16.1 Program overview This program is an energy calculation program useful to lighting designers. This is an ingenious program for the IBM personal computer that gives a coarse grained visual display of building energy flows, useful during the conceptual design phase. Murray Milne developed this program at the UCLA school of architecture (1981).

4.16.2 Calculation method On startup, SOLAR S automatically defaults to typical design values for the building type chosen by the user. As the user gains experience with SOLAR S, it is possible to enter values specific to the user's design and location. It is possible to compare alternate design schemes to a base case by systematically altering building components. This gives a graphic yardstick of each design's energy performance in both summer and winter.

It is possible to review several alternate designs within a few minutes for an experienced user. All results

are displayed graphically, not just numerically which is where the program stands out. By looking for peaks and valleys in the energy use patterns, users can quickly evaluate daily and seasonal performance.

4.16.3 System requirements The program requires an IBM PC/XT or fully compatible microcomputer with two diskette drives or one diskette drive and a hard disk.

4.17 DESIGN LITE

4.17.1 Program overview This program offers the latest development in microcomputer technology for generating the latest in indoor alternative lighting layouts (DESIGN LITE, 1988). Color video displays of the lighting plan appear on the screen, luminaires can be moved, rotated, rows added and deleted all interactively. Different colors highlight the luminaires being changed. At any time, an image of the screen display may be printed to a scale on a standard color printer, using up to 16 colors.

Design Lite overlays the performance output analysis table on the lighting system. The numbers are generated on the screen in a different color, at all calculation points specified. A convenient calculation menu appears on the screen along with the lighting system. Analyses can be performed for illuminance horizontal, vertical, and slope plane; luminance (task and room surfaces), ESI, ESI

Rating, contrast rendering factor, visual comfort probability, and relative visual performance.

Using the Design - Lite graphics output capability a color graphics representation of the work plane, shaded in terms of illuminance or luminance pattern can be obtained. A color simulation of the luminance pattern of any of the walls or the ceilings can also be plotted.

4.17.2 System requirements The package is operational on an IBM PC/XT, AT, or compatible systems. A hard disk is recommended though it can function perfectly on a single disk drive. A memory of 640K is required, as well as a PC-DOS or MS-DOS system. Other items required are a 8087 coprocessor for a PC/XT and a 80287 for a PC/AT.

4.18 LUMEN\$

4.18.1 Program overview In today's lighting industry, effective design must do more than meet the illuminance requirements. It must incorporate sound economic principles as well. As a result, increasing number of designers and other lighting professionals now are presenting clients with accurate lighting cost projections, along with detailed analyses of comparable systems. Lumen\$ (1988) state that this is the most comprehensive software if its kind. It features ease of data input, flexible calculations and graphics

capabilities. Since it is a complete zonal cavity and economic analysis program, Lumen\$ allows rapid comparisons among design alternatives on an average footcandle and life cycle cost basis.

Design options, from the simple to the complex, can be modelled quickly and easily, with basic questions regarding the average footcandles and the cost of two identical systems being answered without tedious calculations. This way, designs can be tailored to provide the aesthetics, illuminance values and cost effectiveness required by the designer. One of the major advantages of this system is its highly evolved data system. The self-documenting worksheet provides an effective format for assembling and organizing data. Since the worksheets can be saved the same data need not be entered twice. This allows ideas and presentation to be made on short notice.

4.18.2 Calculation method When determining average footcandles, Lumen\$ applies the zonal cavity method to almost any room configuration including rectangular, L-shaped, trapezoidal, triangular and circular rooms. Users may define a base or existing lighting condition against which the effectiveness of up to three alternate lighting systems can be evaluated simultaneously. The ability to compare multiple systems in a single run saves additional

hours in project time. Economic evaluations can range from the simple to the complex. A user can model, for example, increased air conditioning and decreased heating load costs created by alternate lighting systems.

The program accounts for cost escalation factors in energy, labor and materials. Tax benefits of lighting system depreciation also can be calculated. Users also can perform initial and effective annual cost, present worth, rate of return and yearly cash flow calculations. Another feature of the program is that it can perform selected maintenance calculations for group, spot, or group and spot lamp replacement.

With Lumen\$, calculations can be more accurate because the software is designed to function with actual photometrics from a user defined database of luminaires. This guarantees more exacting results than with the coefficient of utilization tables alone. If photometric data is unavailable on a particular luminaire, users can input existing coefficient of utilization values as needed.

The program is supplemented by Lumen-Data, a photometric database manager, which is used to store data on direct, indirect, and direct/indirect lighting equipment. Many major lighting manufactures are currently

utilizing this software, and hence are able to provide users with compatible diskettes containing photometric information to help speed the input process. The processing power of Lumen\$ is matched by its flexible output presentations. Results of analysis work can be tailored to the needs of individual client to form a clear, concise report of the design solutions being presented.

4.18.3 System requirements Lumen\$ runs on an IBM PC, PC/XT, AT or any fully compatible hardware, configured as shown below:

1. A system unit with 2 diskette drives or 1 diskette drive and a hard disk.
2. Expanded memory to 256K.
3. 80 column monitor.
4. Epson dot matrix printer.
5. 8087 or 80287 numerical coprocessor.

4.19 ELITE SOFTWARE

4.19.1 Program overview The Elite software lighting fixture calculation program is a powerful yet easy to use program that allows the designer to quickly determine the number of fixtures required to obtain a desired level of foot candles as indicated by Elite (1988). Besides calculating a desired fixture requirement, the program also provides a lighting fixture schedule, and a

comprehensive energy economics report. Depending upon the disk capacity of the computer, the program can handle projects having up to 1000 rooms. To enable immediate usage, photometric data is provided for over 200 common lighting fixtures. The photometric data is stored in a separate file so it can be easily reviewed, revised, deleted, and own fixture data added. There is no limit to the number of fixtures added except the capacity of the computer disk. Along with the photometric data you also are allowed to specify numerous items of information per fixture such as description, cost, watts consumption, manufacturer, and more. An important feature of this program is its ability to automatically "look up" and interpolate the correct coefficient of utilization for any set of given set of room conditions. In addition to always determining the correct coefficient of utilization the program also can accurately determine the proper floor multiplying factor for non-standard effective floor cavity reflectances.

4.19.2 Calculation method The Lighting Program utilizes the zonal cavity method as outlined in the Illuminating Engineering Society (IES) Reference volume. The lighting program users manual goes into great detail as to how you can quickly verify the results with the IES volume.

The input data is requested by the program through a

series of menus and questions. All user responses are checked for validity as the program will not continue past an input section unless valid data has been entered. Upon completion of the input process, all data is saved to disk and can be reviewed and edited whenever desired. Important input items include the following room names and dimensions, design foot candles, ceiling, wall, and floor reflectances, lamp lumen and luminaire depreciation fractions, and the height of the floor and ceiling cavities.

4.19.3 System requirements The lighting program requires a microcomputer with the CPM, MS-DOS or PC-DOS operating systems. With the CPM operating systems the program requires only 48K of memory. With the PC-DOS and MS-DOS operating systems only 96K of memory. Only one disk is required under all systems.

4.20 MICRO - COST - LITE

4.20.1 Program overview This software package from Lighting Sciences Inc., is a highly functional and simple to use program for economic comparison of alternate lighting systems. The package is available for indoor, outdoor or both lighting systems. During a Micro-Cost-Lite run, upto five alternative lighting systems for a single project can be compared side by side, taking into

account initial costs, operating costs, life cycle cost benefits and payback periods. Some of the important functions are described below (MICRO-COST-LITE, 1988).

4.20.2 Calculation method Program capabilities include initial costs based on the cost of luminaires, lamps, and circuits. It can compute each system initial costs based on annual operating costs for any specified energy cost. It can also include the yearly operating cost increases due to any specified annual energy cost escalator. Ballast life and replacement costs can be considered. The program can determine life cycle cost benefit analysis, including pay back periods based on total operating costs and amortized initial costs over the specified life of the project.

Other uses include comparing a selected lighting system operated under conditions. For example comparing the cost effects of spot versus group relamping, different energy costs, various illuminance levels, different light loss factors, and different annual operating hours.

Micro-Cost-Lite output tabulates the economic data for each system side by side, then provides a payback and life cycle comparison between systems. The tabulation includes Luminaire costs, Lamp costs, Taxes, total initial costs, annual power costs, maintenance costs, and total

operating costs.

4.20.3 System requirements The package requires an IBM PC, PC/XT, or PC/AT with 2 disk drives or 1 disk drive and a hard disk. An internal memory of 256K or more is required. The operating system is DOS, with an optional 8087 math co-processor.

5.0 APPLICATIONS OF TWO LIGHTING SOFTWARE PROGRAMS

5.1 INTRODUCTION

In this chapter some common applications of lighting software are highlighted. Examples of two different lighting packages are discussed. Hillman (1988) stated that selection of a particular software package depends on the type of application. At present the market for computer software is flooded with many programs, which perform specialized calculations.

5.2 APPLICATION OF LUMEN MICRO

Two example problems are provided to highlight many of the major features of Lumen Micro (indoor lighting program) input and output discussed earlier. Each example gives a description of the input file created from the blank worksheet and a copy of the resulting output file.

The first example assumes a room dimension of 14 feet by 14 feet by 9 feet, and a luminaire layout as indicated in Figure 7. The luminaire in consideration is a 1'by 4', 2 lamp troffer with a 78 W input and 3150 lumens. Room surface reflectances are .8, .5, and .2 for the ceiling, wall, and floor. There are no reflective inserts present in this example, although Lumen Micro allows reflective inserts to be considered. Horizontal illuminance is desired at a height of 2.5 feet, spread uniformly through the room. Vertical illuminance will be calculated at the

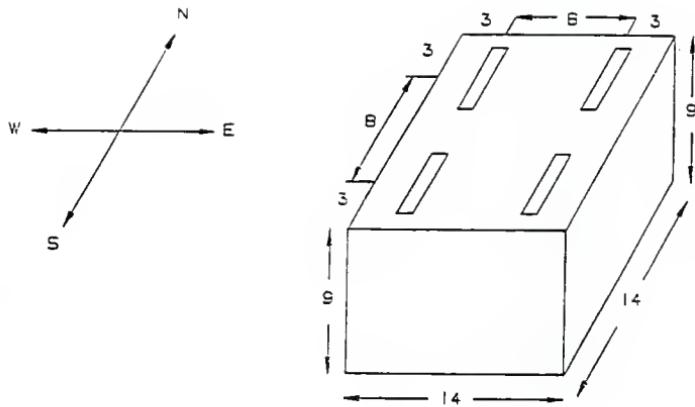


Figure 6. Room layout of example 1. There are 4 1' x 4'
2 lamp luminaires, each with 78W and 3150 lumens. Wall
reflectances =.5, ceiling=.8, and floor=.2.

same points. Room surface exitances can be calculated for any wall, although in this example the room surface exitances will be calculated for the north wall surface. The user also can define the type of contour plot required and grey scale rendering of that plot. For this particular case, a contour plot of the north wall surface exitances is shown; see appendix 3. A summary of the output for example problem 1 is shown in appendix 3. Contour plots for the first example problem are shown in Figures 8 and 9. Figure 8 is a plot of the illuminance at a work surface height of 2.5 feet. Figure 9 is a plot of the equivalent sphere illuminance for the west wall viewing. A detailed explanation of the co-ordinates seen in both plots will be given later in this section.

The second example problem is a 30 by 30 by 10 foot room (see figure 10), with a working plane height of 2.5 feet. The luminaire in consideration for this case is a 2' by 4', 3 lamp parabolic troffer. The input wattage is 122 watts; there are 3150 lumens. For this example the walls are assumed to have a reflectance of .5, the floor .2, and .75 for the ceiling. On the west wall there is a reflective insert (20' by 4'), with a reflectance of .05, assumed to be a dark curtain.

Output for the second example problem is shown in appendix 4. The plots for the second example problem are

ILLUMINANCE

QUANTITY FLOTTED: FOOTCANDLES

SCALE: 1 INCH = 2.0 FEET CRITERION: LESS THAN 35.00

VALUES SYMBOLS

40,000	0
42,000	1
44,000	2
46,000	3
48,000	4
50,000	5
52,000	6
54,000	7
56,000	8
58,000	9
60,000	A

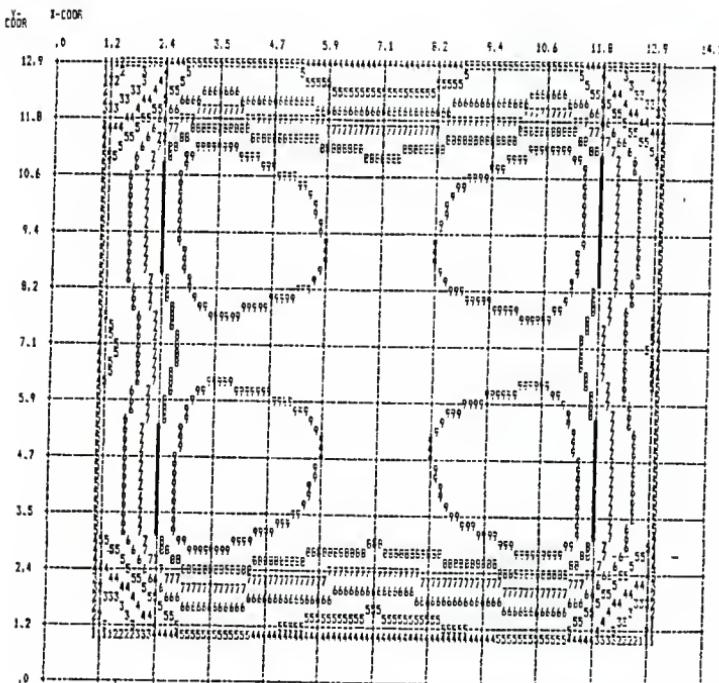


Figure 7. Contour plot of illuminance at 2.5 ft for example 1.

EQUIVALENT SPHERE ILLUMINANCE WEST VIEWING

QUANTITY PLOTTED: SPHERE ILLUMINANCE THAT PRODUCES EQUIVALENT VISIBILITY
PENCIL TAPEST - CONCENTRIC RINGS @ 25 DEGREE VIEWING ANGLE

SCALE: 1 INCH = 2.0 FEET - DISTANCE: LEFT < 30.00

VALUES: SYMBOLS:

15.000	0
20.000	1
25.000	2
30.000	3
35.000	4
40.000	5
45.000	6
50.000	7
55.000	E
60.000	F
65.000	A

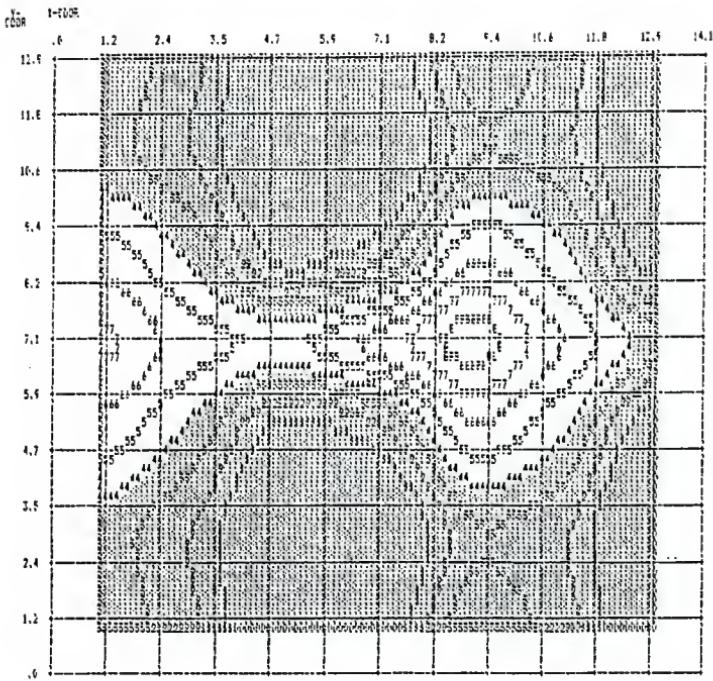
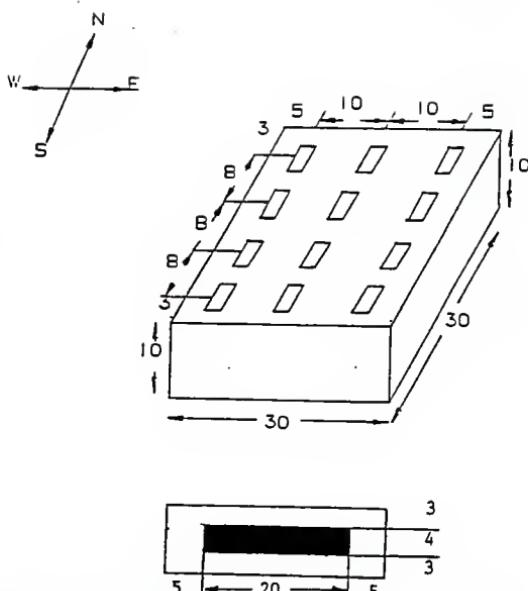


Figure 8. Plot of equivalent sphere illuminance (west viewing) for the work surface of Figure 6.



View of west wall with 20' x 4' insert with .05 reflectance.

Figure 9. Room layout of example 2. There are 12 2' x 4' 3 lamp luminaires, each with 122W and 3150 lumens. Wall reflectances=.5, ceiling=.75, and floor=.2.

ILLUMINANCE

QUANTITY PLOTTED: FOOTCANDLES

SCALE: 1 INCH = 5.0 FEET CRITERION: LESS THAN 30.00

VALUES: SYMBOLS:

30.000	0
35.000	1
40.000	2
45.000	3
50.000	4
55.000	5
60.000	6
65.000	7
70.000	8
75.000	9
80.000	A
85.000	B
90.000	C

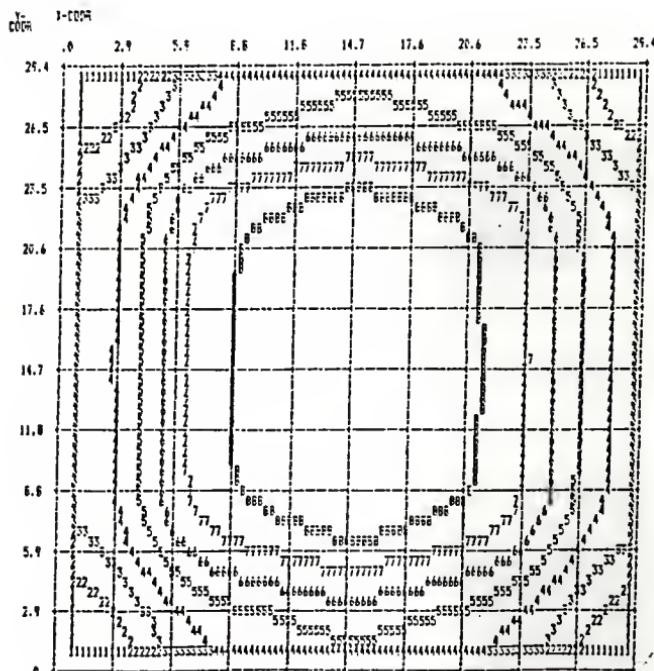


Figure 10. Contour plot of illuminance at 2.5 ft for example 2 (Figure 9) of a 30 x 30 ft room.

EQUIVALENT SPHERE ILLUMINATION WEST VIEWING

QUANTITY PLOTTED: SPHERE ILLUMINANCE THAT PRODUCES EQUIVALENT VISIBILITY
PENCIL TARGET - CONCENTRIC RINGS & 20 DEGREE VIEWING ANGLE

SCALE: 1 INCH = 5.0 FEET DISTANCE LESS THAN 35.00

VALUES: SPHERE

30.00 0
22.00 1
16.00 2
12.00 3
9.00 4
7.00 5
5.00 6

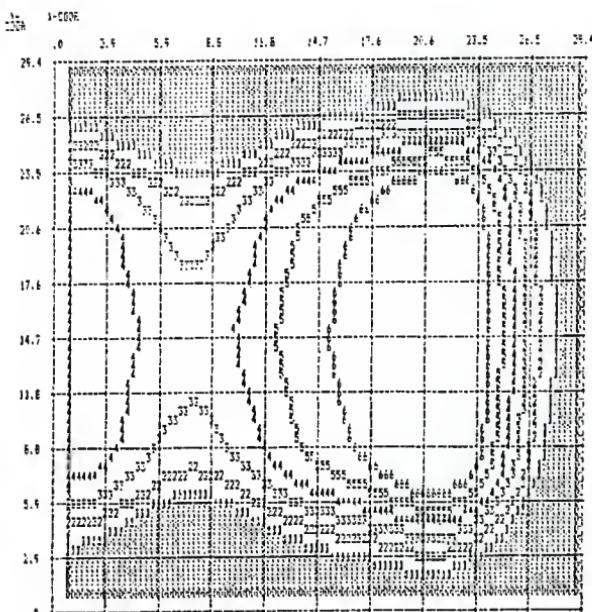


Figure 11. Plot of equivalent sphere illumination (west viewing) for the work surface of Figure 9.

shown in Figures 11 and 12. The plots requested were illuminance, and equivalent sphere illumination for the west viewing. For this particular example there did not appear to be much of an effect due to the insert.

It also is possible to have a maximum of 15 contours specified for any plot. For iso-contour plots above or below a criterion value the plot is shaded. Some of the important features of this program are shown below.

5.2.1 Worksheet The program brings up a blank worksheet. The user can select options by placing an "x" in the appropriate box. The program is completely interactive.

5.2.2 Workplace height It is the vertical distance from the floor to the calculation plane, measured in feet. The input number should be greater than 0 and less than the room height.

5.2.3 Candlepower multiplier This is a single number which accounts for any distribution or lumen depreciation, ballast factor losses and pro-rating of lumens if the actual lumens used differ from test lumens of the photometric report. For the first example a candlepower multiplier of 1 was chosen, and for the second example .7.

5.2.4 Analysis grid The area to be analysed is defined in the program in terms of a grid. There are three ways to define an analysis grid :

1. Choosing a default grid, which has 19 columns and 19 rows.

2. Specifying your own grid of equally spaced columns and rows.

3. Specifying a grid of arbitrarily spaced columns and rows. Columns and rows must be defined except for the default grid. A maximum of 20 columns and 20 rows may be specified for any analysis grid.

For the first example problem a grid of 2 rows and 2 columns was defined based on the luminaire locations. The first column is 3 and the spacing between columns is 8. Similarly the first row is 3 and spacing between rows is 8. This becomes clearer when referring Figure 7. The rows run in the east-west direction and the spacing between rows is 8, and with the first row at 3. The columns run in the north-south direction and the first column is at 3 with a spacing of 8 between them. The second example problem has a grid of 4 rows and 3 columns, the same principle and concept being applied here.

5.2.5 Room data Data in this section includes the room dimensions and room reflectances. Dimensions of the room in the East-West direction correspond to the dimension along the X-axis. Dimensions of the room in the North - South direction corresponds to the dimension along the Y

axis. Height of the room corresponds to the Z axis.

5.2.6 Reflectances A number greater than 0 and less than 1 can be input for the reflectance of the room surface. If inserts are present, then the reflectance of the inserts should be given. Reflective inserts are not allowed on the floor or the ceilings. The reflective inserts can be windows, curtains or doors; it is only required to input the location and reflectance.

5.2.7 Luminaire data Up to 8 types of luminaires can be used in a single analysis. Luminaires can be obtained from the database files, present in the photometric disks provided with the software package.

5.2.8 Luminaire orientation The luminaires can be aimed in two directions, either toward the floor or ceiling.

5.2.9 Rotation The convention in this program is such that 0 degree plane of photometry will be pointed toward the "north wall" unless otherwise specified. The rotation angle enables a rotation of the luminaire at 90 degrees in the horizontal plane from the initial orientation.

5.2.10 Contour plots Contour plots or shaded renderings can be produced for any of the quantities calculated. In the two example problems in this section, contour plots for illuminance and equivalent sphere illumination were

produced. A maximum of 15 contour lines may be specified for any plot. Once again a grid has to be specified. A column number must be greater than 1 but less than 19. The same convention applies to the row number. The spacing between rows must be such that it does not exceed the room dimensions. For the first example (14 by 14 room), the first column was 1 with a spacing of 1 between columns. The first row also was 1 and had the same spacing. Eleven contour lines were specified for each plot. For the second example the first row and column began at 1 with a spacing of 7 between both. Thirteen contour lines were specified for the illuminance plot, and 7 for the equivalent sphere illumination plot. For each plot a certain symbol is plotted. This symbol refers to another value denoted on the plot itself. For example refer Figure 8. Here the symbol O corresponds to a value of 40 footcandles, and so on upto the symbol A which corresponds to 60 footcandles.

5.3 APPLICATIONS OF CALA As mentioned previously this program can be used for point calculations, for both indoor and outdoor lighting. In this section an example problem is provided to give an insight on some possible applications.

The example problem is a simple indoor lighting problem (see Figure 13). The illumination in footcandles

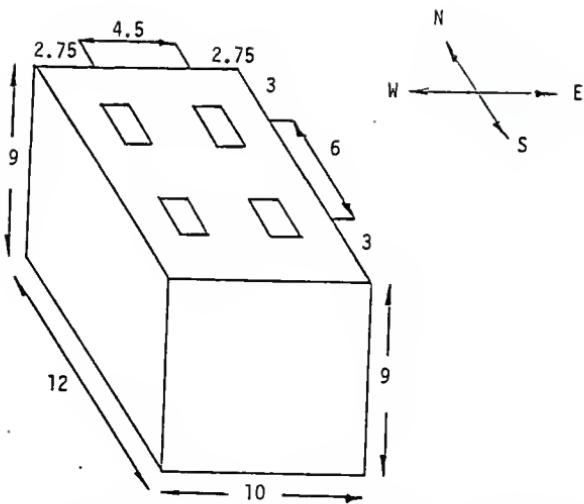


Figure 12. Room layout of example 3. There are 4 1.5' x 2' 1 lamp luminaires, each with 400W. The ceiling reflectance = .8, wall reflectance = .5, and the floor reflectance = .2.

is to be calculated on a workplane 2.5 feet above the floor. The room in consideration is rectangular in shape, with a dimension of 10' by 12'. There are four luminaires, with the lightmeter orientation perpendicular to the plane of the analysis. The luminaires are HOLOPHANE manufactured, 400 W clear HPS. The output for example 3 is shown in appendix 5. The output includes luminaire layout information, and final luminances for the cavity. Also shown in the output are the main area of analysis, perspective sketch of the area, a representation of the point by point luminances and a plan view sketch of the area under analysis; refer to Figures 14, 15 and 16. The main area of analysis is a portion 5' by 6' in dimension indicated in the plan view sketch. A major problem with CALA is that its graphics capability is poor, with diagrams such as the perspective and plan view sketch drawn without dimensions.

In order to understand the mechanics of the CALA program, we will outline some of the important features step by step.

5.3.1 Main Menu CALA brings up a series of worksheets screen by screen, starting with the main menu. There are a series of options, with seven most important ones. The first is the RUN option, followed by the POINT specification, LAYOUT, ANALYSIS, REVIEW, and PRINT option.

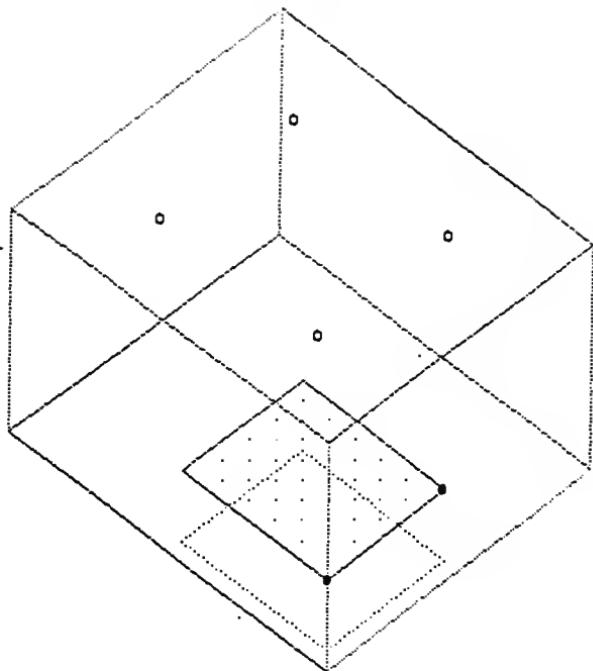


Figure 13. Perspective sketch of area as provided by the CALA output. There are 4 HPS fixtures, each with 400W. The ceiling reflectance = .8, wall reflectance = .5, and the floor reflectance = .2.

ILLUMINEERING (R) ANALYSIS -----

April 28, 1988 SERIAL NO. 8129

HINGE LINE ELEVATION 2.5 FEET

ROTATION ABOUT HINGE LINE 0 DEGREES

NOTE: The HINGE LINE is marked with (----) at the bottom
RESULTS ARE IN FOOTCANOLES

SCALE OF PRINTOUT LEFT TO RIGHT 1 FEET / INCH

SCALE OF PRINTOUT TOP TO BOTTOM 1 FEET / INCH

/4]/4] /
/ / / / / 678. -- 907. 925. 774. 625.

582. 851. 953. 892. 693.

735. 929. 951. 804. 612.

553. 853. 985. 913. 685.

675. 942. 968. 792. 612.

541. 826. 965. 899. 685.

664. 908. 936. 792. 598.

512. 761. 681. 829. 636.

587. 790. 817. 687. 568.

493. 678. 777. 730. 592.

612. 695. 769. 627. 558.

520.----- 650.----- 750.----- 710.----- 585.-----

Figure 14. Point by point luminances for Figure 12.

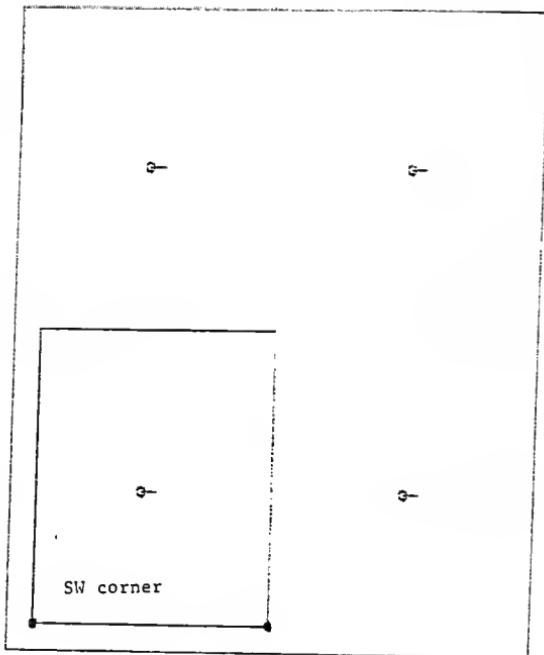


Figure 15. Plan view sketch from CALA of the area under analysis, the results of which are shown in Figure 14. The area can be selected by the user.

There is also a photometric data manager or FILE manager.

If the RUN option is selected, a screen brings up three options:

1. rerun an old job , 2. rerun a current job or 3. create a new job.

If the "new job option" is selected, the screen brings up a customer information sheet which is a basic reference sheet for future use. The next screen brings up the indirect light component sheet which asks for location of the X and Y coordinate of the SW corner of the cavity. Additional data entered at this point are the reflectances for the walls, ceiling, and floor. The CALA convention is such that the X coordinate of SW cavity is nearest the origin coordinates.

5.3.2 Panel size Room surfaces can be divided into panels more than 10 feet (or 3 meter) squared. Computer memory limitations require a limit of 2000 panels. CALA provides a rigorous model of inter reflectances among panels.

5.3.3 Points specification This provides the opportunity to enter, change or review the plan view sketch without the luminaires. All points are described by cartesian coordinates, on the X, Y and Z axes. The height above the floor is the Z axis. Up to 200 points are allowed to describe the perimeter of the area to be analysed.

All jobs require a main area or lines and point

segments. To elevate or rotate, a "hinge line" is required. The first two points of the main area of analysis is the hinge line. Most often the hinge line is thought of as the bottom of the printout. For vertical surfaces, the hinge line is rotated 90 degrees. Points are entered counter clockwise.

5.3.4 Lightmeter option This is an option which allows for the analysis plane to be perpendicular, tilted down or tilted upwards. If the main area is specified, then all points must be entered.

5.3.5 Analysis This option checks for any inconsistancies. Luminaires to be analyzed are obtained through the photometric file manager present on the hard disk.

5.3.6 Review Review allows results to be seen on the screen. Printout option selects the report design. The design of the printout depends on the options requested. As with the other screens this also is interactive.

5.3.7 Plan view sketch The sketch includes a reference sketch, main area, sub area, and a luminaire location. Perspective sketch is a 3 - D representation of the plan view sketch.

5.4 CONCLUSION These two programs are just a few of the

many such programs available. Once a user has worked with such software, it becomes easier to not only become familiar with its capabilities, but also be in a position to compare different software.

6.0 OVERALL EFFECT OF COMPUTER SOFTWARE ON LIGHTING

6.1 INTRODUCTION

In this part of the report an assessment of the overall effect of computer software for lighting applications is examined. Some common questions and doubts about computer software will be reviewed. Factors include the use of a computer as a design aid, whether computers are used exclusively for qualitative analysis, quantitative analysis or both, advantages, disadvantages, and the real benefit of computer software. Additionally some recent advances in programs will be discussed.

6.2 COMPUTERS AS A DESIGN AID : SOME VIEWS

Hibbs (Shankman, 1986) states that lighting designers were most often engineers who wanted feedback as to the validity of their lighting design. Technically oriented analysts started writing programs that would provide the desired design feedback through this resource. He also feels that these earlier programs proved useful to their writers, and, due to demand, these analysis programs became available. The practice of computed results has moved from handy to fashionable to expected.

Another view is that of Eberhard (Shankman, 1986) who felt that computers in the lighting field needs to be looked at in the present perspective as well as likely development in the future. It is his view that the

present use is not at full potential but the future use will be serious and required. The Building Research Board, National Academy of Sciences, has an active program for the development of an integrated database concept, which will allow the selection of software and allow the client to obtain a comprehensive database for the building. Lighting design will be a required part of this database development, and illuminating engineers will be required to participate in the design process.

Burkett (Shankman,1986) is of the opinion that the computer can be an extremely useful design tool. He compares it to an X-ray machine, enabling a clear insight into a lighting design but not the sole means of diagnosis. The computer has made it relatively simple and inexpensive to produce mountains of calculated values. Burkett also states that the industry has not done a good job in educating the masses on how to interpret and apply those numbers produced. A firm understanding of the variables involved in the calculation of any lighting metric is of paramount importance to the proper interpretation of the results.

A similar view is shared by McClusky (Shankman,1986), who also feels that the computer and accompanying software can be a suitable design aid, if the right program is used to solve the appropriate problem. Many computational

problems which might be important in a design are ideally performed by computers. The days of tedious point by point calculations have come to an end. Computers and software have affected many industries and the lighting field is no different. Computer analysis will become more a part of the lighting design process, as better programs are developed. With this type of growth, there is bound to be a period of transition where the tools may not always be used in the most effective manner, but this will pass as the general level of knowledge and sophistication increases.

Briggs (Shankman, 1986) also believes that the computer is finding a place in the lighting field as a design aid. However it should not replace the creative process. With recent innovations in computer graphics, it is becoming easier to evaluate a lighting system based on visual qualities of pattern, shape and uniformity while verifying other qualities such as illuminance. Briggs states that many qualitative issues of evaluating a design (comfort, mood) do not require the use of a computer. He also feels that lighting software may be compromised in two ways, by :

1. Placing incomplete and inconclusive design tools in the hands of specifiers who are not familiar with the products performance.

2. Flaunting increased technical resources without qualified personal to back it up.

Lemons (Shankman, 1986) does not share the view that the computer is a " seal of approval " for any design. Poor designs are accomplished much faster and are more easily recognized. Lemons feels that computer graphics is best suited for establishing differences between alternate designs or modifications to a particular system. There are real limits to what should be expected from computer data and most designers are unable to obtain a true benefit from using a computer in the design process.

6.3 LIGHTING ANALYSIS AND DESIGN : QUALITATIVE OR QUANTITATIVE

Although the initial emphasis of computers and lighting analysis software was certainly quantitative, particularly with luminance and illuminance calculations, trends in the near future will be more toward qualitative evaluation as stated by McClusky (Shankman, 1986). This is already happening to a limited degree by software vendors who are expanding the output capabilities of their software to go beyond just an array of numbers, using a graphic display. In 1986, Lighting Technologies revolutionalized indoor lighting analysis with introduction of full color perspective pictures of rooms

lighted with specified lighting equipment. The release of Lumen Micro Version 4.1 gave the lighting designer the ability to "see" the interaction of a proposed lighting system with its environment before actual installation. Lumen - Micro 4.1 interface with a variety of graphics boards ranging from the EGA to the AT & T Truevision TARGA 16. By utilizing the TARGA 16, Lumen Micro has the ability to produce photographic quality images on a high resolution color monitor. The realism of the color pictures was startling, as was the high cost of the system.

Now, in April 1988, Lighting Technologies is setting the stage to take full color perspective graphics, with the introduction of a screen driver for the IBM Video Graphics adapter (VGA). With the advent of VGA, standard in the new IBM personal system/2 series of computers, color perspectives can be achieved at no extra cost. The VGA has the ability to display 256 colors simultaneously at a resolution of 320 * 200 pixels.

This view is not shared by Lemons (Shankman, 1986), who believes there are limits to what should be expected from a computer software program especially when dealing with qualitative analysis. The author quotes an example, where he is dealing with an open plan office lighting situation. He states that the human eye has a 1000 to 1

contrast latitude while film is only 60 to 1, and TV systems 30 to 40 to 1. His point is that few photos depict interior space equivalent to how the eye actually sees it due to the contrast latitude limit differences.

The TV system provides less contrast latitude and therefore even less opportunity to properly depict what we actually see in an interior space. A trained eye can use photos, TV images, and computer printouts, but, for the untrained, what appears good is probably not the case.

6.4 APPLICABILITY OF COMPUTER GENERATED IMAGES TO LIGHTING DESIGN

As mentioned in the previous section, most designers agree that computer software is applicable for quantitative analyses. However most lighting experts are divided on whether software are reliable for qualitative analysis. Some agree that images produced on computer driven video equipment can be powerful lighting design tools. This use of computer graphics permits the assessment of important aspects of the interaction of a proposed lighting system and the architectural interior containing it (DiLaura et.al., 1988). Reliable assessments require that the image must evoke a response usefully similar to that evoked by the real environment. DiLaura et.al. define usefully similar as similar judgments concerning the effects of the lighting system. This

similarity of evoked response demands that the computer graphic image present accurate brightness ratios, apparent contrasts, and proper perspectives. Brightness and apparent contrast are functions of luminance, spatial distribution, and adaptation. Davis (1984) stressed that both brightness and contrast are powerful visual cues that drive the so called psychological aspects of lighting. Proper geometric perspective is easily provided. Accurate brightness ratios and apparent contrasts prove more difficult to produce. These difficulties arise from the current limitations of computer video equipment : limited size and luminance range. This is in distinction to the relative ease with which different luminances can be displayed because of the high speed resolution that modern computer video equipment can exhibit.

It thus becomes necessary to distinguish between calculated images that are accurate and images that are realistic. Although it is not possible to distinguish between accuracy and realism, this distinction is useful when determining whether a computed image will lead to appropriate lighting judgements. It is possible for a computed image to be realistic but not accurate. DiLaura et. al. reported the development of an appropriate accuracy metric for calculated luminances used in the

generation of computer graphic images of lighting systems. It was found that the metric constructed from shifted luminance locations predicts the extent to which the computer graphic images change. This proposed metric is still under examination. This controversy has attracted a lot of interest, and research work on whether software packages can be used for qualitative purposes has received the needed impetus.

6.5 COMPUTER SOFTWARE FOR LIGHTING : BENEFITS

The basic advantage of computer software is that it creates displays of designs and results in order to hasten and / or clarify communications. Displaying results has been the most active in the last few years. Users of software now are becoming spoiled and want results of their designs displayed in a way that is quickly comprehensible. In case of lighting analysis, you need digital results and graphic results that will quickly allow the user to spot any problems. This development is on an upward curve. Others such as Eberhard (Shankman, 1986) feel that the present benefits are extremely limited, with most major progress still in the research and developmental stage. He also states that most professionals still have not used computers effectively as design tools, but probably will in the near future.

Burkett (Shankman, 1986) states that computer

software has expedited the computational process of lighting and provided more time to concentrate on conceptual design. Another benefit is the wide range of design tools that can be easily accessed easily by lighting analysts. Whether it is simple zonal cavity calculations or perspective rendering displaying the luminances of all the surfaces in the room, there are analysis programs available on computers can be of great assistance in determining a lighting solution.

It would be an oversimplification to state that the quality of design would go down without computer analysis, but there would be some definite changes in the business. Even prior to the advent of computer software there were good lighting designs as well as poor ones, and that situation remains the same today.

One area where the lack of computers might affect the quality of lighting design would be inexperienced lighting analysts who are able to extend their expertise and judgement by the use of computers (McClusky 1995). An innovative design solution is explored via computer analysis which otherwise might not have been explored.

It should be pointed out that although computers and lighting software have been available in one form or the other since 1973, the total number of professionals who

actually use comprehensive software is very small. At present the effect of taking away computers might be small and hardly noticeable. This is, however, bound to change within the next few years.

6.6 CONCLUSIONS

The existing computer software is well established as an important tool for lighting calculations. Sophisticated lighting calculations, which just a few years ago were beyond the means of most lighting analysts, now are readily available and easy to operate. But while generating many tables of calculated values is simple, deriving any meaning from those tables is not. Using the computer as a graphical tool as well as a calculational tool can greatly help interpret the performance of a proposed lighting system.

Computer graphics, in its most basic form, consists of representing a table of numbers as a line contour plot. A good example of this type of graphics is the isofootcandle plot which most lighting practitioners are familiar with. A line contour plot can be made, with many available software programs, of the luminances on a room surface. With new technologies in three dimensional graphics, now it is possible to produce a shaded rendering of a space in a perspective view, giving a photograph like image of the produced lighting environment.

The three dimensional graphics technology provides the ability to evaluate the designed appearance of a space, based on detailed luminance calculations. The potential for this design was discussed by Bernecker (1980). Since then a lot of progress has been made by the computer industry in terms of three dimensional graphic display.

The most important use of present three dimensional graphics in lighting design analysis is for comparing alternate solutions early in the design process. By using the graphical tool in conjunction with more traditional tools, such as task illuminance levels, a clearer understanding of the advantages of various alternatives will result.

Computer graphics is useful in comparing more subtle differences in alternative systems. An example of this is the case of two lighting systems used in the same room, one a cosine distribution indirect system, the other a wide spread distribution system. Though this information could have been gleaned from comparing calculated luminance values, the computer image makes the task of interpretation and communication easier.

Another potential use of three dimensional representations is in predicting people's subjective

responses to various lighting alternatives. Certain psychological responses were documented by Flynn (1975), but the ability to predict these responses during the design phase has been elusive. Research into using computer graphics for this purpose has been reported by Davis and Bernecker (1984), and indicates that, in general, the computed model used was an accurate predictor of the impressions of spaciousness, visual clarity, and overall preference. To increase confidence in the use of these tools, further research is required in the areas of color matching and intensity matching. The possibility of assessing these subjective responses to alternate design solutions is interesting.

The use of computer software will revolutionize the lighting design and analysis process in the future. While it will not replace traditional lighting design metrics, these software are innovative tools whose inclusion in the design process will serve to improve understanding the total results of a proposed lighting environment.

APPENDIX 1

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APPENDIX 2
SOURCES OF LIGHTING SOFTWARE

SOURCE	PROGRAM
BENJAMIN DIVISION Industries Incorporated P.O. Box 180 Highway 70, South Sparta, Tennessee 38583 Phone : (615) 738-2241	SOFT/LIGHT
ELITE SOFTWARE DEVELOPMENT INC. P.O. Drawer 1194 Bryan, Texas 77806 Phone : (409) 846-2340	ELITE
HOLOPHANE 1620, Steeles Ave. Brampton, Ontario Canada L6T1A5 Phone : (416) 793-3111	CALA
LUMEN TECHNOLOGY P.O. Box 1412 Bellaire, Texas 77401 Phone : (713) 465-8636	LUMEN MICRO
SPAULDING LIGHTING INC. 1735, Dreman Avenue Cincinnati, Ohio 45223. Phone : (513) 541-3486	SPAULDING
STERNER LIGHTING SYSTEMS 351, Lewis Avenue 1, Park Lane Winsted, Minnesota Phone : (612) 473-1251	ISCPPOINT

APPENDIX 3 - OUTPUT FOR EXAMPLE 1

LUMINAIRE DESCRIPTIONS :

LUMINAIRE NUMBER : 1
DESCRIPTION :
1' x 4' 2 LAMP TEST TROFFER
FROM DATABASE FILE : LUMDATA.1
LUMINAIRE X-DIMENSION : .92
LUMINAIRE Y-DIMENSION : 3.83
LUMINAIRE Z-DIMENSION : .00
LAMP DESCRIPTION : F40CW
LUMENS : 3150
NUMBER OF SUBLAYOUTS : 1

CANDLEPOWER VALUES, IN CANDELAS/CANDLEPOWER MULTIPLYING FACTOR :

ANGLE FROM NADIR	ANGLE FROM ZERO DEGREE PLANE
	0 45.0 90.0

.0	1720.0	1720.0	1720.0
5.0	1714.0	1701.0	1695.0
15.0	1643.0	1647.0	1645.0
25.0	1506.0	1543.0	1543.0
35.0	1295.0	1350.0	1342.0
45.0	909.0	909.0	837.0
55.0	506.0	383.0	503.0
65.0	253.0	150.0	222.0
75.0	106.0	121.0	104.0
85.0	34.0	43.0	29.0
95.0	.0	.0	.0

SUBLAYOUT NUMBER - 1

AIMING ANGLES OF PHOTOMETRIC NADIR : 0 0
ZERO DEGREE PLANE ROTATED 0 DEGREES
BASIC ORIENTATION OF LUMINAIRE : DOWN
X AND Y DIMENSIONS ACTUALLY USED : .92 3.83
Z-DIMENSION ACTUALLY USED : .00
LUMINOUS SIDES ACTUALLY USED : NONE
SUSPENSION LENGTH : .00
CANDLEPOWER MULTIPLIER : 1.000
NUMBER OF COLUMNS : 2
NUMBER OF ROWS : 2

COLUMN COOR	3.00	11.00
ROW COOR	3.00	11.00

APPENDIX 3 - EXAMPLE 1 (contd)

TOTAL NUMBER OF LUMINAIRES : 4
TOTAL WATTS INPUT TO LUMINAIRES : 312.0
TOTAL WATTS PER UNIT AREA : 1.592

ROOM DIMENSIONS :

EAST - WEST : 14.00
NORTH - SOUTH : 14.00
HEIGHT : 9.00

ROOM SURFACE REFLECTANCES

SURFACE REFLECTANCES

NORTH .50
EAST .50
SOUTH .50
WEST .50
FLOOR .20
CEILING .80

APPENDIX 3 - EXAMPLE 1 (contd)

ILLUMINANCE

WORKING PLANE HEIGHT : 2.50

AVERAGE : 54.91 MINIMUM 43.42 MAXIMUM 59.97 MEAN DEV 3.92

ABS Y COOR	ABSOLUTE X-COORDINATES							
	1.00	2.00	3.00	4.00	5.00	6.00	7.00	

7.00	*	50	55	57	58	58	57	56
6.00	*	50	55	58	59	58	57	57
5.00	*	51	56	59	59	58	58	57
4.00	*	51	57	60	60	59	58	56
3.00	*	50	56	59	59	58	57	57
2.00	*	48	53	56	56	55	54	54
1.00	*	43	48	50	51	50	49	49

APPENDIX 3 - EXAMPLE 1 (contd)

VERTICAL ILLUMINANCE

	NORTH	EAST	SOUTH	WEST
AVERAGE :	22.17	21.86	18.75	18.84
MINIMUM :	19.12	17.16	13.53	13.09
MAXIMUM :	24.89	26.20	24.84	26.20
MEAN DEV:	1.52	2.40	3.91	4.83
TOTAL				
AVERAGE :	20.41			
MINIMUM :	13.09			
MAXIMUM :	26.20			
MEAN DEV:	3.46			

APPENDIX 3 - EXAMPLE 1 (contd)

VERTICAL LUMINANCE

ABS Y COOR		ABSOLUTE X-COORDINATES						
		1.00	2.00	3.00	4.00	5.00	6.00	7.00
7.00	N	23	24	25	25	25	24	24
	E	25	22	18	19	21	24	26
	S	23	24	25	25	25	24	24
	W	13	13	13	18	23	25	26
6.00	N	22	23	24	24	24	23	23
	E	25	22	18	19	21	24	26
	S	23	24	24	25	24	24	24
	W	13	13	13	19	23	25	26
5.00	N	20	21	22	22	22	21	21
	E	26	22	18	19	21	24	26
	S	22	22	22	22	22	22	22
	W	13	13	13	19	23	26	26
4.00	N	19	20	20	20	20	20	20
	E	26	22	18	19	21	24	26
	S	18	18	19	19	18	18	18
	W	13	13	13	19	23	26	26
3.00	N	19	20	20	20	20	20	20
	E	26	22	18	19	21	24	26
	S	18	18	19	19	18	18	18
	W	13	13	13	19	23	26	26
2.00	N	21	22	22	22	22	22	22
	E	25	21	18	19	21	24	26
	S	14	14	14	14	14	14	14
	W	13	13	13	18	23	25	25
1.00	N	23	24	25	25	25	24	24
	E	23	20	17	18	20	22	24
	S	14	14	14	14	14	14	14
	W	14	13	13	18	21	23	24

APPENDIX 3 - EXAMPLE 1 (contd)

AVERAGE ROOM SURFACE EXITANCES

SURFACE	AVERAGE EXITANCE
NORTH	13.71
EAST	13.65
SOUTH	13.72
WEST	13.60
FLOOR	9.04
CEILING	9.71

EXITANCES ON ROOM SURFACE : WEST

ABS Z COOR.	ABSOLUTE Y CO-ORDINATES												
	1	2	3	4	5	6	7	8	9	10	11	12	13
8.0	10	11	11	11	10	9	8	9	10	11	11	11	10
7.0	13	16	18	16	13	11	10	11	13	16	18	16	13
6.0	16	19	21	20	17	13	12	13	17	20	21	19	16
5.0	16	19	20	19	17	15	14	15	16	17	17	16	14
4.0	14	16	17	17	16	15	14	15	16	17	17	16	14
3.0	13	14	14	15	14	14	14	14	14	15	14	14	13
2.0	12	12	13	13	13	13	13	13	13	13	13	12	12
1.0	11	11	12	12	12	12	12	12	12	12	12	11	11

EXITANCES ON ROOM SURFACE : NORTH

ABS Z COOR.	ABSOLUTE Y CO-ORDINATES												
	1	2	3	4	5	6	7	8	9	10	11	12	13
8.0	12	20	26	20	12	9	8	9	12	20	26	20	12
7.0	16	25	30	25	17	12	11	12	17	25	30	25	16
6.0	16	21	25	22	17	14	13	13	16	19	20	18	14
5.0	14	18	20	19	16	14	13	12	14	16	16	15	13
4.0	13	15	16	16	14	13	12	13	14	16	16	15	13
3.0	12	13	14	14	13	12	12	12	13	14	14	13	12
2.0	11	12	12	12	11	11	11	12	12	12	12	12	11
1.0	10	11	11	11	11	11	11	11	11	11	11	11	10

APPENDIX 3 - EXAMPLE 1 (contd)

EXITANCES ON ROOM SURFACE : CEILING

ABS Z COOR.	ABSOLUTE Y CO-ORDINATES											
1	2	3	4	5	6	7	8	9	10	11	12	13
8.0	10	10	10	10	10	10	10	10	10	10	10	10
7.0	10	10	10	10	10	10	10	10	10	10	10	10
6.0	10	10	10	10	10	10	10	10	10	10	10	10
5.0	10	10	10	10	10	10	10	10	10	10	10	10
4.0	10	10	10	10	10	10	10	10	10	10	10	10
3.0	10	10	10	10	10	10	10	10	10	10	10	10
2.0	10	10	10	10	10	10	10	10	10	10	10	10
1.0	10	10	10	10	10	10	10	10	10	10	10	10

APPENDIX 4 - OUTPUT FOR EXAMPLE 2

LUMINAIRE DESCRIPTIONS :

LUMINAIRE NUMBER : 1
 DESCRIPTION :
 1' x 4' 3 LAMP PARABOLIC TROFFER
 FROM DATABASE FILE : LUMDATA.1
 LUMINAIRE X-DIMENSION : 1.87
 LUMINAIRE Y-DIMENSION : 3.76
 LUMINAIRE Z-DIMENSION : .00
 LAMP DESCRIPTION : F40CW
 LUMENS : 3150
 NUMBER OF SUBLAYOUTS : 1

CANDLEPOWER VALUES, IN CANDELAS/CANDLEPOWER MULTIPLYING FACTOR :

ANGLE

FROM NADIR	ANGLE FROM ZERO DEGREE PLANE
	0 45.0 90.0

.0	2800.0	2800.0	2800.0
5.0	2780.0	2795.0	2804.0
10.0	2605.0	2724.0	2798.0
15.0	2693.0	2759.0	2801.0
20.0	2501.0	2668.0	2801.0
25.0	2397.0	2613.0	2804.0
30.0	2256.0	2596.0	2975.0
35.0	2115.0	2579.0	3146.0
40.0	1920.0	2498.0	2704.0
45.0	1725.0	2418.0	2262.0
50.0	1506.0	1885.0	1536.0
55.0	1287.0	1351.0	809.0
60.0	934.0	920.0	507.0
65.0	580.0	489.0	206.0
70.0	338.0	284.0	125.0
75.0	95.0	79.0	45.0
80.0	55.0	45.0	26.0
85.0	15.0	11.0	7.0
90.0	.0	.0	.0

SUBLAYOUT NUMBER = 1

AIMING ANGLES OF PHOTOMETRIC NADIR : 0 0

ZERO DEGREE PLANE ROTATED 0 DEGREES

BASIC ORIENTATION OF LUMINAIRE : DOWN
 X AND Y DIMENSIONS ACTUALLY USED : 3.76 1.87
 Z-DIMENSION ACTUALLY USED : .00
 LUMINOUS SIDES ACTUALLY USED : NONE
 SUSPENSION LENGTH : .00
 CANDLEPOWER MULTIPLIER : .700
 NUMBER OF COLUMNS : 3
 NUMBER OF ROWS : 4

APPENDIX 4 - EXAMPLE 2 (contd)

COLUMN COOR	5.00	15.00	25.00	
ROW COOR	3.00	11.00	19.00	27.00

TOTAL NUMBER OF LUMINAIRES : 12

TOTAL WATTS INPUT TO LUMINAIRES : 1464.0

TOTAL WATTS PER UNIT AREA : 1.627

ROOM DIMENSIONS :

EAST - WEST : 30.00

NORTH - SOUTH : 30.00

HEIGHT : 10.00

ROOM SURFACE REFLECTANCES

SURFACE REFLECTANCES

NORTH .50

EAST .50

SOUTH .50

WEST .50

FLOOR .20

CEILING .75

INSERT COORDINATES 5.00 25.00 3.00 7.00

REFLECTANCE : .05

APPENDIX 4 - EXAMPLE 2 (contd)

ILLUMINANCE

WORKING PLANE HEIGHT : 2.50

AVERAGE : 62.01 MINIMUM 36.60 MAXIMUM 75.33 MEAN DEV 8.11

ABS Y COOR	*****	ABSOLUTE X-COORDINATES								
		1.00	3.00	5.00	7.00	9.00	11.00	13.00	15.00	
15.00	*	49	61	69	70	69	70	73	75	
13.00	*	48	60	68	69	68	69	72	75	
11.00	*	46	59	67	68	65	66	71	74	
9.00	*	47	60	68	69	68	69	72	74	
7.00	*	48	60	68	69	68	69	72	74	
5.00	*	45	57	65	65	64	64	68	71	
3.00	*	41	52	59	59	56	56	61	64	
1.00	*	37	45	51	51	50	50	53	55	

APPENDIX 4 - EXAMPLE 2 (contd)

EQUIVALENT SPHERE ILLUMINATION

TARGET DESCRIPTION : NUMBER 2 PENCIL ON HARD WHITE TABLET

PAPER FOR SPHERE CONTRAST : .1675

WORKING PLANE HEIGHT : 2.50

	NORTH	EAST	SOUTH	WEST
AVERAGE	34.29	35.43	34.32	37.42
MINIMUM	8.57	7.28	7.95	7.70
MAXIMUM	65.72	69.31	65.72	69.11
MEAN DEV	13.37	14.50	12.64	18.20

PERCENT OF POINTS MINIMUM ESI

	N	E	S	W
95	9.9	10.5	9.4	11.4
90	11.5	12.0	11.4	14.3
85	12.4	14.4	14.8	22.4
80	18.1	16.3	18.5	25.0
75	23.7	20.0	23.6	27.4
70	25.4	24.8	25.2	28.6

APPENDIX 4 - EXAMPLE 2 (contd)

COOR	ABS Y	ABSOLUTE X-COORDINATES							
		1.00	3.00	5.00	7.00	9.00	11.00	13.00	15.00

15.00	N 40	19	10	26	64	66	30	12	
	E 32	42	56	69	67	56	53	60	
	S 40	19	10	26	64	66	30	12	
	W 54	59	52	48	52	65	69	60	
13.00	N 41	30	24	39	62	64	44	31	
	E 20	28	47	61	50	34	34	50	
	S 37	17	9	23	57	59	27	11	
	W 46	54	42	30	31	48	61	50	
11.00	N 38	30	26	37	56	58	42	32	
	E 11	14	33	44	24	13	15	35	
	S 37	29	25	36	55	57	41	32	
	W 27	40	30	13	11	23	44	35	
9.00	N 37	17	9	23	58	60	27	11	
	E 19	27	46	60	48	33	33	48	
	S 40	30	24	37	60	62	42	30	
	W 45	53	41	29	30	46	59	48	
7.00	N 40	18	10	26	63	66	29	12	
	E 30	40	53	65	63	52	50	57	
	S 38	17	9	24	60	62	27	12	
	W 52	57	49	45	49	61	65	57	
5.00	N 39	29	24	37	60	62	42	30	
	E 17	24	42	55	43	29	29	44	
	S 34	27	8	20	51	53	23	11	
	W 43	50	38	26	27	42	54	44	
3.00	N 32	27	24	33	47	49	37	30	
	E 7	10	25	33	15	9	12	26	
	S 32	27	24	33	46	47	36	29	
	W 20	32	22	10	8	14	33	26	
1.00	N 25	12	9	16	38	39	18	11	
	E 12	14	27	36	26	16	17	28	
	S 34	34	31	40	48	50	43	36	
	W 28	34	25	15	15	25	36	28	

APPENDIX 4 - EXAMPLE 2 (contd)

RELATIVE VISUAL PERFORMANCE

TARGET DESCRIPTION : NUMBER 2 PENCIL ON HARD WHITE TABLET

PAPER FOR RVP CALCULATION SPHERE CONTRAST : .6967

WORKING PLANE HEIGHT : 2.50

	NORTH	EAST	SOUTH	WEST
AVERAGE	1.000	1.000	1.000	1.000
MINIMUM	.998	.995	.997	.950
MAXIMUM	1.000	1.000	1.000	1.000
MEAN DEV	.000	.000	.000	.000

PERCENT OF POINTS MINIMUM RVP (below)

	N	E	S	W
95	.998	.998	.998	.996
90	.999	.999	.999	.999
85	.999	1.000	.999	1.000
80	1.000	1.000	1.000	1.000
75	1.000	1.000	1.000	1.000
70	1.000	1.000	1.000	1.000

APPENDIX 4 - EXAMPLE 2 (contd)

AVERAGE ROOM SURFACE EXITANCES

SURFACE	AVERAGE EXITANCE
NORTH	15.16
EAST	13.60
SOUTH	15.18
WEST	13.60
FLOOR	11.22
CEILING	9.49

EXITANCES ON ROOM SURFACE : WEST

ABS Z ABSOLUTE Y CO-ORDINATES
COOR.

	1.50	4.50	7.50	10.50	13.50	16.50	19.50	22.50	25.20	28.5
9.5	6	6	6	6	6	6	6	6	6	6
8.5	9	9	7	10	8	8	10	7	9	9
7.5	13	14	11	15	12	12	15	11	14	13
6.5	16	16	14	17	15	15	17	14	16	16
5.5	16	17	16	17	17	17	17	16	17	16
4.5	15	16	17	17	17	17	17	17	16	15
3.5	14	16	16	16	17	17	16	16	16	14
2.5	13	15	16	16	16	16	16	16	15	13
1.5	12	14	15	15	15	15	15	15	14	12
.5	12	13	14	15	15	15	15	14	13	12

APPENDIX 5 - OUTPUT FOR EXAMPLE 3

SUMMARY INFORMATION

NUMBER OF LOCATIONS : 4

NUMBER OF LUMINAIRES : 4

TYPE NUMBER	LUMINAIRE NAME
1 4	IF2A400HPOON

LIGHTMETER ORIENTATION :

PERPENDICULAR TO THE PLANE OF ANALYSIS.

----- LUMINAIRE INFORMATION -----

TYPE - 1

FILE ID :	37196
LUMINAIRE NAME :	IF2A400HPOON
DESCRIPTION :	HOLOPHANE PREDATOR
LAMP DESCRIPTION :	400W CLEAR HPS
TEST LUMENS :	50000
LUMENS USED :	50000
TEST REPORT :	37196
PHOTOMETRY TYPE :	A
LIGHT LOSS FACTOR :	.8
EXPLANATION (LLF) :	MAINTAINED CONDITIONS
TIILT CORRECTION :	NO

APPENDIX 5 (contd)

PLANES LINES AND POINTS OF ANALYSIS UNITS - FEET

=====

MAIN AREA OF ANALYSIS SUB AREA OF ANALYSIS

=====

X Y X Y

=====

0.50	0.50
5.00	0.50
5.00	6.00
0.50	6.00
0.50	0.50

APPENDIX 5 (contd)

LUMINAIRE LAYOUT INFORMATION

ST	NO	X	Y	Z	ORIENT	TILT
N	1	2.50	3.00	8.00	90.0	0.0
N	2	7.50	3.00	8.00	90.0	0.0
N	3	2.50	9.00	8.00	90.0	0.0
N	4	7.50	9.00	8.00	90.0	0.0

X-AIM	Y-AIM	Z-AIM	MULT	TYPE
2.50	3.00	0.00	1.0	1
7.50	3.00	0.00	1.0	1
2.50	9.00	0.00	1.0	1
7.50	9.00	0.00	1.0	1

ST : STATUS N =NORMAL LUMINAIRE T = TRACKING LUMINAIRE
ORIENTATION : The clockwise angular displacement from the positive Y axis.
TILT : The angle the luminaire is aimed up from nadir.

APPENDIX 4 (contd)

CAVITY SURFACE INFORMATION

A maximum panel size of 2 ft was used in the analysis.

General reflectance for each surface : N - 50% , S - 50%

W - 50% E - 50 % C - 80% F - 20%.

Cavity Dimensions : East West - 10 ft. North South - 12 ft.

Top Bottom - 8 ft.

SPECIFIC PANEL REFLECTANCES

NORTH WALL REFLECTANCES

Z\X :	1.0	3.0	5.0	7.0	9.0

7.0	50	50	50	50	50
5.0	50	50	50	50	50
3.0	50	50	50	50	50
1.0	50	50	50	50	50
=====					

SOUTH WALL REFLECTANCES

Z\X :	9.0	7.0	5.0	3.0	1.0

7.0	50	50	50	50	50
5.0	50	50	50	50	50
3.0	50	50	50	50	50
1.0	50	50	50	50	50
=====					

APPENDIX 4 (contd)

EAST WALL REFLECTANCES

Z\Y :	11.0	9.0	7.0	5.0	3.0	1.0
7.0	50	50	50	50	50	50
5.0	50	50	50	50	50	50
3.0	50	50	50	50	50	50
1.0	50	50	50	50	50	50

=====

WEST WALL REFLECTANCES

Z\Y :	1.0	3.0	5.0	7.0	9.0	11.0
7.0	50	50	50	50	50	50
5.0	50	50	50	50	50	50
3.0	50	50	50	50	50	50
1.0	50	50	50	50	50	50

=====

CEILING REFLECTANCES

Z\Y :	1.0	3.0	5.0	7.0	9.0
1.0	80	80	80	80	80
3.0	80	80	80	80	80
5.0	80	80	80	80	80
7.0	80	80	80	80	80
9.0	80	80	80	80	80
11.0	80	80	80	80	80

=====

APPENDIX 4 (contd)

FLOOR REFLECTANCES

Y\X :	1.0	3.0	5.0	7.0	9.0
-------	-----	-----	-----	-----	-----

1.0	20	20	20	20	20
3.0	20	20	20	20	20
5.0	20	20	20	20	20
7.0	20	20	20	20	20
9.0	20	20	20	20	20
11.0	20	20	20	20	20

FINAL LUMINANCES FOR CAVITY

NORTH WALL LUMINANCES

Z\X :	1.0	3.0	5.0	7.0	9.0
-------	-----	-----	-----	-----	-----

7.0	79	134	75	135	75
5.0	199	497	176	478	207
3.0	192	250	185	250	186
1.0	167	192	195	192	186

SOUTH WALL LUMINANCES

Z\X :	9.0	7.0	5.0	3.0	1.0
-------	-----	-----	-----	-----	-----

7.0	75	135	75	135	75
5.0	207	478	176	497	199
3.0	185	250	185	250	193
1.0	166	192	195	193	167

APPENDIX 4 (contd)

EAST WALL LUMINANCES

Z\Y :	11.0	9.0	7.0	5.0	3.0	1.0
7.0	82	135	83	83	135	82
5.0	139	157	169	169	157	139
3.0	123	138	146	146	137	123
1.0	123	134	133	133	134	123

WEST WALL LUMINANCES

Z\Y :	1.0	3.0	5.0	7.0	9.0	
7.0	88	207	91	91	206	88
5.0	145	164	178	179	164	145
3.0	131	141	149	149	141	131
1.0	121	129	131	131	129	122

CEILING LUMINANCES

Y\X :	1.0	3.0	5.0	7.0	9.0
1.0	119	119	119	119	119
3.0	119	119	119	119	119
5.0	119	119	119	119	119
7.0	119	119	119	119	119
9.0	119	119	119	119	119
11.0	119	119	119	119	119

APPENDIX 4 (contd)

FLOOR REFLECTANCES

Y\X :	1.0	3.0	5.0	7.0	9.0
11.0	93	109	108	109	94
9.0	106	125	123	126	109
7.0	102	120	117	120	103
5.0	102	120	117	120	107
3.0	106	125	123	126	109
1.0	92	109	108	109	94

A SURVEY OF COMPUTER APPLICATIONS IN

LIGHTING

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ABSTRACT

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

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1988

A SURVEY OF COMPUTER APPLICATIONS IN LIGHTING

MASTERS REPORT

Lighting is essential for almost any task. The quality of light helps determine how these activities are performed. Two major issues in lighting design and analysis are quality and quantity of light. The use of microcomputers helps solve problems in these areas. Mainframe programs for lighting calculations have been around for many years, but are expensive and difficult to use. A new generation of lighting programs are now available, which are easier to use. The purpose of this report is to examine the use of microcomputers in lighting design and analysis. Software programs which are used for illumination calculations, cost analysis, energy economics, indoor lighting analysis, outdoor lighting analysis, and design will be reviewed. Analysis and comments will be based on testing of current software available to lighting designers. The applicability of lighting computer software for quantitative and qualitative analysis of a lighting system will also be discussed.