OUTDOOR LIGHTING GUIDE

PREPARED FOR DESIGN APPROVAL
COMMITTEES, DEVELOPERS,
ENVIRONMENTAL DESIGNERS,
AND SPECIFIERS.

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INTRODUCTION

It may not be evident to most readers of this guide that an important distinction is being made between good outdoor lighting and adequate outdoor illumination. Most newcomers to lighting planning and design think of the words lighting and illumination as synonymous. They are not. Adequate illumination rarely provides good lighting in all its aspects. Most people find it difficult to grasp the full meaning of this statement, but environmental planners should make every effort to do so, because the quality of our night time environment will depend to a great extent on good lighting design (and engineering) rather than simplistic illumination engineering.

John Brass
February 1977
San Rafael, California

PREFACE

Outdoor lighting can simply provide adequate visibility or it can transform an area into an inviting night time environment. The intent of this guide is to assist design approval teams in their evaluation of outdoor lighting system proposals.

The problem is to provide visually and psychologically effective lighting and to promote the efficient use of energy, without creating a glaring visual nuisance. There is much more to good night lighting than illumination.

Economic factors, performance factors, and environmental / psychological factors form the sections of this guide. They should not be viewed as independent topics, but as parts creating a total concept of outdoor lighting design. The checklists outlining the contents of each section are intended as worksheets for reviewing outdoor lighting system proposals.

OUTDOOR LIGHTING GUIDE CHECKLIST

SECTION I ECONOMIC FACTORS

Initial costs:

1. Preliminary planning
2. Design
3. Preparation and awarding of construction contract
4. Equipment
   A. Luminaires
   B. Lamps
   C. Ballasts
   D. Poles
   E. Electrical power system equipment
5. Equipment installation
6. Engineering review and inspection

Annual costs:

1. Energy consumed
2. Maintenance
   A. Lamp replacement and cleaning
   B. Estimated repairs
   C. Other routine maintenance

SECTION I - ECONOMIC FACTORS

In any investment as permanent as outdoor lighting one must consider the long term costs and effects in addition to the initial costs. The largest initial costs will be for design work, electrical and structural equipment, and installation.

EQUIPMENT

Fierce competition in the lighting industry has led to competitive pricing resulting in many inferior quality products. If a system is expected to be as efficient in a decade as it is today, it must be of superior quality and structural integrity.

The equipment needed will be luminaires, lamps, ballasts, poles, and components of the electrical system. The luminaires, or fixtures, will be discussed in the section on performance factors.

LAMPS

Lamps, commonly called light bulbs, are divided into four groups, incandescent, high intensity discharge, low pressure sodium, and fluorescent. The lamp is the prime component of any lighting design, and its selection depends on far more than wattage. We must find the best balance of over-all lighting cost in terms of lighting results.

Each lamp has its own set of unique characteristics. Lamp manufacturers will provide data on lamp cost, wattage, light output, efficiency, life expectancy, circuitry, optical controlability, size, durability, climatability, color and more.

The amount of visually effective light produced by a given lamp is measured in lumens. The amount of power the lamp draws to create the light is measured in watts. By combining these figures we get a ratio of lumens per watt, which can be used as a basis of comparison of various lamp types.

Lamps range in price from thirty cents to one hundred dollars or more apiece. Life expectancy can be anywhere from seven-hundred hours to twenty-four thousand hours.

Color effects on human complexions can vary from the familiar ruddy tones produced by incandescent to a greenish cast produced by clear high pressure mercury vapor.

In the incandescent filament lamp, light is produced by a tungsten filament which is heated to incandescence (the point at which light is produced) by its resistance to a flow of electric current. Tungsten halogen lamps have lengthened life because of the use of the halogen cycle whereby evaporated tungsten returns to the filament, which greatly reduces bulb blackening. Without the addition of this chemical, the evaporated tungsten adheres to the inside of the bulb, causing a reduction in light output.

In fluorescent lamps, production of light results when a mercury vapor discharge is operated at a low pressure and produces ultra-violet energy; a phosphor coating on the lamp bulb then transforms this energy into visible light.

High intensity discharge (HID) lamps consist of gaseous discharge arc tupes which operate at vapor pressures and current dinsities sufficient to generate quantities of light within their arcs alone.

Low pressure Sodium lamps are relatively large lamps that produce monochromatic (sodium line) greenish-yellow light. Because human cone (day) vision is most sensitive to yellow-green radiation, these lamps produce very high lumens per watt. The color aesthetically unsatisfactory so these lamps are ordinarily used only for utilitarian traffic lighting, even though night vision does not respond well to this color.

BALLASTS

All gaseous discharge lamps need a ballast to start and maintain a steady arc between the electrodes located at either end of the arc tube. A ballast stabilizes electrical conditions (voltage, current, and wave form) for the arc.

Current control is necessary because discharge light sources have "negative resistance" characteristics. Once started, the arc will run away with itself and draw an excessive current that will destroy the lamp if not controlled by a ballasting device.

There are many types of lamp ballasts available for use with HID lamps. Regulator and non-regulator types with auto-transformer, isolating transformer or reactor circuits having low or high power factor characteristics. Selection of the ballast depends on the electrical power system and type of luminaire and lamp being used. A recommendation should be made by the system designer.

The following excerpt clearly illustrates the importance of selecting the best possible ballast for each circumstance. Additional information on ballasts is provided in Section III, under stroboscopic effect and ballast humm.

> Competition in the HID and fluorescent ballast business has led to lower quality for lower prices. Most ballasts run too hot (waste power) and produce extreme peaks of lamp current during each half of the AC power cycle which can have a devastating effect on lamp life. For example, a 400-watt warm deluxe white mercury lamp should provide about 50 percent of initial lumens after 24,000 hours (average lamp life) of operation. However, a ballast that provides a 2.0 lamp current crest factor (some are worse) will reduce this figure to 14%. *

* LIGHTING PRODUCT AND SYSTEM DESIGN Volume 1, No. 2, Published by Lighting Research and Development, San Rafael, Ca.

Lamp manufacturers usually consider that lamp current crest factors up to and including 1.8 are satisfactory for HID lamps, although lower crest factors are preferable. The lamp, ballast, and luminaire should be selected to work properly together as a unit.

MAINTENANCE

The maintenance of the system can be handled in several ways. The luminaires should be cleaned at a maximum of 18 month intervals. The entire optical system should be cleaned including lens, reflectors, housing, and lamp.

The lamps should be replaced when the light level has decreased to the predetermined design minimum (usually based on a 70 percent lamp lumen maintenance factor). These maintenance services can be performed by existing janitorial staff for the area, or can be contracted to a lighting maintenance firm.

HID and fluorescent lamps do not burn out suddenly, but suffer a gradual decrease in lumen output. Therefore, in order to maintain minimum light levels, lamps should be replaced when lumen output drops below about 70 percent of initial design level. Under recommended operating conditions lamps should be replaced at ecconomic lamp life (70 percent initial lumens) and not at rated or average lamp life (burn out).

OUTDOOR LIGHTING GUIDE CHECKLIST

SECTION II PERFORMANCE FACTORS

1. Illumination level
2. Visibility
3. Optical systems
   A. Refractor
   B. Reflector
   C. Diffuser
4. Sky glow
5. Luminaires
   A. Sharp cutoff luminaires
   B. Luminaire efficiency
   C. Cobra head luminaires
   D. Post top luminaires
6. Materials
   A. Plastic characteristics
   B. Heat radiation
   C. Resistance to dirt
   D. Raintightness
   E. U.L. label

SECTION II PERFORMANCE FACTORS

ILLUMINATION LEVEL

How much light is needed to adequately light a given area for specific activities is continually under question. The Illuminating Engineering Society (I.E.S.) has established minimum illumination levels for nearly all possible situations, but there is much more to good lighting than illumination.

The footcandle is a unit of measurement for illumination that is based on the amount of light reaching a surface one foot away from a candle flame. This measurement fails to consider that visibility is affected by the light being reflected back off surfaces. Section III discusses many other ways to achieve good lighting results.

I.E.S. suggests that we light areas uniformly. This can cause visual monotony and unnecessary energy consumption lighting non-active peripheral areas with the same intensity as those which require good visibility.

Alternatively, we can concentrate the light where it is most needed to perform a visual task. This means that some areas will be brighter than others, also helping us to distinguish where activities should be taking place. Lighting illuminates, but it also brightens, accents, guides, identifies, delineates, animates, and beautifies.

The conflict between classic illumination engineering and good lighting engineering is well stated in LIGHTING PRODUCT AND SYSTEM DESIGN. "This calls for a reversal of design and marketing philosophy: from 'maximum foot-candles per dollar of initial cost' to 'maximum visibility per dollar of long range cost'

VISIBILITY

We see brightness and color contrasts not illumination. Visibility is affected by glare, contrasts in the visual field, the brightness to which the conter portion (fovea) of the eye's retina is adapted, and the time available for viewing.

I.E.S. states "The sensation of glare is produced by luminance within the visual field that are sufficiently greater than the luminance to which the eyes are adapted causing annoyance, discomfort, or loss of visual performence and visibility."

Good lighting, therefore, can provide good visibility only if proper brightness and color contrasts are maintained and glare is well controlled. These requirements are not necessarily met when simplistic illumination specifications are satisfied.

OPTICAL SYSTEMS

To direct the light to the task area various optical systems can be employed. Refractors, reflectors, and diffusers can be used separately or in combination to achieve the desired light distribution.

SKY GLOW

When our cities light up at night, the sky glows. A few years ago, we might have marveled at this wonder of modern technology. Today it appears as an unnecessary waste of light energy, a problem for astronomers (astrophysists), and an offensive glare source from within the city.

Legislation has been enacted in eight counties and states <u>prohibiting</u> unfiltered and unshielded outdoor lighting devices. In 1971, scientists at Steward, Kitt Peak National and Smithsonian Astrophysical Observatories published a paper called <u>LIGHT POLLUTION</u>. All of this legislation is concerned primarily with deep blue violet and ultraviolet radiation that goes directly up to the sky from outdoor lighting systems. The basis for this concern is that the film used for recording astronomical observations is highly sensitive to blue violet and ultraviolet radiation (wave legnths shorter than 440 nanometers).

SHARP CUTOFF LUMINAIRES

The astronomers recommendation for shielding of lighting units is simplistic and would destroy the light distribution of many outdoor lighting units. This provides an opportunity for the design and development of a new type of luminaire. This legislation, the concern for energy efficiency, and desirability of glare control have given birth to sharp cutoff luminaires.

Le Corbusier once said, "Like all tools, it was a product of circumstance and, as such, could not have been invented at any other time."

Lighting manufacturers have varied oponions about what the standards and features of sharp cutoff luminaires should be. The majority of the manufacturers are centering their research on producing efficient, glare free luminaires with wide, uniform light distribution, and a 75° cutoff angle.

a shielding angle of 75° allows for maximum light distribution and for a minimum of glare and sky glow. Cutoff is provided by the luminaire until the rooftop of the car conceals the luminaire from view,(see figure 6).

The viewing angle is 15° above the line of sight, so in order for pedestrians or bicyclists to see the source they would have to be looking up at the luminaire, and not where they were going.

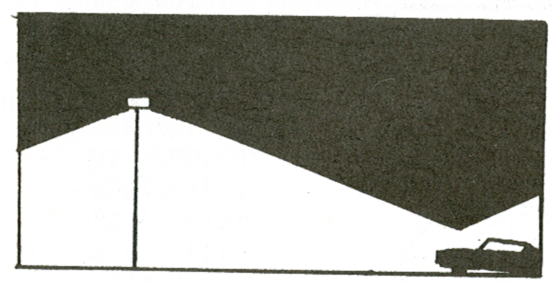

figure 6, sharp cutoff luminaire
75° shielding angle

LUMINAIRE EFFICIENCY

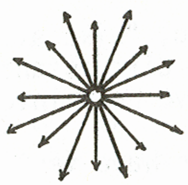

figure 7, bare lamp emits light in all directions (typical post top luminaire)

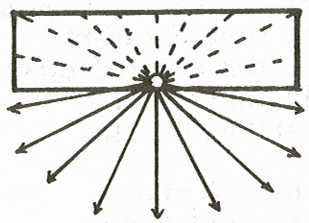

figure 8, shielded lamp without reflector traps light inside luminaire

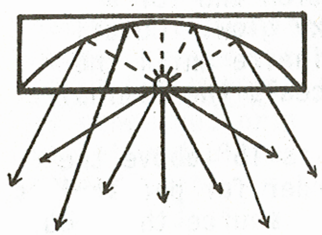

figure 9, shielded lamp with reflector to redirect light

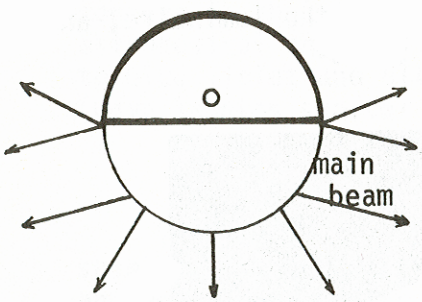

figure 10, cobra head type luminaire

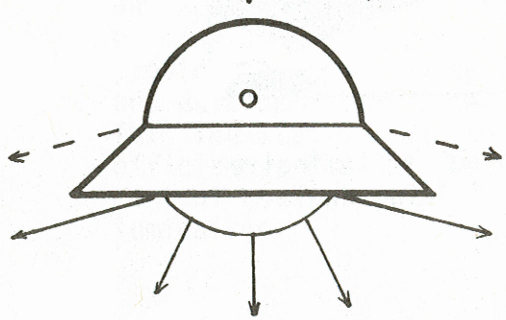

figure 11, shielded cobra head type luminaire (brim blocks a good portion of the main light beam)

LUMINAIRE EFFICIENCY

Most sharp cutoff luminaires use high intensity discharge (HID) lamps. The point source of these lamps emits bright light in all directions (figure 7).

To prevent sky glow and glare the lamp should be shielded to a horizontal plane through the center of the source. The shield can cause over 50% of the light to be trapped inside the luminaire itself (figure 8).

By placing reflectors up inside the luminaire the light can be bounced back down to the task area (figure 9). By controlling the size, shape and angle of the reflectors, the light can be redirected where it is most needed.

Sharp cutoff luminaires are intended to provide enough light where it is needed without spilling light into the sky or becomming a glare source. This excerpt, from a recent lighting peridical, illustrates advanced technology being applied to sharp cutoff luminaire design and production.

> With the advent of high-speed data processing, very complex reflector designs can be developed by computer for a wide range of applications. (Details of the particular lamp and its candlepower are entered into a computer, along with a description of the desired reflected light pattern). The basic procedure used in the reflector

layout is to break the reflecting area into many small facets. Manufacture of the reflector is by an electroforming process, using a bundle of stainless-steel mandrils, each with a reflector facet cut on its end.**

COBRA HEAD LUMINAIRES

The most common application of refractors is the cobra head type luminaire which distributes light evenly over a large area, but also spills light upward (figure 10).

In an attempt to shield some of the glare and skyglow from this type of luminaire a metal band (which resembles a hat brim) is placed around the perimeter of the lens (figure 11). This partially blocks the main beam from the original lens, changing light distribution from a large even area to a smaller, dim, splotchy area.

POST TOP LUMINAIRES

Post top luminaires are usually designed to spread light quite indiscriminately (figure 7). A classic example

** LIGHTING DESIGN AND APPLICATION, I.E.S. July, 1976 "New Techniques for Reflector Design"

is the lantern style borrowed from the times when a gas torch was used for the light source. The pleasing sparkle effect of those lanterns is lost when in order to provide enough light, they are equipped with a high wattage lamp producing an outrageously glaring element in the visual field, as well as an extremely inefficient distribution of light energy.

Spherical lights are sometimes substituted for lantern type luminaires. Where low light levels will be sufficient, dimly lit transluscent globes can provide a nice delineating effect when used in a line along a path. When looking directly at them they should appear no brighter than the moon (700 footlamberts) and being of simular shape and color, this method is often called moonlighting.

PLASTIC CHARACTERISTICS

In recent years, plastics have gained acceptance for outdoor lighting applications, especially for spheres, refractors, lens, and enclosures. A suitable plastic should be able to withstand high operating temperatures, low atmosphere temperatures, intense ultraviolet radiation (UV) from mercury lamps and also from sunlight. It should be dimensionally stable and have high impact strength. These are tough requirements and unfortunately, there is no ideal material available.

The plastics presently available that might be considered for lighting use are acrylic and polycarbonate. Butyrate is not recommended, but is included in the statistics to illustrate some of its obvious drawbacks.

Haze is the degree of cloudiness in a transparent plastic which reduces the efficiency of the plastic in controlling light and detracts from its appearance. Tests show that after three years of exposure, acrylic has 2% haze, polycarbonate has 19% haze, and butyrate has 70% haze.

Polycarbonate has the most resistance to heat, next acrylic has a fair resistance, and butyrate has the least resistance. The color stability, meaning its resistance to yellowing caused by UV, of acrylic is good, of butyrate is fair and of polycarbonate is poor, unless it is UV stabilized and coated. All three have good resistance to impact, but butyrate becomes brittle at temperatures below freezing.

HEAT RADIATION

Provisions should be made for the heat produced from the lamp burning. This heat must be accomodated by sufficient volume in the luminaire so it can be spread out and radiated from the luminaire housing.

Anodized sheet metal has the most efficient heat radiation. Special paints are available to improve heat radiation from bare metal, but the thickness of the paint determines its efficiency. Excessive heat will damage electrical devices, destroy seals in the housing and in the lamp, and cause a loss of lumen output in fluorescent lamps.

RESISTANCE TO DIRT

Resistance to dirt and dust must be carefully considered. Exposed reflectors become dirty rapidly, in this situation a 50% depreciation in light output is not uncommon. Ease of cleaning should be analyzed as part of the preliminary cost analysis.

RAINTIGHTNESS

Raintightness is another important factor. High winds create a vacuum through the fixtures drawing in moisture, dirt, and bugs. This will require more frequent cleaning and possible electrical problems.

Avoid polyester gaskets because they deteriorate in as little as one year under normal weather conditions. Polyether or neoprene will last up to twenty years under the same conditions. Puddling on the top of the luminaire should be avoided because capillary action can draw the moisture inside the housing through small flaws in caulking and seams.

U.L. LABEL

A U.L. approved label does not mean that all important performance criteria have been met. Underwriter Labratories is mainly concerned with maintenance, safety, and the adverse effects of heat on the insulation materials used for wiring, ballasts, etc. They also evaluate the ability of outdoor luminaires to protect insulation against water. They do not evaluate durability or installation and maintenance convenience.

OUTDOOR LIGHTING GUIDE CHECKLIST

SECTION III ENVIRONMENTAL / PSYCHOLOGICAL FACTORS

1. Visibility, safety
2. Placement
3. Identity
4. Materials
5. Scale
6. Color
7. Stroboscopic effect
8. Ballast humm
9. Light pollution

SECTION III

ENVIRONMENTAL / PSHCHOLOGICAL FACTORS

VISIBILITY & SAFETY

The environmental and psychological factors are often the most difficult to assess. Part of the problem is the subjective nature of the criteria themselves. Providing good visibility and a feeling of safety are of primary importance, but good outdoor lighting can do much more.

Beautification, delineation, unification, identification, accenting and advance warning are amoung the additional benefits a good lighting system can provide.

A sense fo security comes from having good visibility. This feeling is enhanced by a sense of direction and position in relation to the environment that can be attained by quality lighting.

PLACEMENT

The placement of the luminaires in relation to the geometry of the environment is critical. Luminaires should not simply be spaced out to provide a certain average level of illumination. Seeing a row of lamp poles and the brightness that is produced on the ground helps delineate the road, path, or area being used. All too often this basic function of lighting is overlooked.

IDENTITY

To unify an area, or to identify it with another, repeating the type of equipment used is effective. By varying the type or size of luminaire, pole height, or color and quantity of light, many effects can be created. Putting more light on an area will draw attention to it. This is a good way to give advanced warning or to accent fixed hazards, traffic conflict areas, bus stops, outdoor furniture, or landscaping.

MATERIALS

The materials used to construct the equipment should harmonize with the character of the environment being created. Using materials with a natural finish and an honest expression of their intrinsic nature will help the equipment to blend with its surroundings. The daylight appearance of the system should not be overlooked.

SCALE

The scale of the equipment, size of luminaires, and pole height, must be well proportioned. The number of units being installed, the scale of adjacent structures and routes, and the size of people, provide specific data for proportinging the size of the equipment.

COLOR

Different light sources have a tendency to favor a particular color range. Lamps can have varried effects on the appearance of our complexions and surroundings. Incandescent lamps produce warm familiar color rendering with reletively poor efficiency, while HID clear mercury lamps are more efficient, but produce a greenish tint to complexions. Phosphor coated mercury and metal-halide lamps produce a reasonably well balanced white light, and high pressure sodium produces a warm pinkish-orange light that maybe aesthetically acceptable. Being aware that some high color rendering lamps have lower luminious efficiencies, there may have to be a trade off against illumination level.

STROBOSCOPIC EFFECT

Mercury, metal halide, high pressure sodium, or fluorescent sources produce a noticeble flicker on rapidly moving objects when operated on single phase alternating current circuits. This condition, stroboscopic effect, is of particular importance in fast moving sports such as tennis and baseball.

Some manufacturers have been assuring purchasers that the light will bounce around on the court surface enough to counteract this effect. This does not even begin to solve the problem, since the first flash of light travels at 186,000 miles per second and is far out of sight by the time the A.C. power supply produces the next flash of light.

The best way to minimize the stroboscopic effect is to connect lamps or luminaires on alternate phases of a three-phase supply, or by employing two-lamp lead-lag ballasts where available. This means that when one lamp is off another one is on, filling in the gaps between the on and off cycle of alternating current.

BALLAST HUMM

If a quiet surrounding is an important factor, the possibly objectionable disturbance resulting from ballast "humm" should be considered. Remote, and or spring mounting of the ballasting equipment may be desirable.

LIGHT POLLUTION

It is obviously undesireable to pollute adjacent residential areas with unwanted spill light. As discussed in section II, spill light is wasteful of energy resources and a public nuisance. To clarify what constitutes a nuisance, American Heritage Dictionary defines glare as ..."to shine intensely, blindly, to dazzel." We all enjoy a dazzeling effect but not at the sacrifice of good visibility. Good spill light control and glare control come hand in hand with quality lighting.

It behoves us all, in planning public lighting installations, to be conscious of the quality of the night environment and to work to improve it. As well as supplying an invaluable service to society, lighting can also enrich the world in which we live, work, and play.

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