Burlington Planning Commission
Ordinance Committee
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Burlington Planning Commission

Ordinance Committee

Thursday, April 4, 2019 @ 5:15 PM

Planning & Zoning Conference Room, Ground Floor, City Hall

AGENDA

1. Continued discussion of amendment to update parking lot lighting standard per Sec. 5.5.2, Outdoor Lighting, (f) *Specific Outdoor Lighting Standards*, 1, *Parking Lot Lighting*

2. Continued discussion of building eave or overhang standards per Sec. 5.2.5, Setbacks, (b) *Exceptions to Yard Setback Requirements*

3. Discussion of nonconforming lot standards per Sec. 5.3.6, Nonconforming Lots, (c) *Changes to a Nonconforming Lot*

4. Adjournment (6:15)

Next Meeting – May 2, 2019

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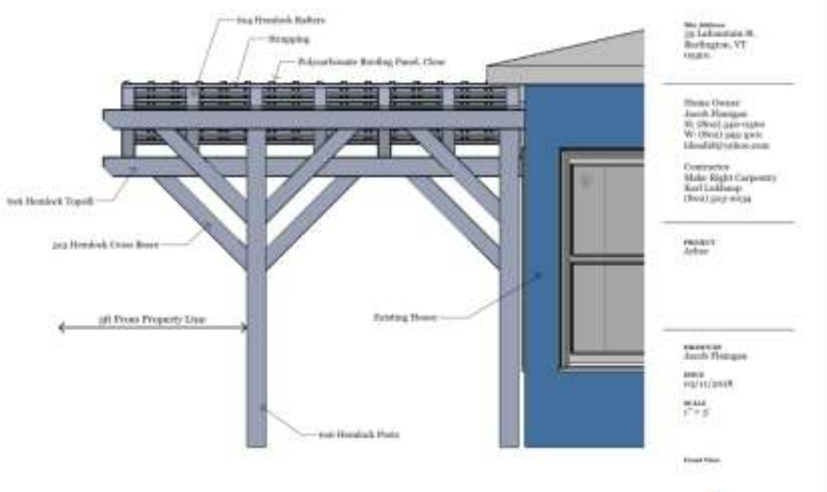
To: Planning Commission Ordinance Committee
From: Mary O'Neil, AICP
Date: March 7, 2019
RE: Discussion of exceptions into setbacks, and Non-Conforming Lot provisions of the CDO

Agenda item #1: Discussion of building eave or overhang standards

Section 5.2.5 (b) Exceptions to ard Setback Requirements
2. Building and Site Features
Eaves, sills, roof overhangs, cornices, steps to first floor entries, walkways, ramps for the disabled, fences, walls and similar building and site features may project into a required yard setback.

The case that recently came to this office involved an architect attempting to gain approval for a carport (constructed without zoning permits and specifically disallowed for rebuilding in a zoning permit condition). The designer wanted to convert the structure to a pergola type landscape feature, intending to secure approval under "encroachments into required setbacks". Although she proposed moving the non-compliant support post out of the setback, a large structural overhang would remain. This prompted the question of what is the definition of an eave/overhang, and when is it simply a cantilevered structure within a setback (and therefore disallowed)?
Neither "eave" nor "overhang" are defined within Article 13 (Definitions.)



Staff feels clarification and perhaps defintions for those terms would be appropriate to facilitate future review of similar requests.

Agenda item #2: Discussion of parking garage entry lighting standard per Section 5.5.2, Outdoor Lighting, (f)
Specific Outdoor Lighting Standards, 5, Parking Garage Lighting

In a recent project review, it was determined that the specific standard identified is no longer in effect and has been replaced. The regulation allows for "current edition", but the specific standard is outdated. The language reads:

A. *Light levels shall not exceed minimums recommended in IESNA document RP-20-98 or current edition.*

The current IESNA document is *Lighting of Parking Facilities IES RP=20-14*.

Agenda item #3:
Section 5.3.5 Non-Conforming Lots
A recent boundary line adjustment appeal review by the Development Review Board stumbled on this language within Article 5. Board members could not concur on how to interpret the requirements to satisfy this specific regulation, and have asked staff to bring the topic up for discussion at PCOC for clarification and clear articulation.

Development may occur on a non-conforming lot only in the following manner:

(a) Existing small lots;
See Section 5.2.1

(b) Required Frontage or Access:
See Section 5.2.2.

(c) Changes to a Nonconforming Lot:
No change shall be permitted to any nonconforming lot which would have the effect of increasing the density at which the property is being used, or increased the structure located upon such lot, if the dimensional requirements and standards, including parking, of the underlying zoning district are not met as a result thereof. Allowance and adaptive reuse and residential conversion bonuses shall be an exception to the foregoing standards. A lot shall be considered nonconforming if there is not sufficient parking, as determined by the standards provided in Article 8. In such cases where a parking waivr or waivers may be or have been legally granted, such a waiver shall not be considered to increase the degree of non-conformity.

RP-20-98

Lighting for Parking Facilities

Publication of this Committee Report has been approved by the IESNA. Suggestions for revisions should be directed to the IESNA.

Prepared by:

The Subcommittee on Off-Roadway Facilities of the IESNA Roadway Lighting Committee

Approved by the IESNA Board of Directors, December 5, 1998, as a Transaction of the Illuminating Engineering Society of North America.

Published by the Illuminating Engineering Society of North America, 120 Wall Street, New York, New York 10005

IESNA Standards and Guides are developed through committee consensus and produced by the IESNA Office in New York. Careful attention is given to style and accuracy. If any errors are noted in this document, please forward them to Rita Harrold, Director Educational and Technical Development, at the above address for verification and correction. The IESNA welcomes and urges feedback and comments.

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Lighting for Parking Facilities

Foreword

The following is a summary history on the evolution of this document (RP-20). It describes the progress leading to the current RP-20.

A *Recommended Practice of Parking Area Lighting* was prepared in 1960 by an IESNA Committee.[1] This document specified as a basic value 11 lux (≈1 fc) average maintained horizontal illuminance, with a 4:1 or better average/minimum uniformity ratio [minimum spot = 2.5 lux (≈0.25 fc)]. A doubling of these values was recommended at parking area entrances and exits.

In 1974, the IESNA Roadway Lighting Committee produced recommendations for lighting safety rest areas along limited access highways.[2] A value of 11 lux (1 fc) was specified for major activity sections, with a 3:1 or better average to minimum uniformity. For lower activity zones (picnic areas, shelters), a 5 lux (0.5 fc) illuminance and a 6:1 uniformity were recommended. These values have been carried forward to the *IESNA Lighting Handbook*, Eighth Edition[3] and represent minimum values of 0.8 to 3.3 lux (0.08 to 0.33 fc).

In 1984, a new IESNA Recommended Practice, *Lighting for Parking Facilities*, (RP-20-84) was published.[4] This document contained separate recommendations for lots and garages. Values were based on average illuminance for vehicle-use only areas of lots plus all areas of garages. For general parking and pedestrian areas of lots, the recommendations were based on minimum illuminance values of 2 to 10 lux (0.2 to 1 fc). Maximum average-to-minimum uniformity ratios of 4:1 were specified in most applications, producing average illuminance values of 8 to 40 lux (0.8 to 4 fc) when designed to this ratio. If designed as a highly uniform layout, such as with a 2:1 uniformity, the average values would range from 4 to 20 lux (0.4 to 2 fc). Differences in assumed levels of activity for various land uses formed the basis of setting the range in recommended minimum illuminance values. This Practice also added vertical illuminance recommendations, specifying these to equal the horizontal values, measured at 1.5 meters (5.0 ft.) above the pavement.

RP-20-84 was not based upon surveys or field measurements of existing parking facilities — state-of-the-art prevailing practice relative to actual maintained illuminance. Subsequent to its publication, reports surfaced of field measurements finding significantly lower levels in typical uses. A sampling survey of cities in 1991 found only one-fifth to be applying the RP-20-84[4] document in checking construction plans for private parking facilities, which constitute the vast majority of lots and garages.

The IESNA Practice dealing with airport parking areas (RP-17-87[5]) recommended 10 to 20 lux (1 to 2 fc), average maintained illuminance, with a 4:1 uniformity ratio [2.5 to 5 lux (0.25 to 0.5 fc) at low point].

In 1992, the Institute of Transportation Engineers (ITE) published its fourth Edition of the *Traffic Engineering Handbook*.[6] Average illuminance values of 10 to 20 lux (1 to 2 fc) were identified for parking lots, with uniformities not exceeding 6:1 [minimum spot 1.7 to 3.3 lux (0.17 to 0.33 fc)]. This was followed in 1994 with the ITE Recommended Practice Guidelines for Parking Facility Location and Design[7] with the same recommendations. Both ITE publications followed the IESNA RP-20-84[4] recommendations for parking garages. These are 50 lux (5 fc) average for general parking and pedestrian areas, with higher levels on ramps, in entrance areas, and on stairways.

The Recommended Building Code Provisions for Open Parking Structures,[8] published by the National Parking Association in 1987, specified 65 lux (6.5 fc) average at 75 cm (29.5 in.) above the floor, with a maximum uniformity ratio of 3:1. An earlier publication, *Parking in the City Center*, commissioned by the Automobile Manufacturers Association, recommended 33 to 54 lux (3.3 to 5.4 fc) in garage parking areas.[9]

1.0 INTRODUCTION

Roadway Lighting Committee studies for the orderly passage of motorists and pedestrians have formed the basis of vehicular and pedestrian illuminance recommendations on public roadways. Combinations of interior, roadway, and pedestrian lighting techniques are applicable to parking lots (open) and parking garages (structures). Included in these facilities are:

- Vehicular traffic circulation, parking access aisles, parking stalls, and interior-access roadways and ramps in garages.
- Pedestrian traffic, including walkways and stairs.

2.0 PURPOSE AND SCOPE

Need exists to update and reach a consensus among the varying recommendations of different organizations. The primary purpose of this Practice is to serve as a guideline for design of fixed lighting for parking facilities. This Practice deals entirely with lighting and does not give advice on construction practice. This is a technical document which can be adopted as a guideline by local regulatory agencies. Its purpose is to provide recommended practices for designing new lighting systems for parking facilities and it is not intended to be applied to existing lighting systems until such systems are redesigned.

These recommendations include interior and exterior lighting practices for the reasonably safe movement of vehicular and pedestrian traffic in parking facilities, the enhancing of personal security and the deterring of vandalism, while conserving energy and minimizing maintenance. They provide minimum guidelines, but are subject to variations based upon sound engineering judgment. For example, retailers may prefer higher levels of illuminance than specified herein, to attract customers or to more strongly address perceptions of personal security needs. (See **Sections 4.1** and **4.3**.)

The guidelines exclude recommendations for public roads (see RP-8-83[10]), bikeways and walkways (see DG-5-94[11]), and airport parking lots (see RP-17-87[5]), which are given in other IESNA publications (as cited). Environmental issues (light trespass, light pollution, stray light, glare and control or light) are covered in detail in RP-33-99, *IESNA Recommended Practice on Lighting for Exterior Environments.*

3.0 TYPES OF PARKING FACILITIES AND ORGANIZATION OF THE PRACTICE

3.1 General

This Practice applies to active parking facilities serving the public or employees. These facilities are classified as *parking lots* or *garages*. A description of both types follows.

3.2 Parking Lots

Parking lots are facilities that are not roofed or enclosed. Parking stalls in a lot that are covered by shed roofs but not otherwise enclosed, and with access aisles open to the sky are considered as parking lots. This Practice does not deal with curb parking along streets (see RP-20-84[4] or the *IESNA Lighting Handbook*[3]) nor with public airport parking lots (see RP-17-87[5]).

3.3 Garages

Garages consist of one or more vertically stacked parking levels, roofed over, and enclosed, plus ramps providing access. In an above-ground facility, some or all of the enclosure walls customarily are partially open to provide ventilation. In an underground garage, enclosure usually is complete, however lightwells are sometimes provided. In any garage, the illuminance needs of the top parking level — if open to the sky — are similar to those of an open lot with enhanced security. This Practice does not deal with garages for vehicle repair or new car storage.

3.4 Organization of the Practice

The illuminance requirements of a parking facility are affected by the layout, operation and vehicular traffic safety issues, plus the visibility and security needs of pedestrians walking to or from their vehicles. There are significant differences between lots and garages. Garages usually require supplemental daytime illuminance in above-ground facilities, and full day and night lighting for underground facilities. Types of lighting equipment, security aspects and illuminance needs are significantly different between lots and garages. Therefore, this Practice is divided into two parts; recommendations for parking lots (**Section 4.0** through **Section 9.0**) and recommendations for garages (**Section 10.0** through **Section 14.0**).

4.0 ILLUMINANCE RECOMMENDATIONS — PARKING LOTS

4.1 General

Parking lots and parking structures have vehicular speeds that are much lower than roadways. More importantly, the *primary* purpose of the lighting here is to benefit the pedestrian. It is intended that a driver (or pedestrian) looking at the brightest spot in the field of view will also be able to detect an object in the dark areas within the field of view. This detection can only occur if the maximum-to-minimum illuminance is limited to a range that the human eye can see. Even when it can be accurately determined, *average illuminance* has no practical bearing on the range of illuminance compatible with seeing. Therefore, citing maximum-to-minimum illuminance for parking lots or parking structures is a better specification method than using average-to minimum illuminance recommended in RP-20-84.

The maximum-to-minimum method is also based on easily obtained measurements as compared with the time-consuming and often impractical (due to parked vehicles) measurement of individual point-to-point values required to calculate the "average" value prescribed in LM-64-91, *Photometric Measurements of Parking Areas* and in the previous edition of this practice (RP-20-84).

Illuminance recommendations for active parking lots open to customers, employees, or the general public are given in **Table 1**. The illuminance is to be measured or calculated on a clear pavement, without any parked vehicles. The maximum and minimum values are *maintained* illuminances. This condition occurs just prior to lamp replacement and luminaire cleaning. If the lamp catalog does not give end-of-life data, these should be secured from the manufacturer.

Note: While illuminance criteria are the basis for lighting recommendations in this Practice, there is a trend to using luminance criteria for many applications. Luminance is what an individual "sees" or perceives. Luminance ratios between surfaces better describe how the eye views and adapts to the visual environment, and luminance contrast is important in detecting objects against their background in visibility-based calculations. (See **Annex D**.)

Data from various studies of *vehicular* accidents in parking lots have shown about two-thirds involved a moving vehicle striking a parked vehicle, less than one-third involved a moving vehicle striking another moving vehicle, about six percent involved striking fixed objects, and one percent involved striking pedestrians.[12] An average of 20 percent of these accidents occurred at night. Furthermore, the highest proportion (38 percent) of these night accidents involved *avoiding* pedestrians. However, this study did not include pedestrian slips or trips and falls, which were not recorded by police accident reports. If these were included in the consideration of parking facility lighting needs, then the proportion of total mishaps involving pedestrians would be greater than one percent. A major study of claims in commercial parking facilities found slip or trip-and-fall pedestrian accidents accounted for about 75 percent of the number of total claims and slightly over 50 percent of the costs paid.[13] The study found seven percent of the claims represented personal assault, nine percent vehicle damage, and five percent gate damage.

A paper by Monahan[14] examined the required contrast to see a 15-cm (6-in.) curb against a concrete floor of assumed reflectance, at a distance of 6 meters (20 ft.). The increased contrast required as a function of illuminance for a 60-year-old observer was plotted

Table 1: Recommended Maintained Illuminance Values for Parking Lots

		Basic[1]	Enhanced Security[2]
Minimum Horizontal Illuminance[3]	lux[4]	2	5
	fc[2]	0.2	0.5
Uniformity Ratio, Maximum to Minimum[6]		20:1	15:1
Minimum Vertical Illuminance[7]	lux[8]	1	2.5
	fc[5]	0.1	0.25

1 For typical conditions. During periods of non-use, the illuminance of certain parking facilities may be turned off of reduced to conserve energy. If reduced lighting is to be used only for the purpose of property security, it is desirable that the minimum (low point) value not be less than 1.0 horizontal lux (0.1 hfc). Reductions should not be applied to facilities subject to intermittent night use, such as at apartments, hospitals, and transportation terminals.

2 If personal security or vandalism is a likely and/or severe problem, a significant increase of the Basic level may be appropriate (see **Section 4.3**). Many retailers prefer even higher levels, with a specification of 10 lux (1 fc) as the minimum value.

3 For **preliminary design**, an *average* value of 10 horizontal lux (1 hfc) for basic, or 25 horizontal lux (2.5 hfc) for enhanced illuminance may be calculated. The minimum points (or areas) and maximum point are then calculated and the uniformity ratio checked for compliance with the **Table 1** values (see **Section 5.3**). *Note:* The 5:1 average-to-minimum ratio is the first step toward directing the design to achieve the maximum to minimum ratios presented in **Table 1**.

4 Measured on the parking surface, without any shadowing effect from parked vehicles or trees at points of measurement.

5 Rounded conversion of lux to footcandles (see **Annex E**).

6 The highest horizontal illuminance point divided by the lowest horizontal illuminance point or area should not be greater than the values shown (see **Section 4.4** and **Annex B**).

7 Facial *recognition* can be made at levels a low as 2.5 lux (0.25 fc). The IESNA Security Lighting Committee recommends that for facial *identification*, the minimum vertical illuminance should be 5.0 lux (0.5 fc).

8 Measured at 1.5 meters (5.0 ft.) above parking surface at the point of lowest horizontal illuminance, excluding facing outward along boundaries (see **Section 4.4** and **Annex B**).

Note 1: The height of the measurement has been lowered from the previous 1.8 meters (6 ft.) of RP-20-84 to be in line with the average human observers eye height of 1.5 meters (5 ft.)

Note 2: A survey of existing installations by the authoring committee found that a value of 1 lux (0.1 fc) minimum vertical illuminance was achievable using cutoff luminaires, but values greater than this may not be achievable.

(see **Annex D, Figure D2**). In this example, when the Visibility-based Analysis Procedure (**Annex D**) is used, a minimum point value of 10 lux (1 fc) must be provided throughout the parking lot (horizontal illuminance on the parking lot surface) or garage to insure the visibility required to see wheel stops, curbs, pole bases, and incidental objects such as broken exhaust system parts which commonly appear on parking lot property.

Basic lighting requirements tend to be similar for most land uses. Typical or average security needs are equally as great in a parking lot serving an apartment building or a regional shopping center. In fact, the higher the pedestrian activity level, the lower the likely security problem. However, greater pedestrian activity usually equates to greater conflict with vehicles. Because these conditions tend to counterbalance, no difference in the basic level of illuminance appears warranted among various land uses. However, customer attraction can be a reason to provide illuminance higher than the basic illuminance level given in **Table 1**. When higher light levels are used, retailers should give careful consideration to the safety consequences of drivers exiting the parking facility directly onto adjacent streets with lower lighting levels. Needs for enhanced personal security are addressed in the table and are further discussed in **Section 4.3**.

4.2 High Vehicular Traffic Locations

Exits, entrances, gate access, internal connecting roadways, or ring roads and cross-aisles should be given special consideration to permit ready identification and to enhance safety. Generally, higher illuminance should be provided along these routes by using luminaires in appropriate locations.

Illuminance of the driveway access to streets should at least match any local public lighting. For high volume driveways, such as at community- or regional-size shopping centers, increasing the average public road lighting level 50 percent is desirable. However, this should be compatible with local conditions. If the street has no lighting, the **Table 1** "basic value" can be used, applicable to the near curb line.

4.3 Security Lighting

In areas where personal security is a likely problem, the recommended increase of the basic parking lot minimum illuminance given in **Table 1** is intended to reduce user apprehension and facilitate the observation of potential assailants. Limited studies have identified lighting as a factor in crime reduction; however they have not been quantified — nor is this likely.

While personal assaults and vandalism do occur in broad daylight because light is only one of many factors influencing security, night time offenses are more likely to occur in areas with little or no lighting. While several major retailers specify a minimum value of 10 lux (1 fc) in their parking lots, measurements within existing facilities often find much less light. Identification of faces is a key factor in the crime deterrent effect of lighting, yet vertical illuminance is rarely specified. In any case, the degree of enhanced lighting to serve perceived security needs is a local judgment factor. At certain locations where night activity levels are high — such as at automatic teller machines — the immediate surrounding area may require illuminance levels substantially greater than those recommended herein. This issue is addressed by IESNA DG-9-97[15], *Lighting for Automatic Teller Machines*. The Color Rendering Index (CRI) also warrants consideration, with values of 60 or greater recommended for enhanced security. See **Section 5.2**, **Section 11.2**, and **Table A1** in **Annex A**.

4.4 Vertical Illuminances

Boyce and Rea found one lux of vertical illuminance is sufficient to obtain a 90 percent probability of correct detection of an approaching person (but not facial recognition).[16] For visibility of objects such as curbs, poles, and fire hydrants in parking areas, and to aid in detecting other pedestrians, the vertical lux value at the lowest unshadowed *point* between luminaires in the area of minimum horizontal illuminance (see **Section 5.3**) is recommended to be at least one-half the minimum horizontal value given in **Table 1**, and preferably greater. These values obviously do not apply to a direction facing *outward* along a boundary, because this would require lighting units beyond the property line. Similarly, the outer side does not apply beyond an outer line of luminaires located inside the boundary line (see **Annex B**). The values are for a location 1.5 meters (5.0 ft.) above the pavement. They may include the vertical illuminance from luminaires at right angles to the point of measurement, because an observer can be located in a broad area between adjacent luminaires (see **Figure C3** and **Section C9.0** in **Annex C**).

4.5 Shadowing and Sight Obstructions

Landscaping of a parking lot often includes trees. These are typically located in boundary strips, parking row end islands, or in curbed strips between parking modules. The light pole locations and mounting height selections should be coordinated with the landscaping plan and/or existing trees. The mature branch spread of trees should be considered so as to minimize future shadowing.

The shadow effects of fixed objects such as large signs or building walls also should be examined. It is sometimes practical to adjust luminaire locations to minimize or even eliminate such conditions. Other effects traceable to changes in landscape topography should also be considered, such as mounded islands and seat walls. Seasonal conditions such as large snow accumulations, plowing patterns for snow removal, and the piling of removed snow may create recurrent obstructions that produce shadows when low-mounted metal halide units are used, a condition which should be accommodated by the lighting design.

5.0 LIGHTING QUALITY FOR PARKING LOTS

5.1 General

While lighting for parking lots should deliver the recommended minimum illuminance levels, it should also provide reasonable quality. The designer will need to consider color rendition, uniformity, and minimized glare.

5.2 Color Rendition

In many parking installations lamp spectral output must be capable of rendering colors so that persons, whether walking or driving in the area, will be able to distinguish colors and differentiate objects within their field of vision. Individuals sometimes have trouble identifying their cars under sources with poor color rendering characteristics. Various lamp types are available that can produce a variety of color environments (see **Table A1** in **Annex A**). This factor should be considered during the lighting system's design. Recent research by A. L. Lewis,[17,18] W. Adrian,[19] and M. C. Belcher[20] show that in low level luminance the spectral output of various lamps plays an important part in the eye's ability to detect objects and hazards within its field-of-view.

5.3 Uniformity

The illuminance at points within parking areas can vary greatly. Calculations for uniformity, employing the horizontal illuminance method, should be made for a maximum-to-minimum ratio not exceeding those recommended in **Table 1**. As a first approximation in design, an *average overall* illuminance value may be chosen — 10 lux (1 fc) for a "basic" design or 25 lux (2.5 fc) for an "enhanced" design. The maximum and minimum points are then calculated. If these points fall within the uniformity ratios of **Table 1**, the design obviously meets these criteria. Further analysis of uniformity, based on areas (see the following paragraph), would be needed for consideration of alternate designs such as using higher wattage lamps at greater spacing, or changing the mounting height to reduce energy consumption or trim capital costs.

As an alternative method, the "minimum" may be considered as a small *area* between luminaires rather than the specific point with the actual lowest value, because this spot could be shadowed by a pole or tree limb. This simplified method will better approximate the Statistical Uniformity Concept proposed by Mathieu or the Coefficient of Variation developed by Armstrong than using only a single spot.[21,22] In general, the minimum area values can be considered the average of those five points at (and immediately surrounding) the point where the calculated or measured minimum values would fall. The test grid should be a square with sides measuring one-tenth of the greatest spacing between luminaires but not more than five meters (16 feet) on a side (see **Annex B** for an example). The greatest spacing between luminaires is determined as follows:

Step 1: For a given pole, determine the distance to that pole which is nearest to the given pole.
Step 2: Repeat *Step 1* for each pole in the layout.
Step 3: The greatest spacing is the largest number obtained in *Step 2*.

Where one or more luminaires is not pole-borne, the distance is determined by using a point at grade directly beneath the luminaire.

Upon completion of the installation, the results obtained may be compared to the design criteria by measuring levels and calculating the uniformities.

5.4 Glare

Glare is the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted, so as to cause annoyance, discomfort, or loss in visual performance or visibility. There are two types of glare:

Disability Glare: reduces the ability to see or identify objects.

Discomfort Glare: produces ocular discomfort, but does not reduce the ability to see.

Reasonable shielding of lamps, reflectors, or lenses will enhance visibility and should be considered during the design process (see **Figure 1**). Glare presents more of a problem for older persons, affecting their ability to clearly perceive objects or obstructions.

For a more definitive analysis of glare, calculate the maximum veiling luminance of the system (L_{Vmax}) and compare it with the average pavement luminance (L_{avg}). The ratio (L_{Vmax})/(L_{avg}) should be less than 0.3 to 1.10

5.5 Obtrusive Light

In open parking areas, upward light represents wasted energy, contributes to undesirable sky glow, and should be minimized. Downward spill light beyond the boundary may be undesirable depending upon where it falls. If the adjacent land use is *residential,* any significant spill light is unwelcome and probably prohibited by local ordinances. For an in-depth treatment of the subject, see RP-33-99, *IESNA Recommended Practice on Lighting for Exterior Environments.*

Ordinances may also limit the spill-over light allowed onto adjacent streets. This should not represent a problem to the community, because additional lighting along the street will typically enhance safety. The designer may wish to discuss this issue with the local officials, because the key concern should be *glare.* In selecting the orientation, location, and mounting heights of luminaires, the designer should strive to control glare beyond the parking boundaries, as well as within.

6.0 Light Sources for Parking Lots

6.1 Characteristics of Lamps

6.1.1 Types. Lamps typically used in parking lots include mercury vapor, high pressure sodium, metal halide, and some low pressure sodium. The advantages and disadvantages of various lamp types are summarized in **Table A2** in **Annex A**. (*Note:* Using mercury HID lamps is considered poor lighting practice because today other more efficient sources are available. However, in some rural locals, mercury vapor lighting is the only readily available equipment. Clear mercury vapor and low pressure sodium have severe spectral distribution limitations. Low pressure sodium, which is a monochromatic source, is used by several cities near important astronomical observatories because the monochromatic spectrum can be easily filtered out during deep sky astronomical observations.)

6.1.2 Life. Life ratings of lamps are furnished by manufacturers. This information should be considered in the design (see **Section 8.2.2**).

6.1.3 Efficacies. The term "lamp efficacy," as used herein, applies to the ratio of total lamp output in lumens to the power input expressed in watts to operate the lamp; i.e., lumens per watt (LPW), including ballast losses, where applicable. It is an energy management issue.

6.1.4 Lumen Maintenance. Lumen depreciation relates to the light output throughout the life of the lamp as a direct result of electrode deterioration and lamp blackening. Each design should provide the required minimum lighting levels at time of relamping. Therefore, design should be based on the relamping program to be used (see **Section 8.2.2**).

6.2 Atmospheric Conditions

When luminaires are selected which will expose the lamp to the effects of temperature and cold seasonal

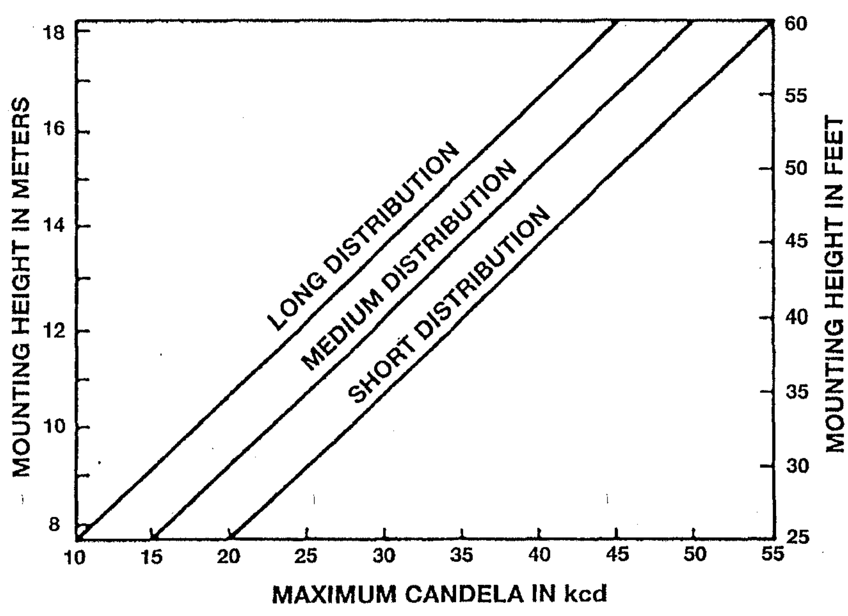

Figure 1. Minimum luminaire mounting heights based on current practice and veiling luminance calculations.

climatic changes, consideration must be given to the possible use of starting aids for gas-discharge lamps. Incandescent filament lamps will operate at any reasonable ambient temperature, but temperatures can affect the starting ability and the light output of other types, particularly some types of fluorescent lamps. Ballasts are available to reduce the effects of ambient temperature down to approximately -30°C (-22°F) and, in some cases, even lower temperatures. (They do not maintain the normal light output obtained when operated at higher ambient temperatures, but they do provide lamp starting ability.) Jacketed lamps are also used at extremely low ambient temperatures or where the lamp is exposed to "airflow" conditions.

6.3 Lamp Configuration

The dimensions of the lamp's luminous element are important because they directly impact the effectiveness of light control. The larger the luminous element, the larger the reflector and/refractor system must be in order to control the light output, and the more difficult the control becomes. However, glare is somewhat mitigated by lower surface brightness. The lamp, ballast, and luminaire combination represents a lighting unit designed for a specific performance. Labels indicating proper lamp wattage are affixed to the luminaire and required by electrical testing laboratories. It is essential that the proper lamp be used if specified lighting criteria are to be met.

6.4 Lamp Information

Each lamp manufacturer publishes the physical size and shape of its lamps and supplies information on lamp life, efficacy, and lumen depreciation. Shape is indicated by a letter or letters, and size by a number indicating the diameter of the lamp. Information is also given for the type of base used. Additional information, such as candela distribution of the lamp and/or lamp/luminaire, restrike time (which may be up to 30 minutes for certain types of lamps), and normal operating position is usually available upon request. If color rendering is an important factor in the selection of the lamp, the designer should refer to **Section 11.2**, to **Table A1** in **Annex A**, and to the *IESNA Lighting Handbook*.[3]

7.0 LIGHTING EQUIPMENT FOR PARKING LOTS

7.1 General

Parking lots use a variety of lamps and luminaires (e.g., area lighting, architectural, post top, wall mounted, high mast, roadway lighting, and floodlighting luminaires). Of these types, the area, roadway lighting, and floodlighting luminaires are most commonly used in outdoor applications.

The luminaire types best suited for a specific application can be determined by comparing lamp and luminaire combinations to basic considerations, such as:

- Size and shape of area
- Mounting height of luminaire
- Location requirements of poles and luminaires
- Illuminance requirements and control of glare
- Uniformity requirements (maximum-to-minimum)
- Energy requirements (lamp source and ballast)
- Code restrictions
- Effects of spill light on any adjacent residential property and on sky glow

7.2 Area Lighting Luminaires

Area lighting luminaires are designed to illuminate specific geometric areas. Typically, they use fixed mounting, and the lighting is controlled by a combination of refractor and reflector elements (or a multiple reflecting system) by location and by orientation within the area to be lighted. They may be further defined as:

- Architectural
- Post top
- Wall mounted
- High mast
- Roadway lighting

7.2.1 Architectural. A wide variety of architectural luminaires is available. These are designed to blend with the total architectural environment and may be capable of producing efficient, uniform illuminance, while offering control of undesirable light or glare. Typically, they are classified in accordance with the *American National Standard Practice for Roadway Lighting*.[10]

Because it is often desirable to obscure the light source in normal applications, architectural luminaires may provide light distribution through reflector systems. Efficiencies of this luminaire type may be comparable to other types; however, with the reduction of disability veiling brightness and discomfort glare, the overall visibility may be improved.

7.2.2 Post Top. Though they have many similarities with architectural luminaires in design philosophy, post top luminaires are distinct due to their location in the parking facility. Generally, they offer a symmetrical distribution of light, but asymmetrical distributions also are available. There are two categories of post top luminaires available; *direct* and *indirect.* These luminaires are usually located within the parking area (away from the perimeter). Mounting heights for direct type luminaires are usually limited to 8 meters (26 ft.) or less. Indirect type luminaires can usually be supplied as an alternate mounting method to (and match the appearance of) arm mounted luminaires. The optical control method used is specific to each post top luminaire type:

Direct — Optical control for direct post top luminaires can be obtained using reflectors as well as refractors. A high luminance source may provide suitable illuminance and a sense of security. However, care should be taken to avoid excessive glare.

Indirect — Indirect post top luminaires shield the light source from normal view. Optical control is gained by totally reflecting the light downward to the area being lighted. This can provide excellent glare control along with important aesthetic values. However, this type is typically less efficient (requires higher lamp output) than the types producing direct light and is usually limited to symmetric distributions.

7.2.3 Wall Mounted. Relatively narrow parking areas that are between or adjacent to buildings can be conveniently lighted by wall mounted luminaires. These luminaires are available in many architectural styles. Mounting height is usually 8 meters (26. ft.) or less. A wide variety of lighting distributions are available for this type but, in general, they fall into two categories; *cutoff* and *semi-cutoff:*

Cutoff — Wall mounted cutoff luminaires are typically projection-type offering good lighting for up to several times the mounting height in front of the luminaire with lateral spacings typically limited to two times the mounting height.

Semi-Cutoff — Wall mounted semi-cutoff luminaires, utilizing a refracting element in conjunction with the reflector, can allow a lateral spacing of one and a half to two times their mounting height, and a longitudinal spacing of six to eight times their mounting height, provided this equipment allows the designer to meet the recommendations for both uniformity and illuminance. Also, excessive glare and the potential for significant light spill must be avoided or controlled.

7.2.4 High Mast. Used at mounting heights of 20 meters (66 ft.) and up, the high mast luminaire provides illuminance for large areas with a limited number of poles. Highly efficient lighting with excellent comfort levels can be provided for very large areas by using high mast installations. Consideration must be given to system maintenance and luminaire accessibility when selecting this type of equipment. Further, it is generally suitable only for nonresidential areas. While other types of area lighting equipment are readily available in many wattage and source combinations, high mast equipment typically uses the higher wattage sources.

Luminaires are available in both symmetrical and asymmetrical distributions utilizing refractor and/or reflector or indirect control of light output. Shielding by metal reflector sheet or optics can provide cutoff of lighting as required. Paint also is used, but gradual deterioration can allow increased glare and variability of photometric performance. With the variety of equipment available, greater flexibility in pole locations is possible in designs so that poles can be placed along perimeters of areas to be lighted with a minimum of interference or spill light encroaching on adjacent properties. A high mounting height for luminaires may assist in minimizing shadows between parked vehicles, but can be offensive to adjacent property owners.

7.2.5 Roadway Lighting. Available with various types of light sources and wattage ratings, roadway lighting luminaires exhibit a range of symmetric and asymmetric distributions. See the *American National Standard Practice for Roadway Lighting.*[10] These units generally have both reflector and refractor control; however, units are available that use only reflector control. Mounting heights are typically 8 meters (26 ft) and higher.

7.3 Floodlighting Luminaires

Floodlighting luminaires are designed with a projected beam for lighting a scene or object to a luminance considerably greater than its surroundings and are usually capable of being aimed in any direction. Their use is dictated primarily by luminaire location and the task size being lighted. For example, if the location is remote from the parking area, floodlighting is required to project light to the task. Also, irregular areas may require the more precise control offered by floodlight equipment.

Floodlighting systems are available in symmetric and asymmetric distributions. Where the area to be lighted requires a wide distribution of light, but further demands control of that light across the area, such as in perimeter lighting, an asymmetric distribution may be employed. For clarification of the types of floodlighting distribution available, refer to the *IESNA Lighting Handbook.*[3] Accessories, such as louvers and visors, are readily available to limit high angle light and thus reduce glare and discomfort; however, they may decrease the light output and useful life of some luminaires. Because of potential spill light and glare control problems, floodlighting may be the least appropriate choice for most parking lots.

8.0 MAINTENANCE OF PARKING LOT LIGHTING

8.1 General

All lighting installations depreciate with time and require a continuing maintenance program to sustain the designed illuminance.[23] The designer must consider, then estimate, the extent and frequency of the required maintenance.

8.2 Maintenance Factors

Specific consideration should be given to compensating for Luminaire Dirt Depreciation, Lamp Lumen Depreciation, and Equipment Operating Factor.

8.2.1 Luminaire Dirt Depreciation (LDD). The gradual accumulation of airborne particles (dirt) on lamps and on the optical surfaces of luminaires reduces illuminance levels and frequently changes the unit's distribution characteristics. It is necessary for the lighting designer to predict the effect of dirt accumulation and to allow for the depreciation in the initial design values. The luminaire type, mounting height, and surrounding areas affect the degree of LDD. Technical information included in the references in this Practice and from other published data provide detailed information on the effect of dirt accumulation on and in luminaires.[23] This information should be used to estimate the cleaning interval required to maintain design illuminance values. Also, lens deterioration and/or discoloration may occur.

8.2.2 Lamp Lumen Depreciation (LLD). A light source's gradual loss of lumen output due to normal in-service aging characteristics is subject to wide variances depending upon the type of source used. Manufacturers' published data for each type and size can be used to predict the LLD rate and to estimate lamp mortality. These predictable losses and life expectancies should be used to develop a program of planned maintenance for lamp replacement based upon the values of illuminance levels established for the lighting design, and to achieve the most favorable economy of lamp replacement. Group relamping normally results in the lowest overall replacement cost and provides the greatest service level through maintaining a low lamp outage rate. Group relamping at about 70 percent of rated life represents good practice. If spot (burnout only) lamp replacement is used, a very low lamp burn out (LBO) factor should be considered in the design, such as 50 percent (LBO = 0.5).

8.2.3 Equipment Operating Factor (EOF). Commercially available luminaires, when compared with laboratory photometric test models, may not provide the same photometric performance due to normal production tolerances. The use of ballasts and lamps which meet the rigorous standards required by photometric laboratories, and precision voltage regulation for obtaining repeatable laboratory data, are not economically feasible for actual lighting installations. Other variances such as lamp operating position, aiming, and luminaire reflector/refractor tolerances tend to reduce the overall luminaire performance below that recorded in the laboratory. The lumen output of fluorescent lamps and some HID lamps depends on the ballast used to operate the lamps. The lumen output on commercial ballasts generally differs from the rated lumen output reported in photometric test data. A correction for this difference should be included in the lighting analysis. Data for this correction are available in various forms as a part of the photometric report or from the ballast manufacturer. Specific values for equipment operating factor (EOF) are difficult to establish, and in the absence of actual data a suggested practice is to approximate these losses at 5 percent (i.e., the EOF = 0.95).

8.3 Maintenance and Operation Manual

To facilitate the maintenance and proper operation of large parking facilities, consideration may be given to the preparation of a manual which would include operations and maintenance procedures as well as information on equipment reordering. See also **Section 14.0**, which discusses the violent failure of certain lamps at end-of-life.

9.0 PARKING LOT APPLICATIONS

9.1 Requirements

The illuminance of open parking lots requires matching the lighting to the task, as in any other lighting application. Aesthetics may be as great a consideration as the illuminance level. Each application has common features, which include guiding the pedestrian and vehicular traffic in, out, and within the facility in a reasonably safe manner and helping protect pedestrians and property with adequate illuminance.

Color rendition may be more important in some applications than in others. Lamp life, initial cost of the luminaire/lamp, lamp efficacy, luminaire efficiency, cost of electricity, and maintenance requirements should also be considered in selecting the source.

Facilities for roadside safety rest areas generally require higher illuminances than the basic.[24] Levels should be based on deterring vandalism and theft as well as pedestrian security.

Illuminance of outdoor pedestrian walkways separate from parking areas should be in accordance with RP-8-83 *American National Standard Practice for Roadway Lighting,*[10] or DG-5-94 *Recommended Lighting for Walkways and Class 1 Bikeways.*[11] Particular attention should be given to the placement and shielding of luminaires, which should be located to prevent glare at eye level (see **Annex C**, reference Figure 24-11 from the *IESNA Lighting Handbook*[3]). In outdoor stairways, it may be necessary to place a unit on every landing, with additional units between if required for safety. Special treatment may be necessary to mark changes in elevation wherever one or more steps are required.

9.2 Vandalism

Vandalism can generally be reduced by mounting luminaires at least 3 meters (9.8 ft.) above ground level. Greater mounting heights are recommended. Materials such as tempered glass, high impact acrylic, and polycarbonate are extremely useful in damage reduction when incorporated into shields, lenses, refractors, or globes. Metallic or high impact plastic guards can help protect luminaire optical assemblies from damage, although such guards may cast shadows and thus reduce the luminaire's efficiency.

9.3 Location of Standards and Light Sources

Support poles should be strategically placed to reduce the probability of damage to (or from) moving automobiles. Designers should be aware that certain automobiles overhang approximately 0.5 to 1.0 meters (1.6 to 3.3 ft.) in front and up to 1.52 meters (5.0 ft.) in the rear. For protection, poles are sometimes mounted on raised concrete bases. However, these bases represent a fixed object hazard. This can be addressed by painting reflectorized bands on the bases.

The locations and mounting heights of all luminaires and accessories must allow access with readily available maintenance equipment. Long brackets should be avoided if luminaires are serviced from ladders or if the mounting poles are to be climbed. Hinged poles may also be considered. It must be possible to energize circuits during the daytime for testing and trouble shooting.

10.0 ILLUMINANCE RECOMMENDATIONS—GARAGES

10.1 General

Lighting for parking structures and parking bays may be characterized as illuminating long, narrow "rooms" having low mounting heights (for luminaires) and low (20-40 percent) surface reflectances.

Parking structures often have a high incidence of pedestrian/vehicle conflict. Here, drivers and pedestrians must contend with structural columns, pipe bollards, guard rails, railings, and changes in surface elevation (involving steps or curbing), and pavement markings, which create a variety of complicated visual tasks requiring adequate visibility.

A high degree of maximum-to-minimum illumination uniformity should be maintained within the parking structure, since the driving lanes are often used by people walking to/from their parked vehicles and the exits, elevators, or stairwells. These pedestrians must often travel *across* the driving lanes to reach these exits, putting them in direct conflict with vehicular traffic. Thus it is important to avoid creating dark areas with improperly-spaced or poorly-maintained luminaires. Dim light or shadows could cause some pedestrians to go undetected by drivers.

The illuminance recommendations for parking structures (garages) are given in **Table 2**. These apply to covered and enclosed self-parking facilities intended for use by residents, customers, and employees of apartment buildings or commercial developments and by the general public. The limited mounting height available in a parking structure, the normal density of vehicle parking, the need for signage, the obstructions that drivers and pedestrians must negotiate, the presence of shadows between vehicles and structures, and the difficulty in maintaining adequate surface reflectance on ceilings, walls, and barricades increases the need for higher initial and maintained illuminance. **Table 2** does not apply to garages used exclusively for repair, vehicle storage, or where all vehicles are parked by attendants. Recommendations for illuminating these facilities appear in the *IESNA Lighting Handbook.*[3]

10.2 Ramps and Entrances

There are two general types of ramps — those contained entirely within the garage structure, and those mounted along the sides or at an end. The latter are usually open to the sky and may require little or no daytime lighting. Ramps with parking along one or both sides are called sloping floor designs and require only basic garage illuminance.

In garages, the entrance area is defined as the drive aisle and any immediately adjacent parking stalls, from the portal or physical building line to about 20 meters (66 ft.) inside the structure. Where parking is not provided next to the drive lane, the width of entrance area should be defined by adjacent walls, if any. However, the width should not exceed 15 meters (50 ft.). Higher illuminance is needed during the day for this transition area which connects full daylight to the relatively low interior illuminance levels. A garage entrance is somewhat analogous to a tunnel portal, except that vehicle speeds are much lower— typically only 10 to 20 km/hr (6 to 12 miles/hr). Ordinarily, garage entry involves turning off a street or service road. Entrances designed with a straight run of 50 meters (164 ft.) or more can accept vehicles at higher speeds and may require correspondingly longer transition areas. Beyond the first 20 meters (66 ft.), the illuminance can be stepped down in successive stages, such as one-third increments, from the 500 lux (50 fc) entrance area to the 20 lux (2 fc) ramp area or the 10 lux (1 fc) basic area, over each 10-meter (33 ft.) run length.

10.3 Uniformity

As with parking lots, the average of the lowest area of garage floor illuminance may be used as an alternative calculation of the minimum rather than the absolute lowest point. This area is a rectangle (see **Annex B**). A point, centered below one of the luminaires, should be used to calculate or measure the most likely maximum illuminance value. To start the design, an *average overall* illuminance value may be chosen — 50 lux (5 fc) for parking floors and proportionately higher values for elements requiring greater illuminance. The maximum and minimum points are then calculated. If the minimum is met and the ratio of the maximum and minimum *points* falls within the 10:1 uniformity ratio given in **Table 2**, the design meets the criterion. Further analysis of uniformity based on minimum areas would be needed if alternate designs are considered (e.g., the use of larger lamps at greater spacing to cut energy consumption and/or reduce capital cost).

Table 2: Recommended Maintained Illuminance Values for Parking Garages

		Miminum Horizontal[2] Lux	fc[4]	Maximum/Minimum Horizontal Uniformity Ratio[3]	Minimum Vertical[5] Lux	fc[4]
Basic[1]		10	1.0	10:1	5	0.5
Ramps[6]						
	Day[7]	20	2.0	10:1	10	1.0
	Night	10	1.0	10:1	5	0.5
Entrance Areas[8]						
	Day[7]	500	50		250	25
	Night	10	1.0	10:1	5	0.5
Stairways[9]		20	2.0		10	1.0

[1] For typical conditions. While these values are intended to address personal security issues, some retailers may increase them to further offset perceived concerns. Top levels of garages open to the sky should use the "Enhanced Security" column of **Table 1** (see **Section 4.1** and **Section 4.3**). Research has shown that, under certain conditions of limited contrast (such as concrete wheel stops on concrete garage floor), this level is needed to provide good visibility of the wheel stop (see reference 18 and **Annex D**).

[2] Measured on the parking surface, without any shadowing effect from parked vehicles or columns. For preliminary design, an *average* value of 50 horizontal lux (5 hfc) for basic (and equivalent for other conditions) may be calculated (see **Section 10.3**).

[3] The highest horizontal illuminance area, divided by the lowest horizontal illuminance point or area should not be greater than the ratio shown (see **Section 10.3** and **Annex B**).

[4] Rounded conversion of lux to footcandles (see **Annex E**).

[5] Measured at 1.5 meters (5.0 ft.) above parking surface at the point of lowest horizontal illuminance, excluding facing outward along boundaries (see **Section 11.1** and **Annex B**).

[6] Applies to clearway ramps (no adjacent parking) but not to sloping floor designs (see **Section 10.2**).

[7] Daylight may be considered in the design calculation (see **Section 10.5**)

[8] A high illuminance level for about the first 20 meters (66 ft.) inside the structure is needed to effect a transition from bright daylight to a lower internal level (see **Section 10.2**)

[9] See **Section 10.4**.

10.4 Stairways

The Building Officials and Code Administrators International (BOCA) building code recommends about 10 lux (1 fc) at building exits, without specifying that it be horizontal, vertical, or direct line-of-sight (if illuminance is from a single source).[25] This value also is specified in other building codes, such as those promulgated by the city of Chicago for vertical exits [which also allow 5 lux (0.5 fc) for horizontal access].

Values in **Table 2** for horizontal and vertical illuminance exceed the nationally recognized (BOCA) recommendations only because of the personal security element. This is critical in garages and especially in stairways.

10.5 Use of Daylight

The higher illuminance levels recommended for garage ramps and entrance areas during the day may be obtained by the combined use of electric lighting and daylight infiltration. The contribution of the latter should be limited to conditions *with* full cloud cover. During the day the portal to the parking structure should have a transition area from the bright sunlight (outdoors) to the darker garage interior lighting. The most critical situation (largest magnitude of change form light-to-dark) occurs at approximately noon on June 21st, under clear sky conditions. The entrance area (transition zone) should be 20 meters (66 ft.) long by 15 meters (50 ft.) wide, measured from the shadow line at the portal (note: this shadow line may be some distance inside the portal). Electric lighting plus sunlight infiltration in the entrance area should meet the uniformity criteria and minimum horizontal illuminance criteria shown in **Table 2**. Luminaires should be circuited and/or controlled to lower the illuminance at night to the value indicated in **Table 2**.

10.6 Emergency Lighting

Emergency lighting units should be located in strategic positions so as to provide a reduced lighting level in case the normal power supply is interrupted. In general, they should provide approximately ten percent of the lighting levels of **Table 2**, with a minimum of 10 lux (1 fc) along the path of pedestrian egress, or meet applicable local code requirements.

10.7 Special Lighting

Closed circuit television (CCTV) monitoring equipment is desirable in some parking facilities. When specifying a camera tube for this purpose, the type of camera (monochrome or color), the lighting level, the light source, the lamp's color-rendering, its distribution pattern, and its aiming must be considered to ensure effective results. CCTV cameras should be positioned to avoid scanning directly at (or across) any luminaires.

11.0 LIGHTING QUALITY FOR GARAGES

11.1 General

From a pedestrian security standpoint, and to reduce personal appreciation; indoor garages need higher illuminance levels than open facilities. The background luminance and eye-adapted luminance for open parking lots (usually coming from asphalt pavement and dark sky) will be much lower than the background luminance inside parking garages (where concrete surfaces are all around). Therefore, where the adapted luminance and background luminance are greater, more illuminance is needed to achieve the same visibility level (see **Annex D, Figure D2**). A minimum point value of 10 lux (1 fc) must be provided throughout the parking garage floor (horizontal illuminance on the parking garage floor surface) to provide the visibility to see curbs, slippery areas, or incidental objects such as broken exhaust system parts which may be found on parking garage floors. Lighting levels should be reasonably consistent with the recommendations in **Table 2**. Good lighting uniformity should be provided to enhance pedestrian safety since aisles are used for walking between cars, stairways, and elevator entrances. (See **Section 10.3** for measuring and calculating the maximum and minimum areas and the uniformity.) While **Table 2** specifies that the minimum vertical illuminance be at least 50 percent of the value in the horizontal low area, a higher proportion is desirable inside garages.

In some cases, garages have been lighted to very high illuminance levels — especially those parking structures with sides open to the exterior. While this may help those in the interior during daylight, it can produce excess night illuminance and exhibit poor energy efficiency. Dimming or switching used with automatic controls (e.g., dual lamp, dual circuit luminaires or high/low dimming), which do not significantly degrade uniformity, should be used to address this problem.

11.2 Color Rendition

Lighting equipment and light sources should be selected on the basis of performance, light output, light distribution, energy usage, color rendition, and ease of installation/maintenance. Color rendition should be considered relative to the identification of traffic control signs, to help patrons locate their vehicles by color, and to provide a generally pleasant appearance (see **Section 5.2** and **Table A1** in **Annex A**).

11.3 Glare

Because of the very low ceiling mounting height limitations, glare control is particularly critical in garages (see **Section 14.0**).

12.0 LIGHT SOURCES FOR GARAGES

Fluorescent lamps were once widely employed for garage lighting due to their low unit brightness per meter of length. However, the development of low wattage, high intensity, efficient metal halide and high pressure sodium (HPS) sources has broadened the designer's choice of suitable sources. In colder climates, the decreased light output of fluorescent lamps operated outdoors may preclude their use in favor of other sources. An advantage of fluorescent lamps, compared with some metal halide and other HID types, is the quick restart after a momentary power outage. Furthermore, the continuing development of "compact" fluorescent lamps invites their use in stairwells, ramps, and some parking bay applications.

The light sources typically used in garages today are metal halide and HPS. Development efforts continue to improve both these sources; HPS in color rendition and efficacy, and metal halide in lumen maintenance and life. **Table A2** in **Annex A** summarizes general advantages and disadvantages of various lamps now in common use. The designer should consult manufacturers' data when comparing these two sources.

13.0 LIGHTING EQUIPMENT FOR GARAGES

13.1 General

Selecting luminaires for above-ground garages involves many of the same photometric and environmental considerations that apply to parking lots. Here, open-wall structures are exposed to the same temperatures as open lots. Design parameters are generally determined on the basis of specific needs such as unique photometric performance requirements, additional clearance requirements, or (more commonly) stringent physical requirements to thwart vandalism. Luminaires for garages are typically categorized as *cutoff* and *non cutoff*.

13.2 Cutoff Luminaires

Cutoff luminaires limit high-angle light (above 80 degrees) and usually have a flat lens to provide a shielded light source with resultant low brightness and glare. They are limited to direct lighting only, and spacings must be closely related to mounting height to achieve a good design by overlapping the individual light patterns. (Full cutoff luminaires are those where zero candela intensity occurs at an angle of 90°, and at all greater angles from nadir.)

13.3 Non-Cutoff Luminaires

Non-cutoff luminaires are most commonly available with a dropped luminous diffusing lens or cover element to allow wider spacings. However, because of the typically low mounting heights, glare control is essential. This may dictate lower-wattage units and locating the luminaires out of the driver's direct field of-view. These units may be adapted for higher ceilings or wall mounting and may provide the best combination of horizontal and vertical illuminance. Consideration should be given to the environmental requirements of such equipment. Indirect surface-mounted luminaires are available. With good wall reflectances and assuming that adjacent building surfaces are properly maintained, non-cutoff luminaires can provide good visibility.

14.0 GARAGE APPLICATIONS

Lighting for garages should conform to good lighting practice developed for areas subject to a high incidence of pedestrian/moving vehicle conflict. Assume that very few beneficial inter-reflections will occur since a high density of parked vehicles may be present and their emissions will cause surface reflectances to deteriorate rapidly. Only in parking structures that are routinely well maintained and washed or painted should consideration be given to non-depreciated values for ceiling and wall reflectances.

Garage luminaires should feature sealed/gasket construction designed for a hostile corrosion- and emission-prone outdoor environment. Typically, these luminaires must withstand the corrosive atmosphere generated by humidity, salt, and vehicular emissions. Mounting is typically on concrete surfaces. Designers should be aware that certain lamp types, including metal halide and tungsten-halogen, can (on rare occasions) fail violently at end-of-life when continuously operated. This can be avoided by group relamping or by turning the lights off for short periods on a regular (e.g., weekly) schedule.

Extremely low mounting heights require vandal-resistant components and materials that will resist damage when struck by vehicle antennas. Low mounting heights also dictate that the luminaires must have excellent glare control combined with wide light distribution. Low wattage HID luminaires designed with sharp cutoff distributions may provide viable solutions to some parking structure applications. However, cutoff luminaires offer less vertical illuminance than the non-cutoff type. Careful assessment should be made of enclosed reflector and/or refractor type low bay luminaires. Excessive direct glare, which is a function of the lamp size and wattage, can cause temporary discomfort, disability, and distraction. Limiting the light output from the luminaire between 75° and 90° above the horizontal plane will reduce glare.

When luminaires must be mounted in precast, coffered ceiling construction, care should be exercised so that the expected wide light distribution is not trapped by the "Tee" stems. In certain circumstances these stems can provide luminaire shielding for glare control. Generally, bare fluorescent strip luminaires should not be considered despite the low initial cost. Such bare strips are susceptible to breakage, have reduced light output at low temperatures, and, due to the low reflectances of nearby surfaces, exhibit poor utilization of the upward light output component.

Selected HID luminaires in each parking bay may be equipped with standby auxiliary sources to provide immediate emergency lighting should a power loss or momentary power interruption extinguish the HID lamps.

A lamp and luminaire maintenance program should be developed as part of the lighting design, including a write-up for maintenance personnel.

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Annex A —Tabular Comparisons of Common Lamp Types

This annex is not a part of the Recommended Practice. It contains two tables; **Table A1** showing the color rendering index (CRI) for various common lamp types, and **Table A2** comparing various lamp groups by noting the advantages and disadvantages of each listed group.

Table A1: Color Rendering Index Range of Lamps

Lamp Type		Color Rendering Index (CRI)
Fluorescent		
	Lite White	> 40
	Warm White	> 50
	Warm White Deluxe	> 70
	Cool White	> 60
	Cool White Deluxe	> 80
	White	> 60
	Daylight	> 70
	T12 Rare Earth Phosphor	> 69 to > 80
	T8 Rare Earth Phosphor	> 70 to > 90
	Natural	> 80
	Incandescent	> 80
	Compact T4, T5	> 80
	C50, C70, DSGN 50	> 90
Mercury Vapor		
	Clear	15 to 25
	Coated	40 to > 50
Metal Halide		
	Clear or Coated	60 to > 90
High Pressure Sodium		
	Standard	> 20
	Color Improved	> 60
	High Color Rendering	> 80
Low Pressure Sodium		< 20

Note: For enhanced security, it is suggested that light sources with a CRI of > 60 be used.

Table A2 is a "layman's" reference table, and is provided as a basic guide to help those readers who are unfamiliar with light source characteristics. It is not intended to be an in-depth treatment of the subject. Consult manufacturers' data for specific information.

Table A2: Comparison of Various Lamp Group Characteristics

	Lamp Group						
Lamp Characteristic	**High Pressure Sodium**	**Metal Halide**	**Deluxe Mercury**	**Flourescent**	**Compact Flourescent**	**Low Pressure Sodium**	**Incandescent**
Efficacy (lumens/watts)	high to very high	moderate to high	moderate	moderate	moderate	highest	low
Life	long to very long	long	very long	long to very long	long	moderate	very short to short
Lumen Maintenance	good	fair	fair to good	fair to good	good	good	good
Optical Control	good	good	fair	poor	fair	poor	good
Ballast Required?	yes	yes	yes	yes	yes	yes	no
Color Rendition	poor to fair	good to very good	fair	fair to very good	very good	poor	very good
Brightness	high to very high	high to very high	high	low	low	moderate	high
Operating Position Limits	none	some	none	none	none	some	none to few
Compactness	fair to good	fair to good	fair to good	poor to fair	fair to good	poor	good
Starting Time (to full output)	very slow	very slow	very slow	instant to fast	fast	very slow	instant
Temperature Sensitive?	no	no	no	yes	yes	no	no
Application:							
Parking Lots	acceptable	acceptable	acceptable	poor	poor	poor	poor
Garages	acceptable	acceptable	poor	acceptable	acceptable	poor	poor

Energy-saving lamps are available in most lamp groups.

Source: Adapted from IESNA RP-26-95, **Table 4**.

Annex B — Illustrated Methods for Measuring Illuminance and Making Photometric Evaluations in Parking Lots and Garages

This annex is not a part of the Recommended Practice. It contains figures illustrating methods of measuring illuminance levels and making photometric evaluations in parking lots and garages.

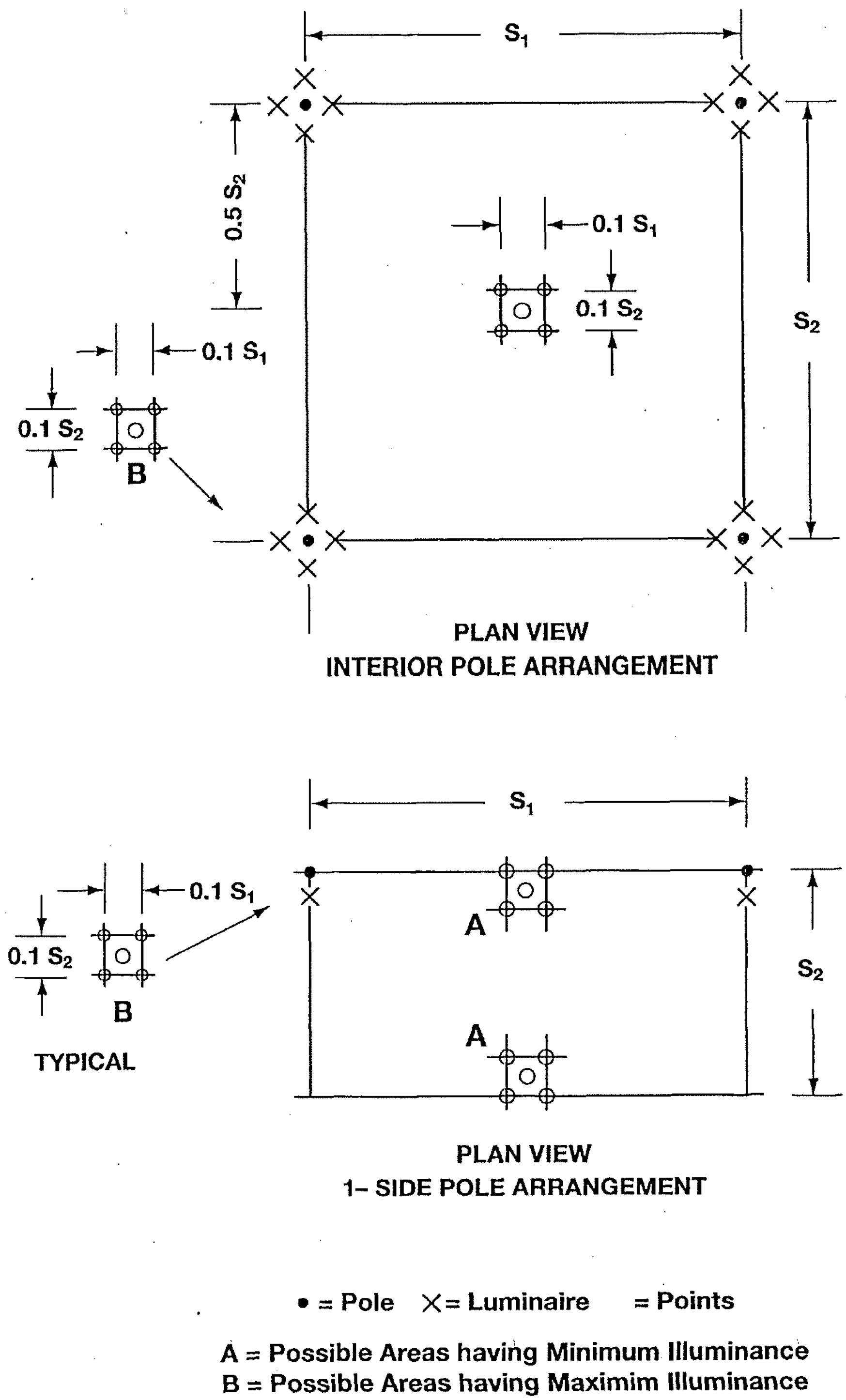


Figure B1. Method of locating areas of minimum and maximum illuminance in parking lots.

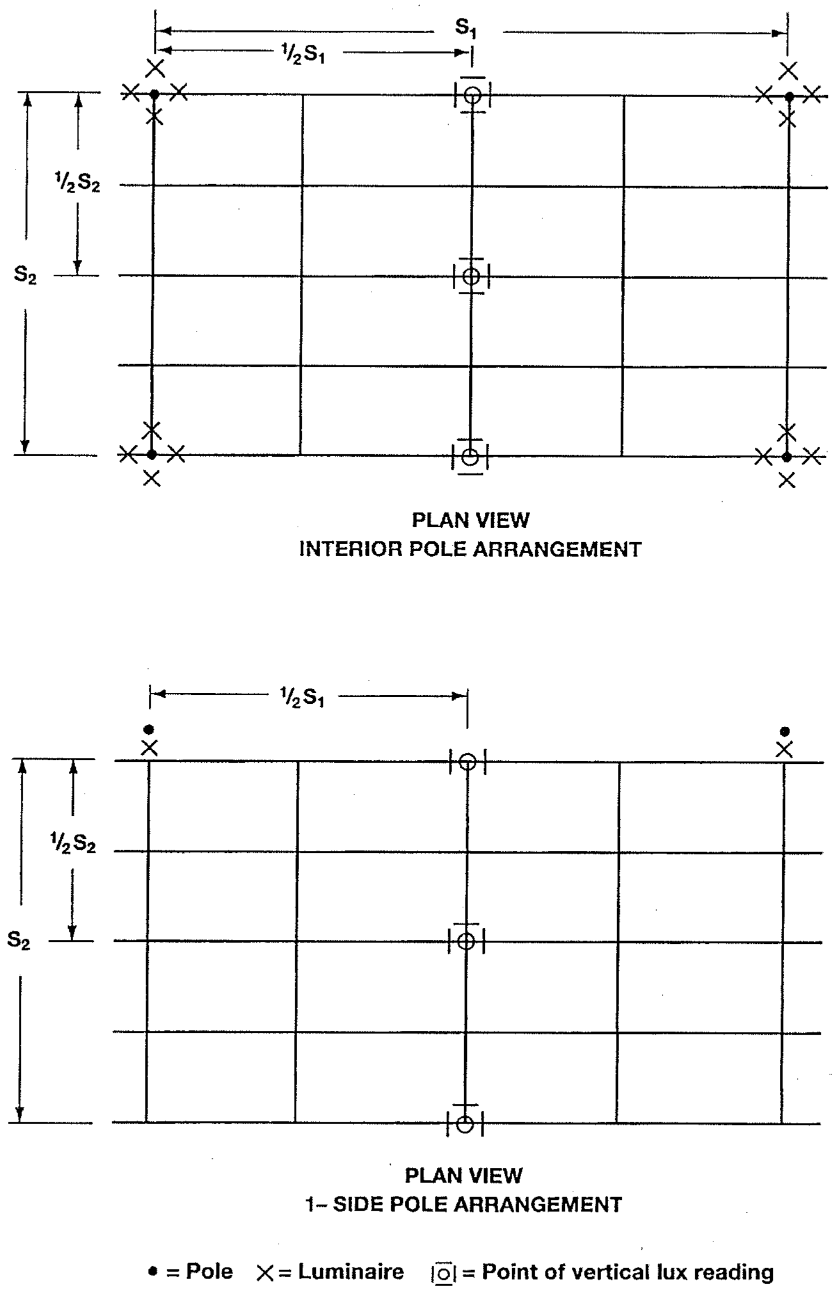
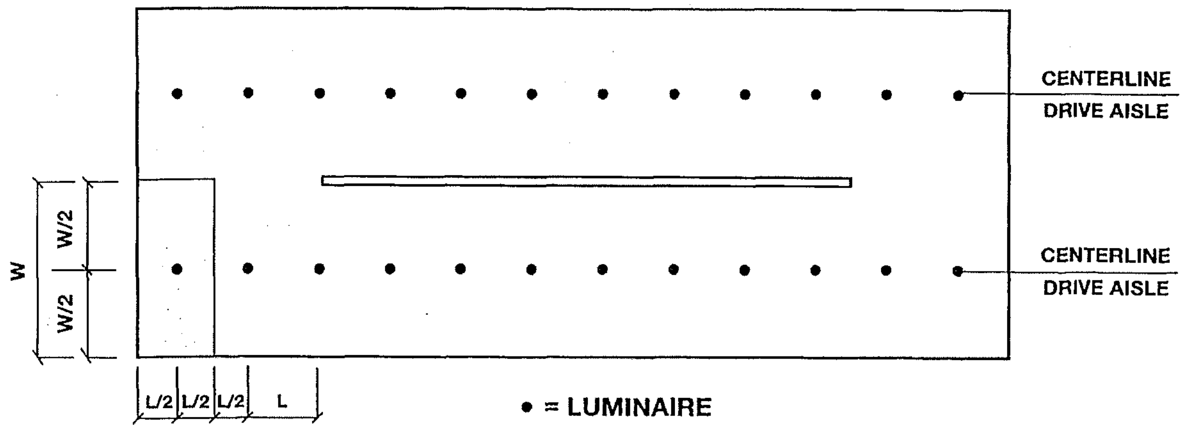
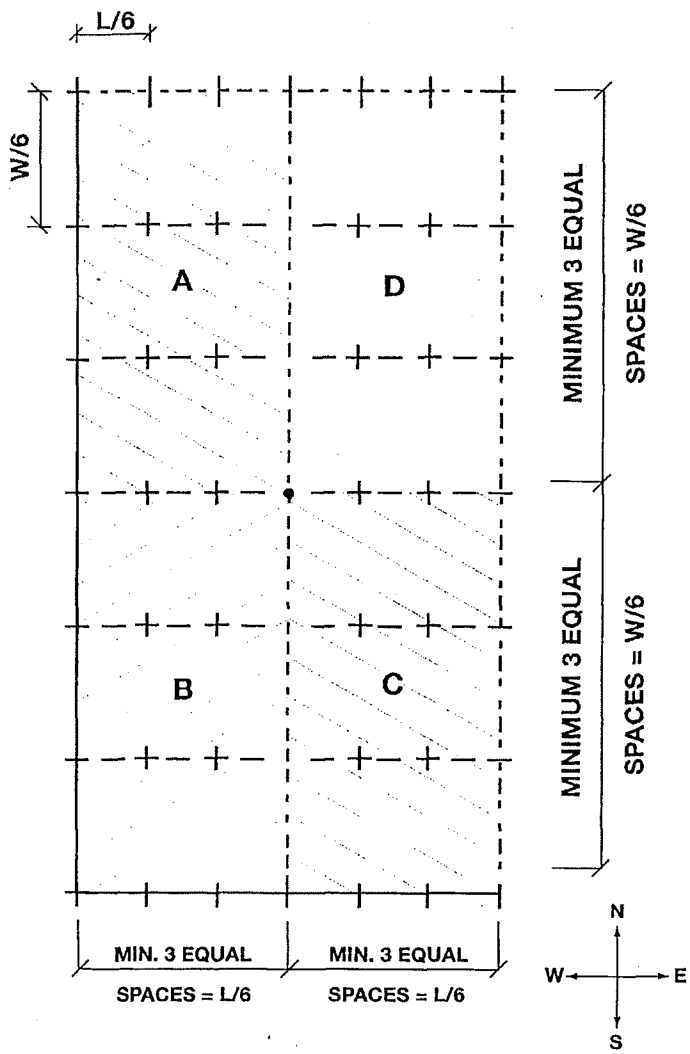


Figure B2. Method of making vertical illuminance measurements in parking lots.





NOTES:

1. HORIZONTAL ILLUMINANCE SHALL BE TAKEN IN EMPTY FACILITY (i.e. NO VEHICLE OBSTRUCTIONS) WITH LIGHT METER PLACED FACE UP ON FLOOR.

2. VERTICAL ILLUMINANCE SHALL BE TAKEN IN EMPTY FACILITY WITH LIGHT METER AT 1.5 METERS ABOVE FLOOR. READINGS SHALL BE TAKEN IN FOUR ORTHOGONAL DIRECTIONS AT EACH GRID POINT. IN QUADRANT A, DO NOT INCLUDE READINGS WITH LIGHT METER FACING WEST. IN QUADRANT B, DO NOT INCLUDE READINGS WITH LIGHT METER FACING WEST OR SOUTH. IN QUADRANT C, DO NOT INCLUDE READINGS WITH LIGHT METER FACING SOUTH. IN QUADRANT D, INCLUDE ALL FOUR DIRECTIONS, EXCEPT WHERE WALL OBSTRUCTION MAY OCCUR BETWEEN FIXTURES AT NORTH SIDE. IN THAT EVENT, EXCLUDE THE READINGS WITH THE LIGHT METER FACING NORTH.

3. SEE FIGURE B4 FOR EXAMPLES OF AREA METHOD FOR DETERMINATION OF MINIMUM OR MAXIMUM ILLUMINANCE.

Figure B3. Photometric evaluation of a single row of luminaires along the drive aisle centerline of a parking garage.

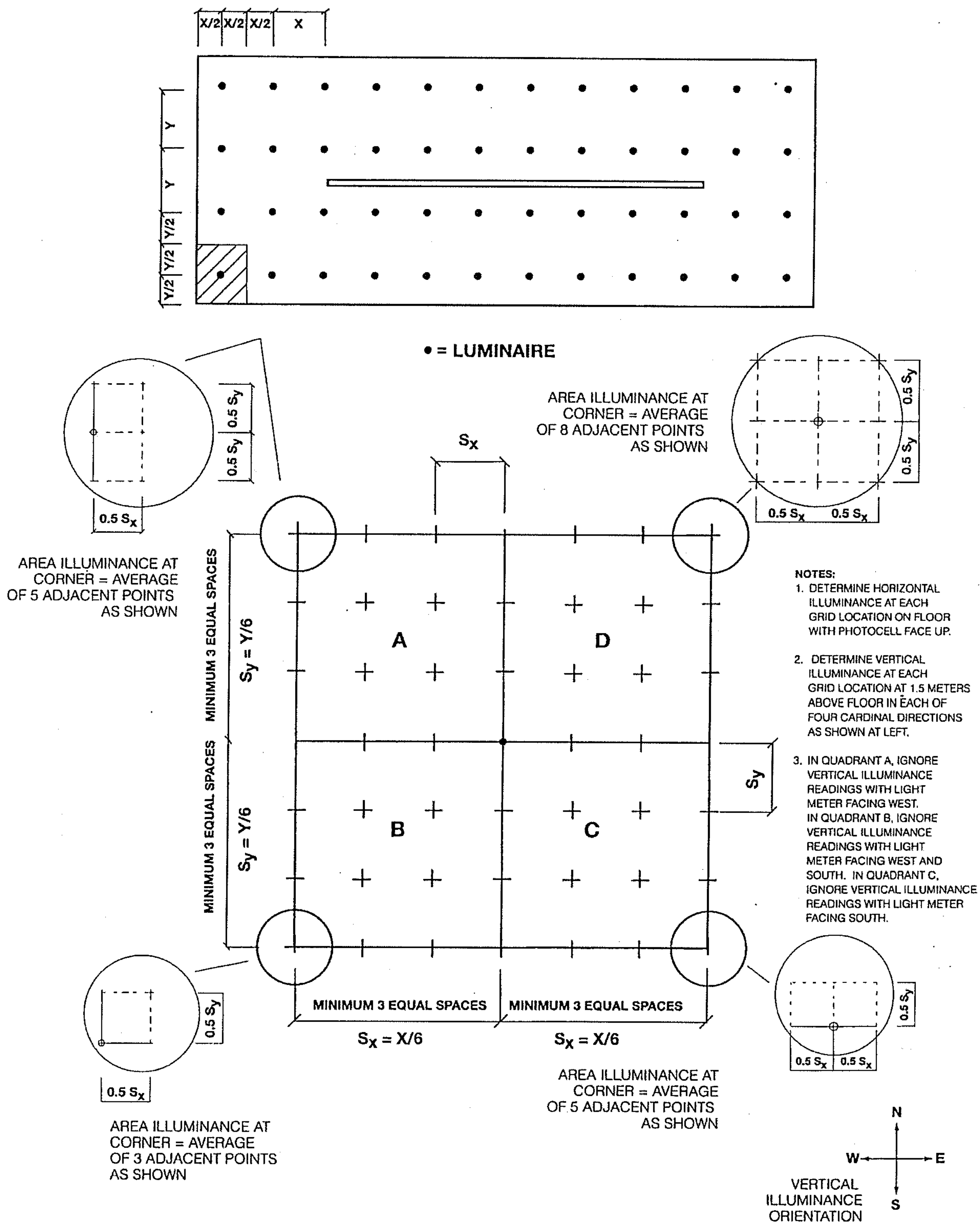
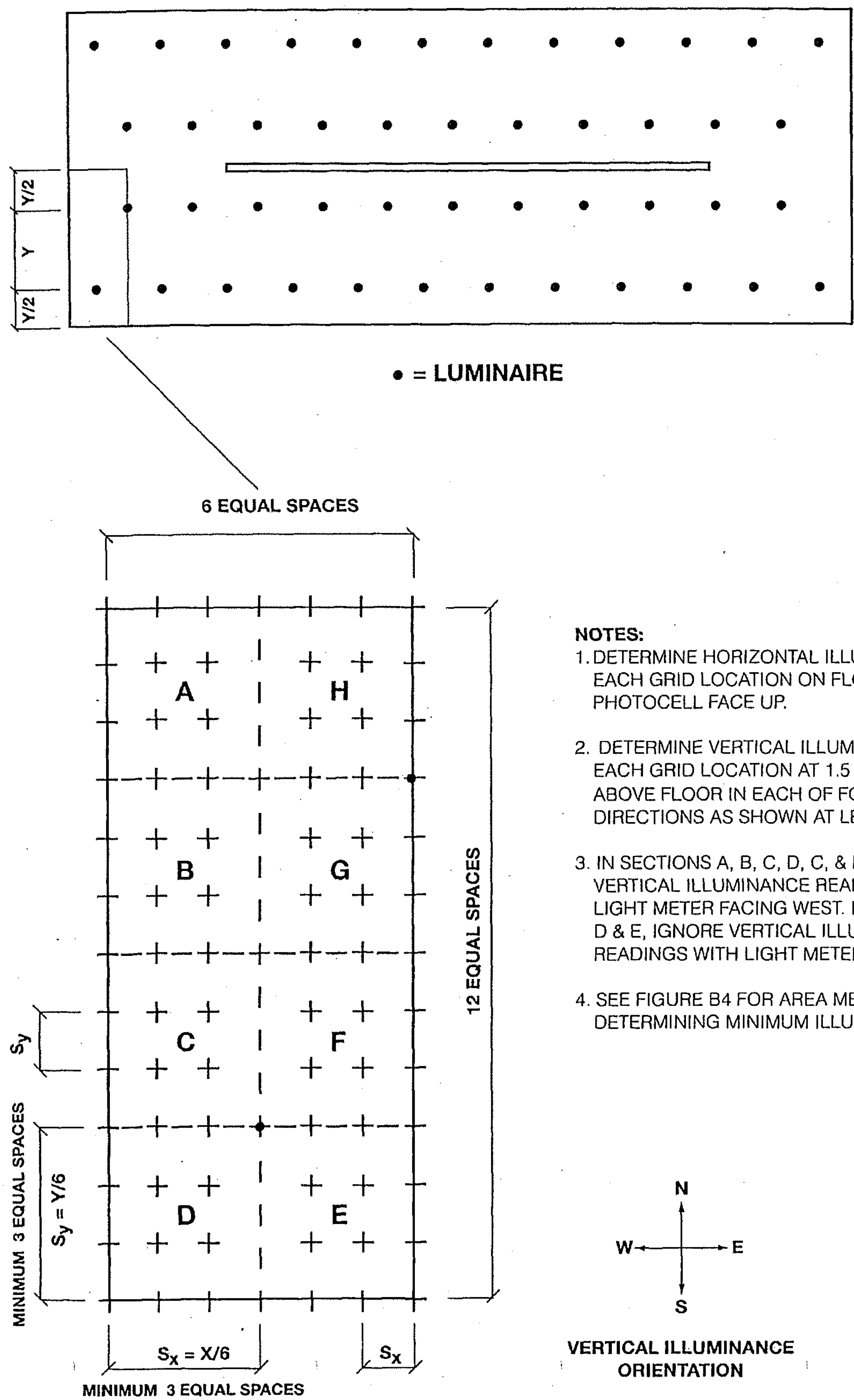


Figure B4. Photometric evaluation of a double row of luminaires along the sides of a parking garage drive aisle.



NOTES:
1. DETERMINE HORIZONTAL ILLUMINANCE AT EACH GRID LOCATION ON FLOOR WITH PHOTOCELL FACE UP.

2. DETERMINE VERTICAL ILLUMINANCE AT EACH GRID LOCATION AT 1.5 METERS ABOVE FLOOR IN EACH OF FOUR CARDINAL DIRECTIONS AS SHOWN AT LEFT.

3. IN SECTIONS A, B, C, D, C, & H, IGNORE VERTICAL ILLUMINANCE READINGS WITH LIGHT METER FACING WEST. IN SECTIONS D & E, IGNORE VERTICAL ILLUMINANCE READINGS WITH LIGHT METER FACING SOUTH.

4. SEE FIGURE B4 FOR AREA METHOD OF DETERMINING MINIMUM ILLUMINANCE.

VERTICAL ILLUMINANCE ORIENTATION

Figure B5. Photometric evaluation of a staggered, double row of luminaires along the sides of a parking garage drive aisle.

Annex C — General Procedure for Calculating Maintained Illuminance in Parking Lots and Garages

This annex is not a part of the Recommended Practice. It contains a general procedure for calculating maintained illuminance in parking lots and garages, including worked examples. For these examples, the raw data will be given in both SI (metric) and inch-pound units. However, in the interests of clarity and brevity, the examples will be worked exclusively with SI parameters (see **Annex E** for conversion factors).

C1.0 Calculation Procedure for Maintained Illuminance

The general procedure for calculating maintained illuminance consists of a series of steps before the actual calculations begin. These steps are divided into two major groups: (1) objectives and specifications; and (2) the light loss factors. A third group covers the calculations and will vary in the number and type of steps depending on the illuminance desired — *average* or *at a point*. **Section C.2** through **Section C.8** show the steps for calculating maintained levels of horizontal illuminance, and the lowest level of illuminance on a parking surface. **Section C9.0** gives a calculation procedure for vertical illuminance.

C2.0 Objectives and Specifications

C2.1 Quality Required

A knowledge and understanding of the quality of illuminance required for seeing in parking facilities is important.

C2.2 Quantity Required

The average maintained levels of illuminance to be utilized are given in this Recommended Practice (RP-20).

C2.3 Area Atmosphere

The main ambient atmospheric contamination is generated from the adjacent atmosphere. **Figure C1** shows five groups of typical area atmospheres.

*Select the appropriate curve in **Figure C1** in accordance with the type of ambient condition as described by the following examples:*

Very Clean — No nearby smoke- or dust-generating activities and a low ambient contaminant level. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per cubic meter.

Clean — No nearby smoke- or dust-generating activities. The ambient particulate level is no more than 300 micrograms per cubic meter.

Moderate — Moderate smoke- or dust-generating activities nearby. The ambient particulate level is no more than 600 micrograms per cubic meter.

Dirty — Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.

Very Dirty — Smoke or dust plumes generated by nearby activities commonly envelope the luminaires.

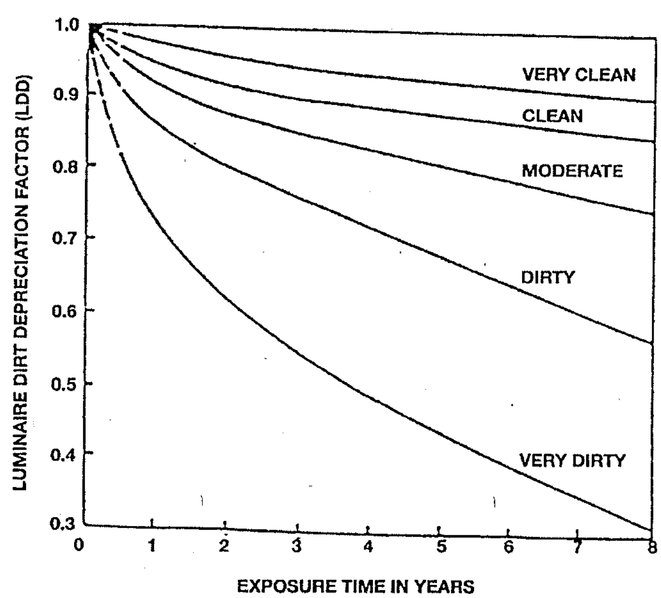


Figure C1. Chart for estimating luminaire dirt depreciation factors for enclosed and gasketed luminaires.

C2.4 Selection of Luminaire

Selection of the type of luminaire depends upon dimensions of the area, mounting height, luminaire dirt depreciation, lamp choice, maintenance consideration (including cleaning and lamp replacement), luminaire and installation appearance, color rendition, and cost of equipment. All factors, whose relative importance will vary from project to project, should be examined in detail first, then reviewed so that proper weights will be given to each one.

C3.0 Light Loss Factors (LLFs)

Once the basic values discussed in **Section C2.0** are established and a preliminary choice of a luminaire is made, light loss factors can be studied. Several of these factors — including one formerly known as *maintenance factor* — are the result of time-dependent depreciation effects to the original design. Others — such as equipment factor — will exist initially and continue through the life of the installation. However, all factors should be studied and reduced to the extent practical, because they will diminish the planned output of the lighting system.

C3.1 Maintenance Factor (MF)

Deprecated term no longer valid. See **Section C3.0**.

C3.2 Lamp Lumen Depreciation (LLD)

Information about the chosen lamp and its lumen depreciation are available from lamp manufacturers' tables and graphs. Rated average useful life should be determined for specific hours per start. A typical parking lot lighting system will be in operation about 4,000 to 4,300 hours per year, if operated all night. Luminaires in above-ground garages will operate longer, while those in underground garage levels will operate full-time (nearly 8,800 hours per year). From these facts, a practical group relamping cycle should be established and then, based on the hours elapsed to lamp removal, the specific LLD factor can be determined. Consult manufacturers' data or the latest *IESNA Lighting Handbook* for LLD factors.

C3.3 Luminaire Dirt Depreciation (LDD)

The accumulation of dirt on luminaires results in lost light output. This loss is known as the LDD factor and is determined by estimating the dirt category (very clean, clean, moderate, dirty, or very dirty) from definitions given in **Section C2.3** and **Figure C1**. From the appropriate dirt condition curve in **Figure C1** and the proper elapsed time in years of the planned cleaning cycle, the LDD factor is then found.

C3.4 Burnouts

Unreplaced burned-out lamps will vary in quantity, depending on the kinds of lamps and the relamping program used. Manufacturers' lamp mortality statistics should be consulted for the performance of each lamp type so that the number of burn-outs can be estemated before the time of planned replacement is reached. Practically, the quantity of lamp burnouts is determined by the quality of the lighting services program and by the physical performance of the program.

C3.5 Equipment Factors (EFs)

Light loss factors that are not dependent on time relate mostly to the specific equipment selected, and they usually have such little effect that correction is impractical. However, they can diminish the total light output of the system and should be minimized to the extent possible.

C3.6 Ambient Temperature

The effect of ambient temperature on the output of some lamps may be considerable. Each particular lamp-luminaire combination has its own distinctive characteristic of light output versus ambient temperature. To apply a light loss factor due to ambient temperature, the designer must know the highest and lowest temperatures expected and obtain data showing variations in light output with changes in ambient temperature for the specific lamp and ballast to be used.

C3.7 Voltage

In-service voltage levels are difficult to predict, but high (or low) voltage at the luminaire will affect the light output of most lamps.

C3.8 Ballast Factor

The ballast factor of the ballast used in a production luminaire (fluorescent or high intensity discharge) can cause significant differences in light output when compared to the ballast used to generate the photometry of the luminaire in a photometric laboratory. The manufacturer should be consulted for these necessary factors.

C3.9 Luminaire Surface Depreciation Factor

Surface depreciation results from adverse changes in a luminaire's metal, paint, and plastic components and produces reduced light output.

Because of the complex relationship between the light-controlling elements of luminaires using more than one type of material it is difficult to predict losses due to deterioration. Also, for various luminaire surfaces, the losses will be differentially affected by the type of atmosphere to which each surface is exposed. No factors accounting for luminaire component depreciation are available at present.

C3.10 Change in Physical Surroundings

The designer should try and anticipate future changes that may affect surface conditions. In the design process, it is desirable to know when the pavement is in poor condition and if it is likely to be resurfaced early in the useful life of the lighting system. Consideration may also be given as to whether trees or border areas will be added, new buildings constructed nearby, or old buildings demolished.

C4.0 Total Light Loss Factor

The total light loss factor is obtained by multiplying together all the contributing factors just described. When certain factors are not known, or believed to be reasonably small, they are omitted. Otherwise, they are estimated based on past experience at similar locations. In all cases, a light loss factor should be used that at least considers the LLD and the LDD. At this point, if the total light loss factor estimate is excessive, it may be desirable to re-select the luminaire and/or lamp, or modify the cleaning and/or maintenance schedule.

C5.0 Calculations

Illuminance calculations fall into three general types: (1) the determination of the average over an area; (2) the illuminance at a specific point on the surface; and (3) the uniformity of illuminance.

Calculations are based on luminaire photometric data curves that have been published in two formats. One method presents the data based on "per 1,000 lamp lumens" of a specific lamp, and the other method is based on "rated initial lamp lumens" of a specific lamp.

C6.0 Determinations of Average Illuminance

C6.1 General

The average illuminance over a large pavement area may be calculated by means of a "utilization curve," or by computing the illuminance at a large number of specific points and averaging the values found. The utilization curve is a part of the data presented as a result of following LM-31-95, the *IESNA Approved Method for Photometric Testing of Roadway Luminaires Using Incandescent Filament and High Intensity Discharge Lamps.*

C6.2 Utilization Curves

Utilization curves, available for various types of luminaires, afford a practical method to determine average illuminance over the surface where lamp lumen output, mounting heights, width of paved area, and spacing between luminaires are known (or can be assumed). Conversely, the desired spacing — or any other unknown factor — may readily be determined if accurate data is available for all the other factors.

Figure C2 is an example of a utilization curve of a typical luminaire. Some manufacturers combine the utilization curve with the isolux curve and present both sets of curves on the same figure. The utilization curve indicates how much light falls on the surface, but reveals little about how light is distributed. Therefore, it should be used in conjunction with the isolux curve to evaluate the true performance of the luminaire, especially concerning compliance with the recommended uniformity ratios.

The total coefficient of utilization (CU) is the percentage of rated lamp lumens received on the horizontal using an area of given width and infinite length. The curves indicate the percentage of flux falling on the area in front of the luminaire (street side) and behind the luminaire (house side). Both areas are strip-like, of infinite length, with widths expressed as a ratio of width to mounting height. To obtain the total utilization for a given area, the CU for both the street side and the house side areas must be determined from the curves and then added. The luminaire is considered mounted as tested (level) and oriented over the reference line which divides the street side from the house side.

A calculation for *average* luminance illustrates the use of a utilization curve:

Given: the layout is as shown in **Figure C3** with:

Staggered luminaire spacing	33 meters (108 ft.)
Street width curb-to-curb	17 meters (66 ft.)
Luminaire mounting height	10 meters (33 ft.)
Luminaire overhang	2 meters (6.5 ft.)
Luminaire dirt depreciation factor	0.70
Lamp (initial rating)	20,000 lumens
Lamp lumen depreciation factor	0.85

Required:

Calculate the minimum average illuminance in lux for the given lot layout. (*Note:* Parking lots come in all shapes and sizes. Often multiple luminaires are attached to poles within the lot or down the center. This simplified example is intended to illustrate all of the *principles* involved).

Solution (for average illuminance):

First, determine the coefficient of utilization for the "street-side" of the luminaire. To do this find the $\text{Ratio}_{\text{street-side}}$ from the following expression:

$$\text{Ratio}_{\text{street-side}} = \frac{\text{(Street width) - (Luminaire overhang)}}{\text{(Luminaire mounting height)}}$$

Substituting numerical values from the given data:

$$\text{Ratio}_{\text{street-side}} = \frac{\text{(17 meters) - (2 meters)}}{\text{(10 meters)}} = \frac{15}{10} = 1.5$$

The coefficient of utilization for a $\text{Ratio}_{\text{street-side}}$ of 1.5 is found to be 0.51 from **Figure C2**.

Next, determine the coefficient of utilization for the "house-side" of the luminaire. To do this find the $\text{Ratio}_{\text{house-side}}$ from the following expression:

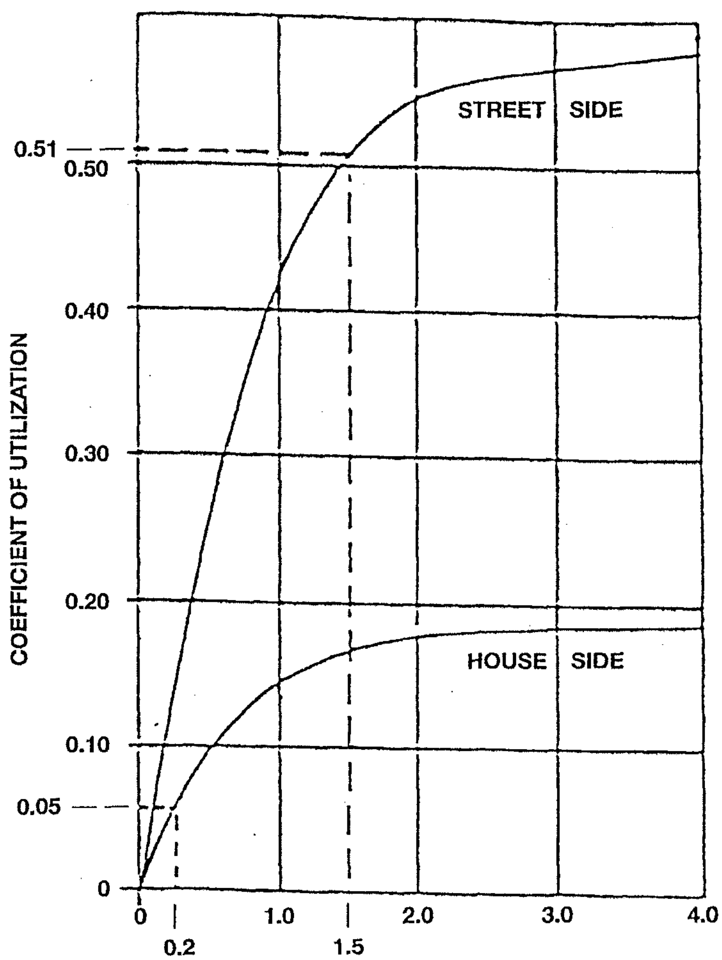
$$\text{Ratio}_{\text{house-side}} = \frac{\text{(Luminaire overhang)}}{\text{(Luminaire mounting height)}}$$

Substituting numerical values from the given data:

$$\text{Ratio}_{\text{house-side}} = \frac{\text{(2 meters)}}{\text{(10 meters)}} = 0.2$$

The coefficient of utilization for a $\text{Ratio}_{\text{house-side}}$ of 0.2 is found to be 0.05, again from **Figure C2**.

Therefore, the total coefficient (the "street-side" plus the "house-side") is 0.56.



$$\text{RATIO} = \frac{\text{TRANSVERSE WIDTH (STREET OR HOUSE SIDE)}}{\text{LUMINAIRE MOUNTING HEIGHT}}$$

Figure C2. Example of Coefficient of Utilization (CU) curves for a luminaire providing medium semi-cutoff, Type II light distribution.

The basic equation for determining average initial horizontal illuminance is:

$$E_{H(avg)} = \frac{(\text{Lamp Lumens})(CU)}{(S)(W)}$$

Where:

$E_{H(avg)}$ = average initial horizontal illuminance in lux
CU = Coefficient of Utilization
S = spacing between luminaires in meters
W = width of area in meters

A further modification of this equation is necessary to determine the average maintained horizontal illuminance on the lot. For this calculation, which is indicative of the illuminance on the pavement when the illuminating source is at its lowest output and the luminaire is in its dirtiest condition, the equation is:

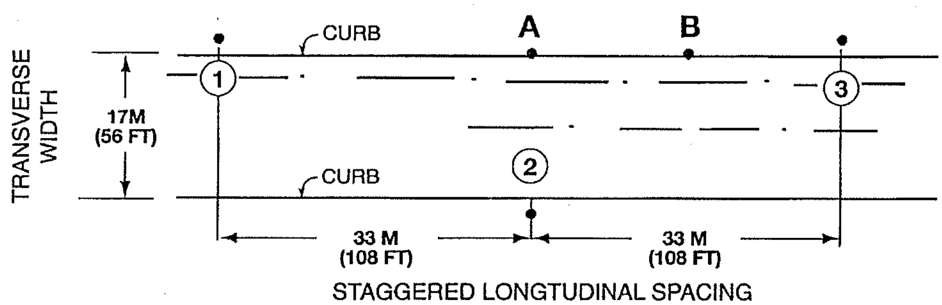
$$E_{M(avg)} = \frac{(\text{Lamp Lumens})(CU)(LLF)}{(S)(W)}$$

Where:

$E_{M(avg)}$ = average maintained horizontal illuminance in lux
CU = Coefficient of Utilization
LLF = light loss factor = LDD x LLD
S = spacing between luminaires in meters
W = width of area in meters

Note: The spacing between luminaires (S) is the longitudinal distance between luminaires if they are spaced in a staggered or one-sided arrangement. This distance is one-half the longitudinal distance between luminaires if the luminaires are arranged in opposite spacing.

Now the average illuminance in the area (and at the spacing) shown in **Figure C3** can be found. Assume that **Figure C2** was prepared using a 20,000-lumen



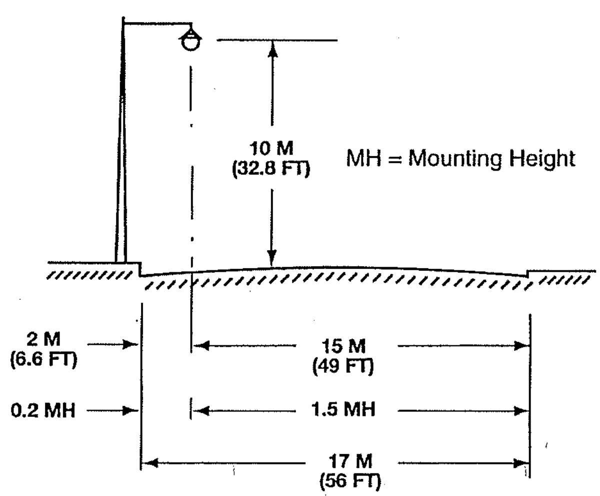


Figure C3. A luminaire and parking lot layout (assumed for typical computation) that uses a staggered arrangement of luminaires.

lamp in the luminaire, and use the equation just given for calculating $E_{M(avg)}$:

$$E_{M(avg)} = \frac{(20{,}000)(0.56)(0.70)(0.85)}{(33)(17)} = 11.9 \text{ lux}$$

If average illuminance is the desired value (fractions of a lux should be rounded to the nearest whole lux), it is also necessary to check whether the uniformity ratio is met. To do this, the illuminance at the lowest point on the lot must be calculated.

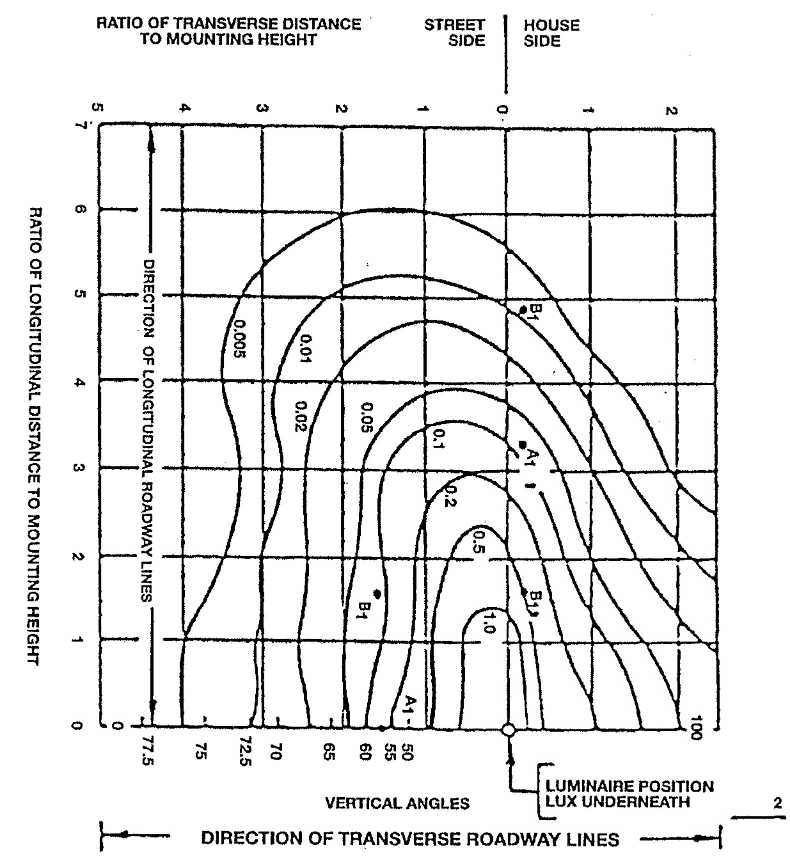
C7.0 Determination of the Illuminance at a Specific Point

C7.1 General

The horizontal illuminance in lux at a specific point may be determined from an "isolux" curve (**Figure C4**) or by means of the inverse square calculation method (see the latest edition of the *IESNA Lighting Handbook*). Since the isolux curve follows LM-31-95 (the *IESNA Approved Method for Photometric Testing of Roadway Luminaires Using Incandescent Filament and High Intensity Discharge Lamps*), this method will be discussed.

C7.2 Isolux Diagram

An isolux diagram is a graphical representation of points of equal illuminance connected by a continuous line. These lines may show lux values on a horizontal plane from a single unit having a definite mounting height, or they may show a composite picture of the illuminance from a number of sources arranged in any manner or at any mounting height. They are useful in the determination of the level of illuminance at any specific point. In order to make these



Mounting Height (m)	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mounting Height (ft.)	26.2	29.5	32.8	36.1	39.4	42.6	45.9	49.2
Scaling Factor	**1.27**	**1.00**	**0.81**	**0.67**	**0.56**	**0.48**	**0.41**	**0.36**

Figure C4. Example of an isolux diagram of horizontal lux on pavement surfaces for a luminaire providing a medium semi-cutoff, Type II light distribution (per 1,000 initial lamp lumens). The isolux data are based on a luminaire mounting height of 9 meters (29.5 ft.). For other mounting heights, multiply the isolux data by the appropriate scaling factor. (See the scaling factor list below the isolux diagram.)

curves applicable to all conditions, they are computed for a given mounting height but horizontal distances are expressed in ratios of the actual distance to the mounting height. Correction factors for other mounting heights are usually given in a tabulation alongside the curves.

To use the typical isolux diagram, the point on the pavement is located with respect to each luminaire in the system and the dimensions are determined in transverse and longitudinal multiples of the mounting height. The point is located on the isolux diagram (**Figure C4**) for each position it assumes with respect to a luminaire. The value of lux contributed by that luminaire is then estimated. If the isolux diagram is of the format based on "per 1,000 lamp lumens," the total illuminance value must be multiplied by the ratio:

(Rated Lamp Lumens)/(1000)

The total lux contribution from at least the three nearest luminaires should be added together to obtain the total illuminance at a point.

To express the illuminance of the point in terms of maintained illuminance, multiply the *initial* value by the light loss factor.

The following example illustrates this calculation process, utilizing the layout shown in **Figure C3**, the roadway and depreciation factors (as used for the utilization curve and average lux examples), and **Figure C4**.

Required: To determine the illuminance at point "A," which is the total of contributions from luminaires 1, 2, and 3.

Solution:

First the location of point "A" with respect to a point on the pavement directly under the luminaire is dimensioned in transverse and longitudinal multiples of the mounting height. Assume that the luminaire distribution provides isolux lines as shown in **Figure C4**. Point "A" is then located on this diagram for its position with respect to each luminaire.

Next, determine the contribution of luminaires 1 and 3 to point "A:"

Locate point "A" - Transverse 2 meters to "house side."
(2 meters)/(10 meters) = 0.2 times mounting height
Longitudinal 33 meters along pavement
(33 meters)/(10 meters) = 3.3 times mounting height

At point "A" the estimated contribution is 0.08 lux from *each* luminaire, uncorrected (value obtained from **Figure C4**). Therefore, luminaires 1 and 3 together provide 0.16 lux (per an initial 1,000 lamp lumens).

Now determine the contribution of luminaire 2 to point "A:"

Locate point "A" - Transverse 15 meters to "street side."
(15 meters)/(10 meters) = 1.5 times mounting height
The longitudinal location is 0, directly across from the luminaire.

Therefore, at point "A" the estimated contribution from luminaire 2 is 0.17 lux, uncorrected (value obtained from **Figure C4**).

Assuming initial 1,000-lumen lamps are used, the total contribution at point "A" from the three luminaires is 0.16 + 0.17 = 0.33 lux. Because initial 20,000 lumen lamps are used, this contribution value must be multiplied by 20, to yield 6.6 lux. However, the subject luminaire mounting height is 10 meters, whereas the test lamp of **Figure C4** is mounted at 9 meters. Thus it is necessary to correct the 6.6 lux value. (To do this, multiply by 0.81, the correction factor given for a 10-meter mounting height given in **Figure C4**). The total contribution at point "A" thus becomes 0.81 x 6.6 = 5.3 lux.

The value of 5.3 lux assumes clean luminaires with lamps producing rated output. To express the contribution level in terms of lux when the illuminating source is at its lowest output and when the luminaire is in its dirtiest condition, it is necessary to multiply the non-depreciated value (5.3 lux) by the LDD factor (0.7) and by the LLD factor (0.85). (Note: when multiplied together these depreciation factors become approximately 0.6.) Therefore, the fully corrected point "A" illuminance value is: 5.3 x 0.6 = 3.2 lux. This is the value to compare with the calculated, maintained (depreciated) average value of 12 lux for the subject example, if average to minimum lux is to be calculated.

C8.0 Uniformity Ratios

The illuminance uniformity requirements of this Practice should be determined by computing the uniformity ratio:

(Maximum Horizontal Lux)/(Minimum Horizontal Lux)

In the subject example, the maximum lux under the lamp as given in **Figure C4** is 2 (assuming an initial 1,000-lumen lamp). For an initial 20,000-lumen lamp, the maximum lux under the lamp is: 2 x 20 = 40 lux. Correcting for the 10-meter mounting height this becomes: 40 x 0.81 = 32 lux, then correcting for the combined maintenance factor this maximum lux value becomes: 32 x 0.6 = 19 lux.

Using the lux value already calculated at point "A" for the contribution from luminaires 1, 2, and 3, the uniformity ratio is 19/3.2 or 6:1, which is well within the maximum-to-minimum ratio requirements of RP-20, *if* point "A" is the minimum. A sufficient number of specific points over the area (in addition to point "A") should be checked to ascertain accurately the location and value of the minimum point.

Again, using the subject example and checking point "B:"

Luminaire 1 (**Figure C3**) — Point "B" is 0.2 MH (mounting height) house-side and $1^1/_2$ the spacing, or 4.9 MH longitudinal. From **Figure C4**, the uncorrected illuminance value is 0.01 lux.

Luminaire 2 — Point "B" is 1.5 MH street-side and $^1/_2$ the spacing, or 1.6 MH longitudinal. The uncorrected **Figure C4** illuminance value is 0.09 lux.

Luminaire 3 — Point "B" is 0.2 MH house-side and $^1/_2$ the spacing, or 1.6 MH longitudinal. The uncorrected **Figure C4** illuminance value is 0.5 lux.

The total illuminance from all three luminaires is 0.01 + 0.09 + 0.50 = 0.60 lux (assuming initial 1,000-lumen lamps). For initial 20,000-lumen lamps, the maximum lux is: 0.60 x 20 = 12 lux. Correcting for a 10-meter instead of 9-meter mounting height gives 0.81 x 12 = 9.7 lux.

The final correction for lamp and dirt depreciation (using the combined factor of 0.6) is 0.6 x 9.7 = 5.8 lux. Therefore, the maximum-to-minimum uniformity ratio at point "B" is 19/5.8 or 3.3:1. This is lower (better uniformity) than the uniformity ratio calculated at point "A," so point "A" remains the minimum lux point. If the uniformity ratio at point "A" (6:1) exceeds the designer's desired value, the luminaire in the example design problem should not be utilized unless a greater mounting height can be used. For the 10-meter mounting height, a Type III distribution is probably preferable on this width of lot.

If the designer is using *average* illuminance calculations, some manufacturers are now supplying curves of the type shown in **Figure C5**, which indicate the average-to-minimum lux ratio for a particular arrangement of luminaires, as area width and spacing are varied. Such curves are a convenient aid to determine the average-to-minimum illuminance ratios for a given spacing and width, or to determine the permissible spacing for a desired uniformity ratio. They can also be used to determine the relationship between average illuminance and spacing and width. Each different combination of luminaires, lamp type, lamp size, and arrangement of luminaires will produce a different set of these characteristic curves.

C9.0 Vertical Illuminance

The procedure for calculating vertical illuminance at a point and at a given elevation above the surface (e.g., 1.5 meters), can utilize much of the material presented in **Section C8.0** for horizontal illuminance calculations, including use of isolux curves of horizontal illuminance. The mounting height (MH) of the luminaire is reduced by 1.5 meters to place the isolux curve on the same plane where the point of vertical illuminance is to be calculated. For the example given in **Figure C3**, the MH becomes 8.5 meters (10 minus 1.5). The actual lowest vertical reading will be just short of the next luminaire (luminaire 2 in **Figure C3**, when checking vertical illuminance from luminaire 1). However, the most *critical* point for vertical illuminance, from the personal security standpoint, is felt to be in the area of lowest horizontal illuminance – the "darkest" spot. This is point "A" in the **Figure C3** layout. To calculate vertical illuminance at this point, proceed as follows:

- The longitudinal spacing is 33 meters (consider *either* luminaire 1 or 3). This is divided by the 8.5-meter MH to get the MH ratio: 33/8.5 = 3.9
- The lateral spacing is 2 meters (house side). This is divided by the 8.5 meter MH to get the MH ratio: 2/8.5 = 0.24

Entering **Figure C4** at this point (0.24) and interpolating between the 0.02 and the 0.05 lines, gives an estimated value of 0.03 lux, uncorrected.

The horizontal value represents the cosine of the beam candela, and the sine represents the vertical. It is therefore necessary to calculate the angle to the point being checked. The diagonal, horizontal distance is equal to the hypotenuse of the triangle formed by the leg of the 2-meter overhang of luminaire 2 and the 33-meter spacing in the subject example. If "X" is the length of the hypotenuse, it is found from:

$$X = \sqrt{2^2 + 33^2} = 33 \text{ meters (rounded)}$$

Then, by proportions:

$$(V)/(HL) = (MH)/(X)$$

Where:

V = vertical lux
HL = horizontal lux
MH = mounting height for point 1.5 meters up
X = horizontal hypotenuse

A MH correction is needed due to the difference between the calculation value of an 8.5-meter MH and the **Figure C4** diagram basis of a 9-meter MH. This correction is based upon the inverse square law and is easily calculated. The correction is:

$(9^2)/(8.5^2) = 81/72 = 1.13$

The initial 0.03 lux value (assuming 1,000-lumen lamps) must be increased because in this case, 20,000-lumen lamps are used. Thus, 0.03 is multiplied by 20, giving a value of 0.6 lux. Correcting for depreciation, and again using the LDD factor of 0.7 and the LLD factor of 0.85, gives a multiplier of 0.6.

Therefore: 0.6 x 0.6 = 0.36 lux. Finally, correcting for mounting height, 0.36 x 1.13 = 0.41 *horizontal* lux.

Using the proportion equation, the vertical lux (V) at Point "A" from luminaire 1 is:

$V/(0.41) = (8.5)/(33)$; $V = [(0.41)(8.5)]/33 = 0.11$ lux

The low point also will receive vertical illuminance from luminaire 2 at right angles to that produced by luminaire 1. An observer can be any place in the area bounded by the north curb (assume north to the top in **Figure C3**, upper part), the south curb and the east/west area between luminaires 1 and 2.

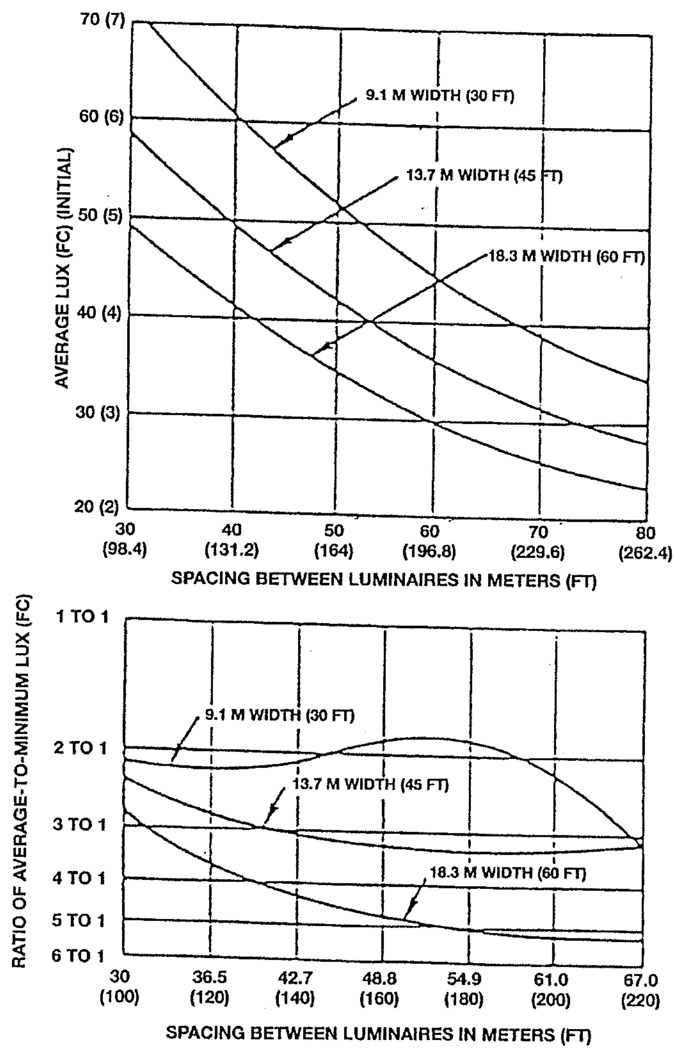


Figure C5. These charts show average lux (fc) versus luminaire spacing (top) and average-to-minimum uniformity ratios versus luminaire spacing (bottom) for a staggered luminaire arrangement. The values of average lux (initial) are based on an initial lamp output of 30,000 lumens, and the ratio of average lux to minimum lux is the lowest value area. The luminaire distribution classification is medium semi-cutoff, Type II. Caution: While data taken from isolux diagrams may represent actual luminaire light output (as is shown in this figure), isolux data is most often presented as a value per 1,000 emitted lamp lumens.

Therefore, it is felt appropriate to add the vertical illuminance from luminaire 2 to that of luminaire 1. This calculation involves the direct distance of 15 meters from the lower part of **Figure C3** and use of the prior calculation of 0.17 horizontal lux, uncorrected (see **Section C7.2**). Applying the correction factors (multiply by 20 to scale up to 20,000-lux lamps; multiply by 0.6 to account for all maintenance factors; and multiply by 1.13 to correct for the actual mounting height) gives 2.3 lux horizontal. Using the proportion equation, the vertical lux (V) at Point "A" from luminaire 2 is:

$(V)/(2.3) = (8.5)/(15)$; $V = 1.30$ lux

The total vertical illuminance is $0.11 + 1.30 = 1.41$ lux. This is then compared with the value in the Standard Practice Table.

The basic principles for calculating vertical illuminance have just been presented. Many parking lot calculations will be more complex — for example, when using twin or quad luminaires on each pole, with a grid pattern layout. With such a configuration the lowest horizontal illuminance point will normally be in the midpoint of the rectangle. Up to four luminaires could contribute illuminance to this point from a quad luminaire. In this case the calculated lux value would be doubled to yield the total vertical, as well as horizontal illuminance (see **Annex B**).

Annex D — Visibility-Based Analysis of Parking Facility Lighting

This annex is not a part of the Recommended Practice. It contains a visibility based analysis of parking facility lighting.

D1.0 Introduction

The lighting recommendations in the previous edition of RP-20 as well as those in the current edition, rely primarily on *illuminance-based criteria* — the amount of incident light falling on a surface or object. While illuminance–based criteria have served the lighting industry reasonably well, there has been a trend toward using *luminance* criteria for many types of facilities including roadway lighting. Substantial research has been conducted toward making *small target visibility* (STV) a potential criterion for roadway lighting. This annex uses current STV research as a basis for visibility-based lighting calculations for a typical visual task required in a parking facility and then relate these calculations to the illuminance criteria of **Table 1** and **Table 2** in the main document.

D2.0 Visibility Parameters

Parking facility lighting systems must provide adequate illuminance for the safe movement of vehicular and pedestrian traffic. Here the primary visual task is the timely detection of moving vehicles, pedestrians, and any obstacles that may represent a potential safety hazard. Curbs, wheel stops, posts, columns, and walls must be perceived sufficiently in advance of potential contact so that reaction and evasive action can take place in time to avoid impact.

Detection of an object is based upon adequate luminance contrast between the object and its background. The amount of luminance contrast required is a function of the adapted luminance, object size, object distance, speed (time of fixation), contrast polarity (negative versus positive contrast), and the observer's age. Since luminance = (illuminance x reflectance)/π, a relationship can be derived between luminance contrast (visibility) and illuminance. This relationship is based upon targets and backgrounds of known reflectance, assuming diffuse (Lambertian) surfaces.

Contrast, normally expressed by $\Delta L/L$, consists of photometric units. Visibility is based on light sensation. When a certain light level for a specified visual task is reached that evokes a sensation of visibility, the light level is called the "threshold value," indicating the threshold for perception. For basic visual functions this is indicated by the luminance difference between the task and its background (example: the limit of readability of optotypes). These limits are characterized by photometric values such as ΔL or VA.

The calculations for visibility level (VL) presented here are based upon a visibility model that was first published in German in 1967, followed by an extended version written in English in 1981, 1987, and 1993. The model is based on the experimental data of Adrian, Aulhorn, Blackwell, Knoll and Tousey, Siendentopf et. al., and has long been used in Europe for calculating the visibility threshold of objects. After verification tests in Hendersonville, NC, it is now expected to be included in the next edition of IESNA/ANSI RP-8 *American National Standard Practice for Roadway Lighting.*

There is also Blackwell's model for VL (based on Blackwell-Taylor data) that holds for photopic luminance only. These data are not compatible with Blackwell's own data of 1946, which were reconfirmed and generally accepted.

The visibility model presented here reflects Blackwell's 1946 data (Tiffany Study). However, this annex describes an extended model, developed by Dr. Werner Adrian and announced in his paper "The Physiological Basis of the Visibility Concept" presented October 26-27, 1993 at the Second Annual Symposium on Visibility and Illuminance in Roadway Lighting in Orlando, FL.*

Blackwell (1946) used the *forced choice* method and his data holds for 50 percent probability of seeing. Dr. Adrian and the other researchers just mentioned used a method by which luminance (L) was *adjusted* until a visibility threshold was reached.

As evidenced from the new data obtained by adjustment, the Blackwell data (1946) can be transformed into data corresponding to a 99.97 percent probability of seeing if a factor of 2.6 is used. The new data were found from laboratory experiments that covered the range from purely photopic levels down to near scotopic levels. The results are also valid for the mesopic vision range.

The methodology proposed by Adrian and others consists of calculating the theoretical difference in luminance required (between an object and its background) so that an observer can perceive the object with a 99.9 percent "success rate" (probability), which is called the *luminance difference threshold.* The ratio of the actual luminance difference to the luminance difference threshold is called the *visibility level* (VL). The required visibility level is a function of the background luminance and visual acuity required for the task.

**Sponsored by the Lighting Research Institute, New York, NY (Now the Lighting Research Office, EPRI, CA.)*

Since the majority of liability claims implicating parking facilities involve slips, trips, and falls, the visibility of curbs and/or wheel stops was investigated as a function of illuminance. The relevant visibility parameters are discussed in the following sections.

D2.1 Reflectance

Calculations were performed for an unpainted concrete curb (reflectance = 35 percent) on an asphalt pavement (reflectance = 7 percent), and on a dirty concrete floor (reflectance = 20 percent). Asphalt pavement is typically found on open-surface parking lots, while concrete floors are typically used in covered parking structures. These reflectance values are representative of measurements taken in numerous parking facilities.**

D2.2 Detection Distance

The distance at which a stationary object must be detected to avoid impact depends upon how fast the vehicle or pedestrian is moving, the perception-reaction time required to initiate evasive action, and the distance required to execute the evasive action. The typical vehicle speed in a parking facility is approximately 15 km/hr (9.3 miles/hr). The average pedestrian walking speed is approximately 4.7 km/hr (2.9 miles/hr). The perception-reaction time required is approximately one to two seconds.

Therefore, the perception-reaction distance is approximately 5 to 10 meters (16.4 to 32.8 ft.) for a moving vehicle. To this must be added a stopping distance of approximately 3 meters (9.8 ft.) for a total distance of 8 to 13 meters (26.2 to 42.6 ft.). The perception-reaction distance for a pedestrian is approximately 2 to 3 meters (6.6 to 9.8 ft.). (The pedestrian can execute evasive action nearly instantaneously.) Therefore, the distance factor should be in the 3 to 13 meter (9.8 to 42.6 ft.) range. A consensus-value distance of 6 meters (19.7 ft.) has been used in these calculations. (This consensus value gives primary consideration to the perception-reaction time needs of pedestrians.)***

***Original data gathered by Off-Roadway Facilities Subcommittee member D. R. Monahan.*

****See "Desicion Sight Distance for Highway Design and Traffic Devices," Federal Highway Administration, FHW A-RD-78-78. Internet contact: chris.gaskins@fhwa.dot.gov*

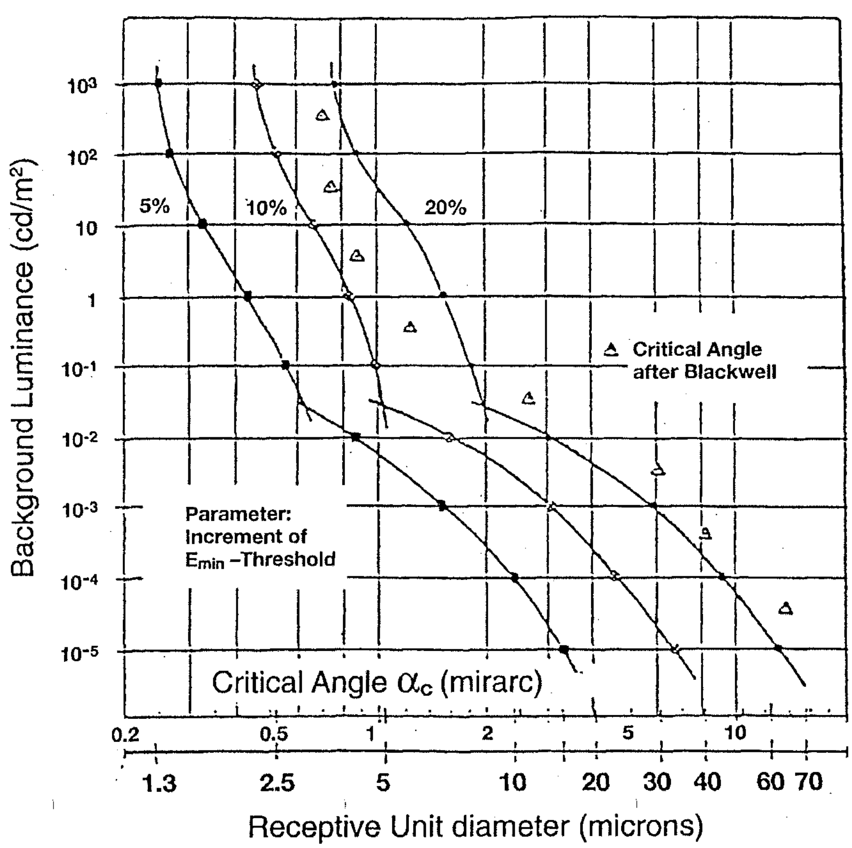


Figure D1. Calculated critical angle α_c (minarc) for 5, 10, and 20 percent deviation from Ricco's Law expressed as E_{MIN} = constant. The triangles are data of Blackwell. The second abscissa (microns) reflects the diameter of the receptive units over which spatial integration takes place.

D2.3 Target Size

The "target" object selected was a 15-cm by 1.8-meter (6-in. by 6-ft.) concrete wheel stop. This target is an elongated object with an approximate height-to-length ratio of 1:12. The experiments underlying the small target visibility model utilize the angular size of concentrated targets (either round or square) of equal area and expressed in minutes of arc (minarc). This angle is formed by the diameter of the target and the distance from the target to the eye.

Discussions with Dr. Adrian indicate that conversions of odd-shaped targets can only be handled within the critical Ricco-angle. This angle specifies the retinal area in which spatial integration takes place. In **Figure D1**, Ricco's critical angle is depicted for various background luminances. It reveals that where the background luminance (L_B) equals 10^{-2} cd/m^2 (0.9 10^{-3} cd/ft.^{2}), the angular size over which integration occurs measures around 3 minarc. This is far below the size of a wheel stop as seen from a distance of 3 to 13 meters (9.8 to 42.6 ft.). Therefore, only a part of a concrete curb's horizontal extension (equal to about three times the height) is utilized and converted into a concentrated target of equal area. Though this target is also outside the Ricco angle, it allows a more accurate estimate. The equivalent target diameter is then 30 cm (11.8 in.) which, at a distance of 6 meters (19.7 ft.), results in a target size of 171 minarc.

D2.4 Observation Time

Small target visibility (STV) research has found that the average fixation time of a target is between 0.1 and 0.2 seconds in daylight and 0.3 to 0.45 seconds at roadway lighting levels. Therefore, a value of 0.2 seconds is utilized for fixation time for parking facility lighting levels [2 lux to 100 lux (0.2 fc to 10 fc)], which are less than daylight levels but higher than roadway levels. The time factor increases the threshold luminance difference by 2.03.

D2.5 Contrast Polarity Factor

Since the target (wheel stop) is brighter than the background (i.e., there is positive contrast), the contrast polarity factor is 1. (For discussion/determination of polarity factor, see Dr. Werner Adrian's original research paper as described in **Section D2.0**)

D2.6 Age Factor

The luminance difference threshold is adjusted for a 60-year-old observer. This adjustment factor is calculated to be 1.77. (For discussion/determination of age-related adjustment factor, see Dr. Werner Adrian's original research paper as described in **Section D2.0**)

D3.0 Analysis

Calculations of the luminance difference required at illuminances ranging from 1 lux to 200 lux (0.1 fc to 20 fc) are indicated in **Table D1**, and are plotted in **Figure D2**. The visibility level (VL) required to allow a certain "form perception" level for various values of visual acuity (VA), is plotted versus the background luminance (L_B) in **Figure D3**.

Assuming diffuse (Lambertian) pavement surfaces, the background luminance (L_B) was calculated from the illuminance based on an assumed reflectance of 20 percent for concrete pavement and an assumed reflectance of 7 percent for asphalt pavement.

The calculated curve of visibility level (VL) versus increasing illuminance for a concrete wheel stop on an asphalt pavement is shown in **Figure D4**. Overlaid on this curve are plots of (1) the required VL for VA = 0.66 and (2) the required VL for VA = 0.8. The intersection of each *required* VL plot with the *calculated* VL curve indicates the minimum illuminance required for visibility of the wheel stop. These minimum illuminances are approximately 1.6 lux (0.16 fc) when the VA = 0.66 and approximately 4.5 lux (0.45 fc) when the VA = 0.8.

Similarly, the calculated curve of VL versus increasing illuminance for a concrete wheel stop on a concrete pavement is shown in **Figure D5**. Applying the graphical method of curve intersections just described, it is found that when VA = 0.66 the minimum illuminance required for visibility is approximately 4 lux (0.4 fc) and when VA = 0.8 the minimum illuminance required for visibility is approximately 11 lux (1.1 fc).

Most open parking lots are constructed with asphalt pavement, where the RP-20 minimum illuminance level (see **Table 1**) is 2 lux (0.2 fc). Most garage floors are of concrete, where the RP-20 minimum illuminance level (see **Table 2**) is 10 lux (1 fc). Therefore, a visibility-based calculation of the minimum illuminance (i.e., an intersection value from **Figure D4** or **Figure D5**) needed to make concrete wheel stops visible (at normal viewing distance) compares favorably with the consensus values arrived at by members of the RP-20 subcommittee.

Table D1: Visibility-Based Analysis of Parking Facility Lighting

Visibility calculations are based upon Werner Adrian's formula for Delta L (ΔL) with adjustment factors for time of observation, contrast polarity factor, and age of observer. Observation time is taken as 0.2 seconds based on current research for parking facility lighting levels. The distance from the object to the observer of 6 meters (19.7 ft) represents a practical balance between driver visibility as one pulls into a stall, and pedestrian visibility walking between vehicles. The size of the object is 15 cm (5.9 in) high by 1.8 meters (5.9 ft.) long, which represents a typical precast concrete wheel stop. Reflectance values are based upon field measurements of a random sample of parking facilities.

ASPHALT PAVEMENT

Illuminance footcandles	Illuminance lux	Pavement Reflectance	Object Reflectance	Background Luminance (cd/m^2)	Target Luminance (cd/m^2)	Delta L Actual	Delta L Threshold	Visibility Level	Required VL (VA=0.66)	Required VL (VA=0.8)
0.095	1.00	0.07	0.350	0.022	0.111	0.089	0.003	27	35	85
0.189	2.00	0.07	0.350	0.045	0.223	0.178	0.005	36	30	75
0.284	3.00	0.07	0.350	0.067	0.334	0.267	0.006	42	25	62
0.379	4.00	0.07	0.350	0.089	0.446	0.357	0.008	47	21	52
0.473	5.00	0.07	0.350	0.111	0.557	0.446	0.009	52	20	48
0.568	6.00	0.07	0.350	0.134	0.668	0.535	0.010	56	19	44
0.663	7.00	0.07	0.350	0.156	0.780	0.624	0.011	59	18	41
0.758	8.00	0.07	0.350	0.178	0.891	0.713	0.011	62	17	38
0.852	9.00	0.07	0.350	0.201	1.003	0.802	0.012	65	16	36
0.947	10.00	0.07	0.350	0.223	1.114	0.891	0.013	68	15	
1.042	11.00	0.07	0.350	0.245	1.225	0.980	0.014	70		
1.136	12.00	0.07	0.350	0.267	1.337	1.070	0.015	72		
1.231	13.00	0.07	0.350	0.290	1.448	1.159	0.016	75		
1.326	14.00	0.07	0.350	0.312	1.560	1.248	0.016	77		
1.420	15.00	0.07	0.350	0.334	1.671	1.337	0.017	79		
1.515	16.00	0.07	0.350	0.357	1.783	1.426	0.018	81		
1.610	17.00	0.07	0.350	0.379	1.894	1.515	0.018	82		
1.705	18.00	0.07	0.350	0.401	2.005	1.604	0.019	84		
1.799	19.00	0.07	0.350	0.423	2.117	1.693	0.020	86		
1.894	20.00	0.07	0.350	0.446	2.228	1.783	0.020	88		
2.367	25.00	0.07	0.350	0.557	2.785	2.228	0.023	95		
2.841	30.00	0.07	0.350	0.668	3.342	2.674	0.027	100		
3.314	35.00	0.07	0.350	0.780	3.899	3.119	0.031	102		
3.788	40.00	0.07	0.350	0.891	4.456	3.565	0.035	103		
4.261	45.00	0.07	0.350	1.003	5.013	4.011	0.038	104		
4.735	50.00	0.07	0.350	1.114	5.570	4.456	0.042	106		
5.682	60.00	0.07	0.350	1.337	6.685	5.348	0.050	108		
6.629	70.00	0.07	0.350	1.560	7.799	6.239	0.057	109		
7.576	80.00	0.07	0.350	1.783	8.913	7.130	0.064	111		
8.523	90.00	0.07	0.350	2.005	10.027	8.021	0.072	112		
9.470	100.00	0.07	0.350	2.228	11.141	8.913	0.079	113		
18.939	200.00	0.07	0.350	4.456	22.282	17.825	0.148	121		

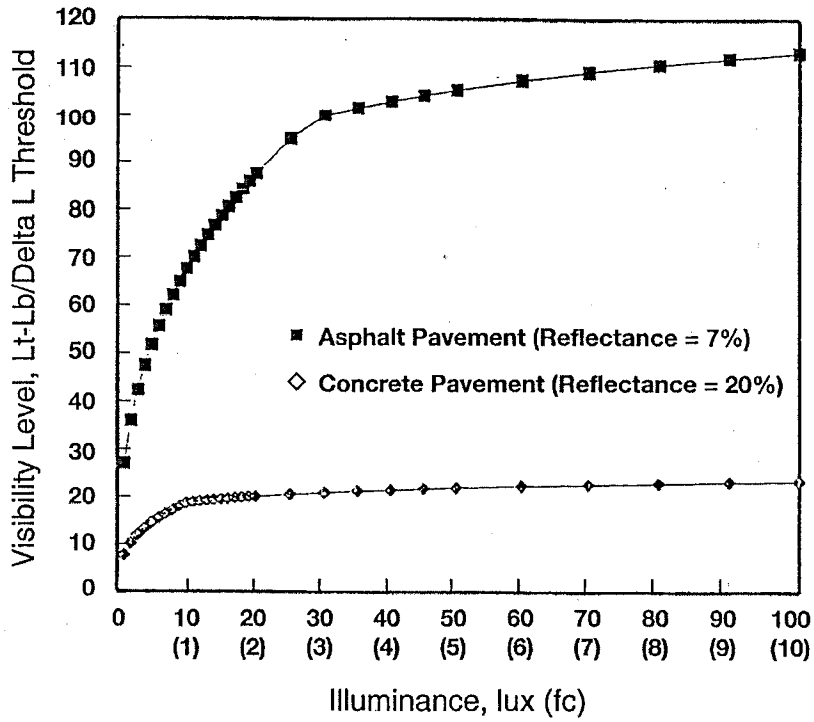
Note: Multiply cd/m^2 data by 0.0929 to get $cd/ft.^2$ data.

Table D1: (continued) Visibility-Based Analysis of Parking Facility Lighting

CONCRETE FLOOR

Illuminance footcandles	Illuminance lux	Pavement Reflectance	Object Reflectance	Background Luminance (cd/m²)	Target Luminance (cd/m²)	Delta L Actual	Delta L Threshold	Visibility Level	Required VL (VA=0.66)	Required VL (VA=0.8)
0.095	1.00	0.200	0.350	0.064	0.111	0.048	0.006	8	28	60
0.189	2.00	0.200	0.350	0.127	0.223	0.095	0.009	10	20	45
0.284	3.00	0.200	0.350	0.191	0.334	0.143	0.012	12	17	35
0.379	4.00	0.200	0.350	0.255	0.446	0.191	0.014	13	14	30
0.473	5.00	0.200	0.350	0.318	0.557	0.239	0.016	14	12	27
0.568	6.00	0.200	0.350	0.382	0.668	0.286	0.018	15	11	24
0.663	7.00	0.200	0.350	0.446	0.780	0.334	0.020	16	10.5	22
0.758	8.00	0.200	0.350	0.509	0.891	0.382	0.022	17	9.7	21
0.852	9.00	0.200	0.350	0.573	1.003	0.430	0.024	18	9	20
0.947	10.00	0.200	0.350	0.637	1.114	0.477	0.026	19	8.5	19.5
1.042	11.00	0.200	0.350	0.700	1.225	0.525	0.028	19	8	18.8
1.136	12.00	0.200	0.350	0.764	1.337	0.573	0.030	19		17.7
1.231	13.00	0.200	0.350	0.828	1.448	0.621	0.032	19		17
1.326	14.00	0.200	0.350	0.891	1.560	0.668	0.035	19		16
1.420	15.00	0.200	0.350	0.955	1.671	0.716	0.037	19		15
1.515	16.00	0.200	0.350	1.019	1.783	0.764	0.039	20		14
1.610	17.00	0.200	0.350	1.082	1.894	0.812	0.041	20		
1.705	18.00	0.200	0.350	1.146	2.005	0.859	0.043	20		
1.799	19.00	0.200	0.350	1.210	2.117	0.907	0.045	20		
1.894	20.00	0.200	0.350	1.273	2.228	0.955	0.048	20		
2.367	25.00	0.200	0.350	1.592	2.785	1.194	0.058	21		
2.841	30.00	0.200	0.350	1.910	3.342	1.432	0.069	21		
3.314	35.00	0.200	0.350	2.228	3.899	1.671	0.079	21		
3.788	40.00	0.200	0.350	2.546	4.456	1.910	0.089	21		
4.261	45.00	0.200	0.350	2.865	5.013	2.149	0.099	22		
4.735	50.00	0.200	0.350	3.183	5.570	2.387	0.109	22		
5.682	60.00	0.200	0.350	3.820	6.685	2.865	0.129	22		
6.629	70.00	0.200	0.350	4.456	7.799	3.342	0.148	23		
7.576	80.00	0.200	0.350	5.093	8.913	3.820	0.167	23		
8.523	90.00	0.200	0.350	5.730	10.027	4.297	0.186	23		
9.470	100.00	0.200	0.350	6.366	11.141	4.775	0.205	23		
18.939	200.00	0.200	0.350	12.732	22.282	9.549	0.387	25		

Note: Multiply cd/m² data by 0.0929 to get cd/ft.² data.



Distance = 6 m (20 ft.)
Wheel Stop Reflectance = 35%

Figure D2. Visibility of concrete wheel stops for a 60-year-old observer.

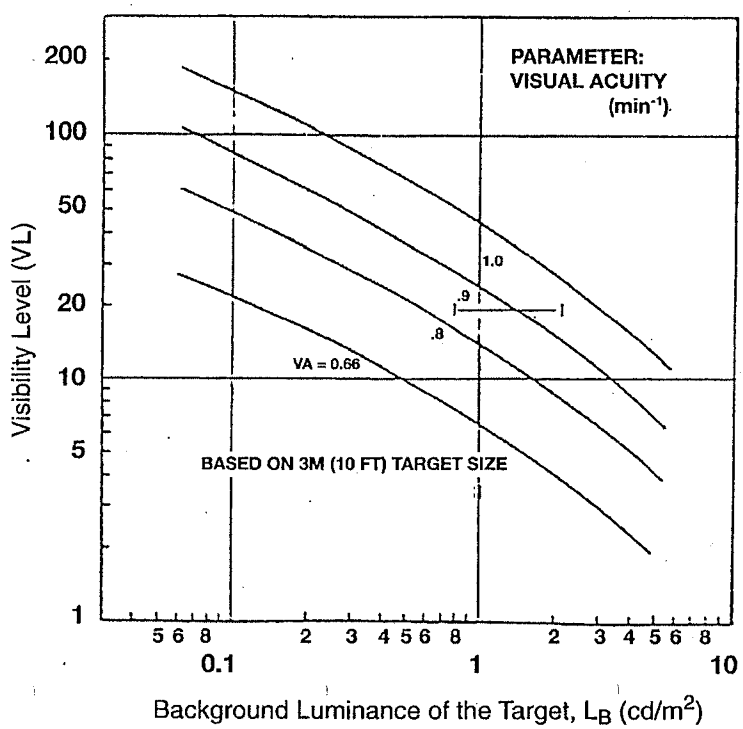
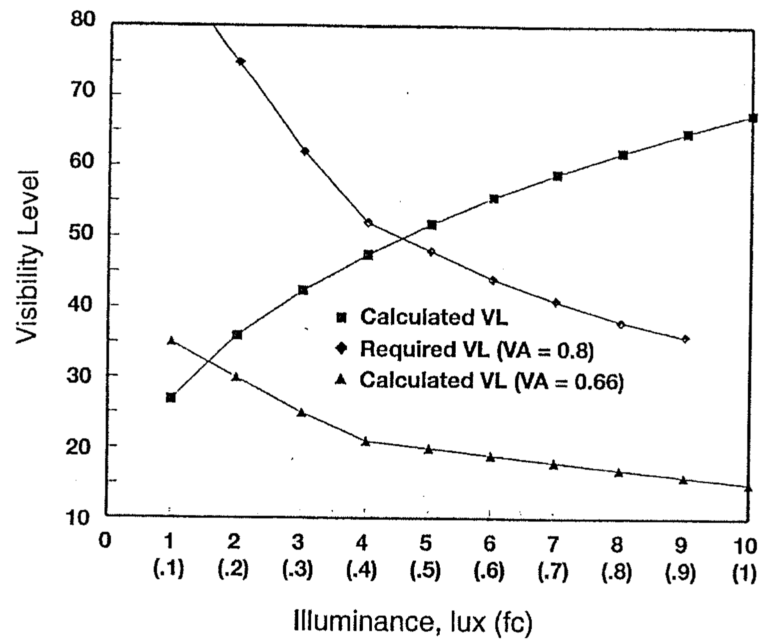
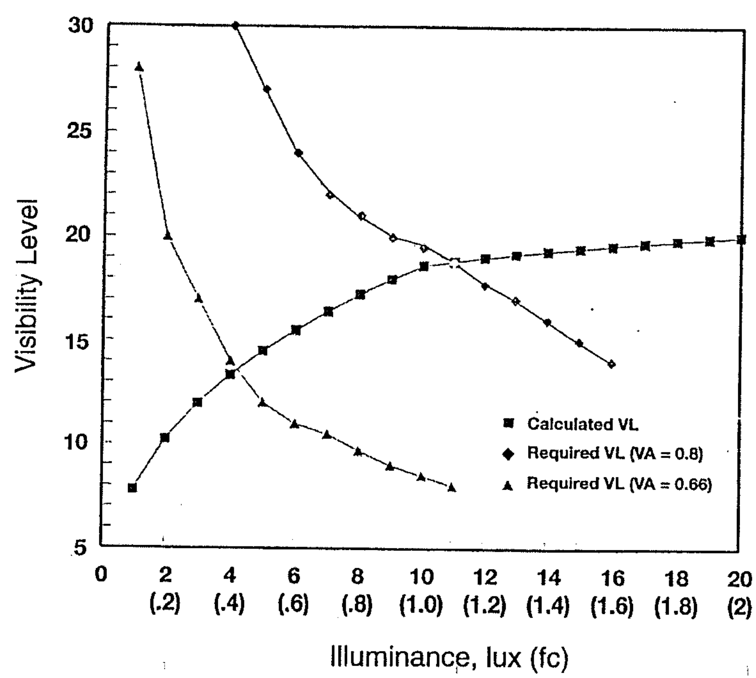


Figure D3. Derived visibility levels (VLs) required in street lighting for different levels of form perception. In the background luminance (L_B) range of 0.2 to 0.6, VLs of 20 to 40 appear to be necessary to provide form perception relating to a visual acuity (VA) of 0.8.



Notes: 60-year-old observer at a distance of 6 meters (19.7 ft.)
Reflectances: Curb = 35%, Asphalt = 7%

Figure D4. Required illuminance for visibility of a concrete curb (wheel stop) on an asphalt pavement.



Notes: 60-year-old observer at a distance of 6 meters (19.7 ft.)
Reflectances: Curb = 35%, Floor = 20%

Figure D5. Required illuminance for visibility of a concrete curb (wheel stop) on a concrete pavement.

Annex E— SI (Metric) Conversions

This annex is not a part of the Recommended Practice. It contains useful conversion factors for translating data between the SI (metric) and inch-pound (English) measurement systems.

During the service life of this Recommended Practice, use of the SI system in North America is expected to expand. The following "rounded" factors are appropriate for most conversions involving the inch-pound system. This is because the SI quantities given in most text, tables, and figures typically do not have precision beyond two significant figures. When making conversions, it is important that the product not imply a greater accuracy than existed in the original dimension or quantity. However, certain applications (such as structures) may require that conversions be performed with great precision. Conversion factors for such purposes are given in parentheses.

Length

1 inch = 25 mm (25.4)
1 inch = 2.5 cm (2.54)
1 foot = 0.3 m (0.3048)
1 yard = 0.91 m (0.914)
1 mile = 1.6 km (1.61)

Volume

1 cubic inch = 16 cm^3 (16.39)
1 cubic foot = 0.028 m^3 (0.02831)
1 cubic yard = 0.77 m^3 (0.7645)
1 quart = 0.95 liters (0.9463)
1 gallon = 3.8 liters (3.785)

Speed

1 foot/second = 0.3 m/second (0.3048)
1 mile/hour = 1.6 km/hour (1.609)

Temperature

Convert degrees Fahrenheit (°F) to degrees Celsius (°C): °C = 5/9(°F - 32)

Convert degrees Celsius (°C) to degrees Fahrenheit (°F): °F = 9/5(°C) + 32

Area

1 square inch = 6.5 cm^2 (6.452)
1 square foot = 0.09 m^2 (0.0929)
1 square yard = 0.84 m^2 (0.836)
1 acre = 0.4 hectares (0.405)

Mass

1 ounce = 28 g (28.34)
1 pound = 0.45 kg (0.454)
1 ton = 900 kg (907)

Light

1 footcandle = 11 lux (10.76)
1 footlambert = 3.4 candela/m^2 (3.42)

For conversions between other units refer to the American Society of Testing and Materials (1916 Race Street, Philadelphia, PA 19103) Standard for Metric Practice E 380.

Source: Box, Paul C.; Units of Measure: Overcoming the Metric/English Barrier, *ITE Journal,* Institute of Transportation Engineers, Washington, D.C., 1989.

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TO:	Planning Commission Ordinance Committee
FROM:	Scott Gustin
DATE:	April 4, 2019
RE:	Roof overhang / eave discussion

Below is some information gathered by Leo to aid our continued discussion of roof overhangs and eaves insofar as projections into setbacks may be allowed.

https://www.completedesign.cc/client-resources/dictionary-of-construction-terminology
https://www.homebuildingmanual.com/Glossary.htm

Eave
The horizontal exterior roof overhang.

Overhang
Outward projecting eave-soffit area of a roof; the part of the roof that hangs out or over the outside wall. See also Cornice.

Cornice
Overhang of a pitched roof , usually consisting of a fascia board, a soffit and appropriate trim moldings.

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Burlington Planning Commission

Ordinance Committee Meeting Minutes

Thursday, April 4, 2019 @ 5:15 PM

Planning & Zoning Conference Room, Ground Floor, City Hall

Attendance

- **Committee Members:** Alexander Friend (AF), Leo Sprinzen (LS), Bruce Baker (BB), Austin Hart (AH)
- **Absent:** Andy Montroll (AM)
- **Public:** Steven __
- **Staff:** Scott Gustin, Mary O'Neil (Planning & Zoning)

1. **Recommended amendment to updated parking lot lighting standards per Sec. 5.5.2, *Outdoor Lighting*, (f) *Specific Outdoor Lighting Standards*, 1, *Parking Lot Lighting*.**

   Committee members agreed to change the section to simply refer to the current IESNA standard for parking garage illumination. Refer to full Planning Commission.

2. **Discussion of building eave or overhang standards per Sec. 5.2.5, *Setbacks*, (b) *Exceptions to Yard Setback Requirements*.**

   Committee members discussed the recommended changes and agreed to define "eave" as
   The edge of the roof which overhangs the face of a wall and, normally, project beyond the side of a building; performing the primary function of the roof in throwing water clear of the walls.
   Refer to full Planning Commission.

3. **Discussion of nonconforming lot standars per Sec. 5.3.6, *Nonconforming Lots*, (c) *Changes to a nonconforming lot*.**

   Deferred until a future meeting.

4. **Adjournment**

   The Committee adjourned at 6:00 PM.