CONTENTS

GENERAL INFORMATION

1.1 CONCEPT

In recent years, probably no element of urban street design has changed more than street lighting and its related concepts. In the area of street design, a specific cautionary word is appropriate. The designer should make every attempt to review current literature and research results prior to embarking on any design work for conversion of old lighting systems or installations of new.

1.2 CONDITIONS

1. The design for street lighting is normally completed by the local utility company for Jurisdictional review. The Design Engineer may design lighting for IDOT projects on primary roads that are used for funding determination. The design, where practical, should locate lighting poles outside of the roadway clear zone. Where lighting poles are located within the clear zone, a suitable impact attenuation feature, normally a breakaway design, is used. Breakaway poles should not be used on streets in densely developed areas particularly with sidewalks. In general, the design of street lighting should be in conformance with the following:

   A. Urban Design Standards Manual.

   B. American National Standards Institute (ANSI) and the Illuminating Engineering Society of North America (IES) Standard Practice for Roadway Lighting.

   C. Iowa Department of Transportation/Federal Highway Administration.

   D. Recognized design books for Street Lighting.

   E. Conflict - In case of a conflict between the above design standard, the Jurisdictional Engineer should be contacted for clarification.

2. Construction Standards

   Construction Standards shall be the most recent revision of the Urban Standard Specifications for Public Improvement or Utility Accommodation Policies for construction of utilities within public right-of-ways.

3. Project Submittals

   If project submittals are required by the Jurisdiction, a street lighting plan showing location and type of lighting must be submitted for review. This plan must be approved by the Jurisdiction prior to the construction. In some cases a permit must be issued.

1.3 DEFINITIONS

1. Light Terms and Units - The following are the important terms currently in use to describe the physical properties of light and corresponding units of measurement.

    A. Lumen (lm) - A unit of measure of the quantity of light. One lumen is the amount of light which falls on an area of one square foot every point of which is one foot from the source of one candela (candle). A light source of one candela emits a total of 12.57 lumens.

    B. Foot-candle (fc) - The illumination on a surface one square foot in area on which there is uniformly distributed a light flux of one lumen. One foot-candle equals 10.76 lux.

    C. Lux (lx) - The International System (SI) unit of illumination. It is defined as the amount of light on a surface of one square metre all points of which are one metre from a uniform source of one candela. One lux equals .0929 foot-candle.

    D. Horizontal foot-candle - One lumen distributed uniformly over a horizontal surface 1 square foot in area. Thus, horizontal foot-candle is a measure of the light that strikes the pavement surface.

    E. Vertical foot-candle - One lumen distributed uniformly over a vertical surface 1 sq. ft. in area. Thus, vertical foot-candle is a measure of the light that strikes vertical surfaces such as curbs, piers, or retaining walls.

    F. Luminance (L) - The luminous intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction (measured in foot-lamberts).

    G. Foot-lambert (fl) - The unit of photometric brightness (luminance). It is equal to 1/pi candela per square foot. One foot-lambert equals 3.426 candela per square metre.

    H. Candela (cd) - The unit of luminous intensity. Formerly the term "candle" was used.

    I. Illuminance - The density of the luminous flux incident on a surface. It is the quotient of luminous flux by area of the surface when the latter is uniformly illuminated.

    J. Average Maintained Illuminance - The average level of horizontal illuminance on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factors; expressed in average foot-candles (lux) for the pavement area.

1.3 DEFINITIONS (Continued)

2. Equipment Terms - Current terminology relating to hardware and its mounting include the following:

   A. Lamp - A generic term for a man-made source of light and which is produced either by incandescence or luminescence.

   B. Efficacy, Luminous Efficacy - The quotient of the total luminous flux delivered from a light source divided by the total power input to the light source. It is expressed in lumens per watt.

   C. Ballast - A device used with an electric-discharge lamp to obtain the necessary circuit conditions (voltage, current and wave form) for starting and operating.

   D. Luminaire - A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

   E. Lighting Standard - The pole with or without bracket or mast arm used to support one or more luminaires.

   F. Bracket or Mastarm - An attachment to a lighting standard or other structure used for the support of a luminaire.

   G. Lighting Unit - The assembly of pole or standard with bracket and luminaire.

   H. Mounting Height (MH) - The vertical distance between the roadway surface and the center of the apparent light source of the luminaire (fixture position relative to the edge of the roadway).

   I. Spacing - The distance between successive lighting units measured along the centerline of the roadway.

3. Luminaire and Light Distribution Terms - Terms relating to data on luminaires and on light distributions include the following:

   A. Isofootcandle Diagram - This diagram is available from the manufacturer of the light source and shows the horizontal foot-candles on the pavement surface at various points away from the source. Mounting height must be known to properly use the diagram.

   B. Coefficient of Utilization Curve (CU) - This curve shows that percentage of the total light output which will fall on the roadway. Mounting height (fixture position relative to the edge of roadway)and width of roadway must be known to apply the curve.

1.3 DEFINITIONS (Continued)

C. Lump Lumen Depreciation Curve (LLD) - This curve gives information on the relationship between length of service and light output. All lamps deteriorate with time, and total light output becomes less.

D. Luminaire Dirt Depreciation (LDD) - These curves assist in planning maintenance so that depreciation due to accumulated dirt does not become excessive.

E. Equipment Factor (EF) - Relates the actual field performance of a new luminaire to laboratory performance data. Generally, an EF of 0.90 to 0.95 is used for roadway lighting computations.

F. Maintenance Factor - A depreciation factor which is the product of the Lamp Lumen Depreciation Factor (LLD) and the Luminaire Dirt Depreciation Factor (LDD). This factor is applied to the initial average foot-candles to account for dirt accumulation and lamp depreciation at some predetermined point after installation.

G. Transverse Roadway Lines (TRL) - One set of lines which establish a coordinate system for roadway lighting analysis. This set runs perpendicular to the curbline or edge of pavement.

H. Longitudinal Roadway Lines (LRL) - Another set of lines used in the coordinate system. This set runs parallel to the curbline of the roadway.

I. Isocandela Diagram - A series of lines plotted in appropriate coordinates to show directions in space at which the candlepower is the same.

J. Roadway Width - The curb to curb width for urban section and edge to edge pavement width for rural sections.

1.4 ROADWAY LIGHTING LAMPS - The general types of lamps presently in use for roadway lighting are shown in Table 1.1.1

TABLE 1.1 ROADWAY LIGHTING LAMP CHARACTERISTICS

Type of Lamp	Initial Light Output lumes x 10^3	Approximate Efficacy lumes/Watt	Approximate Lamp Life* hour x 10^3
Incandescent	0.6 - 15	9.7 - 17.4	2 - 6
Clear Mercury	3.7 - 57	37 - 57**	18 - 28
Phosphor-coated Mercury	4.0 - 63	40 - 63**	18 - 28
Metal Halide	34 - 100	85 - 100**	10 - 15
High Pressure Sodium	9.5 - 140	95 - 140**	15 - 28
Low Pressure Sodium	1.8 - 33	100 - 183**	10 - 18

* Number of hours for a group of lamps at which 50% will remain in operation; based on 10 hours of operation per start (except 3 hours per start for fluorescent lamps).

** These values exclude wattage losses due to ballast.

1. The incandescent or filament lamp was for many years the most commonly used. However, its low efficacy and short rated life have made it undesirable for new installations.

2. The mercury lamp replaced the incandescent lamp in popularity. The initial cost is higher and it requires a ballast, but its high efficacy and long life make it considerably more attractive than the incandescent lamp. The blue-white color of the clear lamp is generally acceptable, and the arc tube size provides a light source that is small enough to permit good light control. A phosphor-coated outer bulb, featuring both higher output and more pleasing color rendition, is also available. However, the light source is the size of the outer bulb, presenting a problem in light control.

3. The metal halide lamp is a type of mercury lamp in which the arc tube contains, in addition to mercury, certain metal halides which improve both the efficacy and the color rendition without the use of a phosphor-coated bulb. The light source size is that of the arc tube, permitting good light control in the same fixture used for clear mercury lamps.

4. The high pressure sodium (HPS) lamp is presently replacing the mercury lamp. It is characterized by a golden-white color light output. HPS lamps are normally operated with special ballasts that provide the necessary high voltage to start the lamp. However, lamps are available that can be operated from certain types of mercury lamp ballasts, but with poorer lumen maintenance and shorter life. There are also HPS lamps available that provide improved color rendition or almost instant restart after a power interruption; either feature results in a reduction in rated life.

1.4 ROADWAY LIGHTING LAMPS (Continued)

5. The low pressure sodium (LPS) lamp is characterized by a monochromatic bright yellow color light output. These lamps require special ballasts and increase materially in size as the wattage increases; the 185-watt lamp is 44 in. long. This large size makes it difficult to obtain good light control in a reasonably sized fixture. For a long time the poor color rendition of the LPS lamp made it unpopular for use in other than industrial or security applications. However, the current trend toward energy conservation coupled with the high efficacy of the lamp has resulted in an increasing acceptance of LPS lamps for lighting both commercial and residential areas. Presently available LPS lamps also have outstanding lumen maintenance, having no drop in light output over life, however, the wattage (energy used) increases as time passes.

All roadway lighting lamps, with the exception of the series-circuit incandescent lamp and certain LPS lamps, suffer the common problem of lumen depreciation - the reduction in light output over the lamp's life. The lumen depreciation varies with the type and operating condition of the lamp (See Section 2).

In addition, the lumen output of a mercury or metal halide lamp varies with its operating position, the normal horizontal position resulting in a lower value than the vertical operating position. Both of these reducing factors must be considered when calculating the average maintained illumination.

ROADWAY LIGHTING DESIGN

2.1 ROADWAY LIGHTING DESIGN

1. General

The basic goal of roadway lighting is to provide patterns and level of horizontal pavement luminance and of horizontal and vertical illuminance of objects. A driver's eye discerns an object on or near the roadway due to contrast between the brightness of the object and the brightness of the background or pavement, or by means of surface detail, glint, or shadows.

Lighting design is concerned with the selection and location of lighting equipment so as to provide improved visibility and increased safety while making the most efficient use of energy within minimum expenditure. There are two basic concepts of lighting design, i.e., the illumination concept and the luminance concept.

The illumination concept, which is almost universally used in the United States, is based on the premise that, by providing a given level of illumination and uniformity of distribution, satisfactory visibility can be achieved. The luminance concept, which is fairly popular in part of Europe, and is promoted by some people in the United State, is based on the premise that visibility is related to the luminance of the pavement and the objects on the pavement. Estimation of the reflectivity of varying pavement surfaces and objects within the drivers vision are difficult. Although other design concepts are under review, such as Small Target Visibility (see IES RP-8-90) the illuminance method design remains predominant in the United States. Therefore, for the purpose of this design manual, the illuminance method will be the only design concept discussed.

2. Design Process

By definition, lighting design according to the illumination method relies on the amount of light flux reaching the pavement and the uniformity of the light on the pavement surface. The steps in the design process are as follows:

A. Determination of the foot-candle value by assessing the facility to be lighted.

B. Selecting the type of light source (Type I-V).

C. Selecting light source size and mounting height.

D. Selecting luminaire type.

E. Determining luminaire spacing and location.

F. Checking for design adequacy.

2.1 ROADWAY LIGHTING DESIGN (Continued)

These steps are arranged in the order in which they are usually encountered in the design process. However, as mentioned in Section 1.2, most roadway lighting designs are completed by the local utility companies for jurisdictional review. Due to this fact, the following section will focus on checking for design adequacy.

3. Design Criteria

A. Calculation - The calculation of the average horizontal illuminance produced by a lighting system is essentially an iterative design process. The most frequent calculation used to determine average illuminance levels is shown below:

<u>Formula Computation</u>

$$\text{Average Maintained Level of Illumination} = \frac{LL * CU * MF}{S * W} \qquad \text{Equation 2.1}$$

WHERE:

LL = Initial Lamp Lumens
CU = Coefficient of Utilization
MF = Maintenance Factor (LLD * LDD)
LLD = Lamp Lumen Depreciation
LDD = Luminaire Dirt Depreciation
S = Luminaire Spacing
W = Roadway width

This formula can be used in both the English, metric or SI system of measures.

B. Determining the level of illuminance (foot-candle value).

(1) Level of Illuminance - As stated above, the roadway illuminance level is an expression of the quantity of roadway lighting. Most local jurisdictions have set policies which recommend average illumination levels for various roadway classifications and pavement type. In the absence of local values, Table 2.1 gives recommended levels of illuminance for various classifications of roadways and areas. The units for illuminance are foot-candles in the English system and lux in the metric or SI system.

(2) Uniformity - Light uniformity along the roadway is the second element of illuminance design. Uniformity is measured in terms of a ratio of the average to minimum illuminance along the roadway. In the absence of local Jurisdictional values, Table 2.1 gives recommended values.

TABLE 2.1 RECOMMENDED ILLUMINANCE VALUES AND UNIFORMITY RATIOS
(REFERENCE SOURCE NO. 3)

Road Classification	(1) Area Classification	(2) Average Illuminance Foot-candles	(2) Average Illuminance Lux	Uniformity Ratio (Aver./Min.)
Arterial (Minor & Major)	Commercial	1.1	12	3 to 1
	Intermediate	0.8	9	
	Residential	0.6	6	
Collector (Minor & Major)	Commercial	0.7	8	4 to 1
	Intermediate	0.6	6	
	Residential	0.4	4	
Local	Commercial	0.6	6	6 to 1
	Intermediate	0.5	5	
	Residential	0.3	3	
Alleys	Commercial	0.4	4	6 to 1
	Intermediate	0.3	3	
	Residential	0.2	2	
Sidewalks (Roadside)	Commercial	0.2	3	3 to 1
	Intermediate	0.6	6	4 to 1
	Residential	0.2	2	6 to 1
Pedestrian Ways (3) & Bicycle Lane		1.4	15	3 to 1

(1) Area Classification
- (a) Commercial - That portion of a municipality in a business development where ordinarily there are large numbers of pedestrians and a heavy demand for parking space during periods of peak traffic or a sustained high pedestrian volume and a continuously heavy demand for off-street parking space during business hours. This definition applies to densely developed business areas outside of, as well as those that are within, the central part of a municipality.
- (b) Intermediate - That portion of a municipality which is outside of a downtown area but generally within the zone of influence of a business or industrial development, often characterized by a moderately heavy nighttime pedestrian traffic and a somewhat lower parking turnover than is found in a commercial area. This definition includes densely developed apartment areas, hospitals, public libraries, and neighborhood recreational centers.
- (c) Residential - A residential development, or a mixture of residential and commercial establishments, characterized by few pedestrians and a low parking demand or turnover at night. This definition includes areas with single family homes, townhouses, and/or small apartments. Regional parks, cemeteries, and vacant lands are also included.

(2) For PCC Roadways. For ACC roads multiply values by 1.43.

(3) This assumes a separate facility. Facilities adjacent to a vehicular roadway should use the illuminance levels for that roadway.

2.1 ROADWAY LIGHTING DESIGN (Continued)

C. Classification of Luminaire Light Distributions

(1) Luminaires - A luminaire is composed of a light source, a reflector, and usually a glass or plastic lens or refractor. It is the function of the reflector and refractor to gather the light from the source, direct it toward the roadway, and shape it into a desired pattern on the roadway. Proper distribution of the light flux from the luminaire is one of the essential factors in good roadway lighting. All luminaire light distributions are classified according to their vertical and lateral distribution patterns and the light control in the upper portion of the beam. Glare shields may be added to reduce objectionable light emissions toward adjacent buildings or areas.

(2) Performance - The ultimate performance of a lighting system is dependent upon the control of luminous flux from the light source. Manufacturers provide to the designer photometric data for various lamp-luminaire combinations that can be used in determining the amount and direction of luminous flux. For standardization purposes, IES has classified light distributions on the basis of the following:

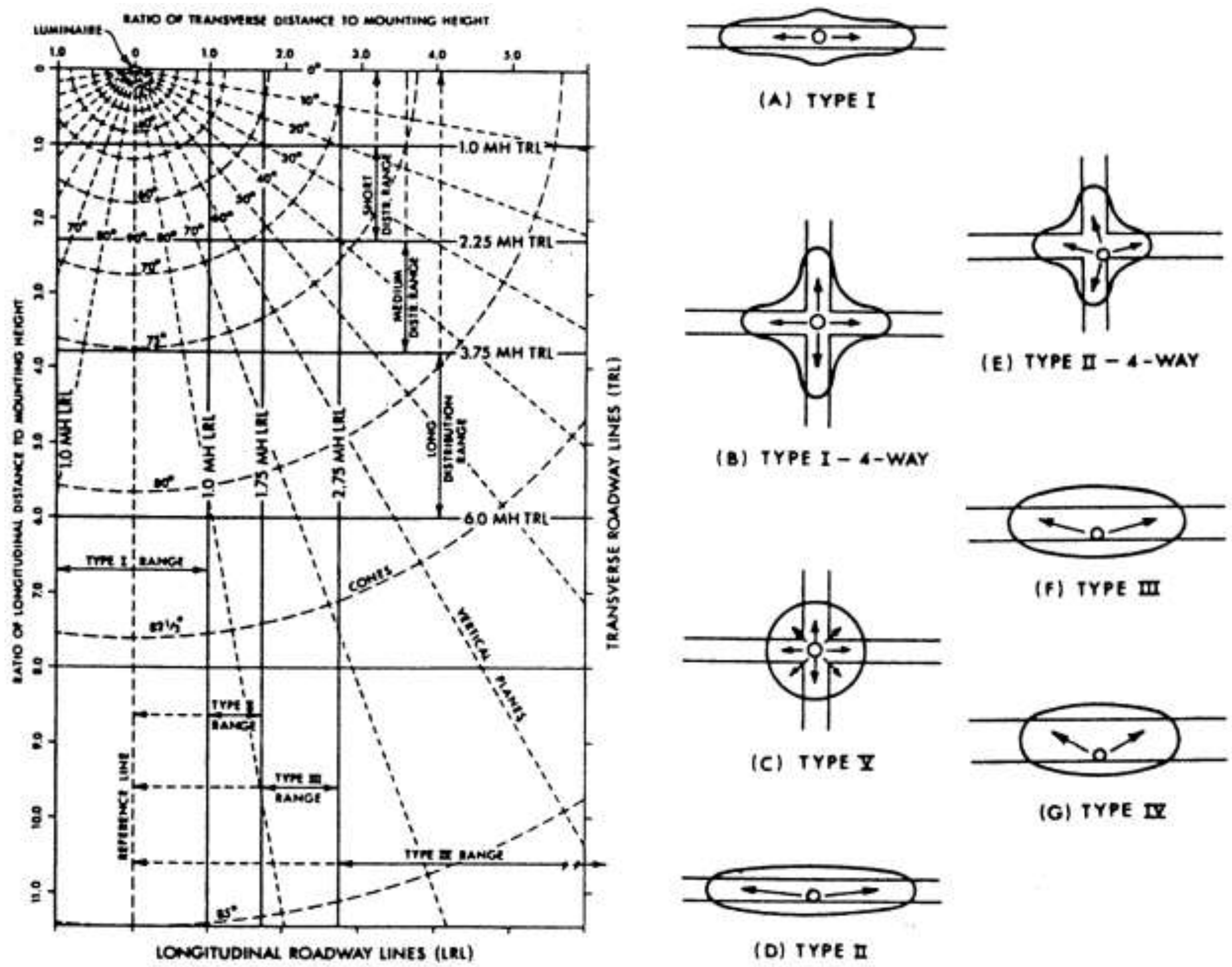
(a) Vertical light distribution

(b) Lateral light distribution

(c) Control of light distribution above maximum candlepower

The classification of light distributions is made on a plan view of a roadway which has superimposed on it a series of lines parallel with the roadway and another series transverse to the roadway. These lines, which are spaced in multiples and fractions of the mounting height, are referred to as Longitudinal Roadway Lines (LRL), and Transverse Roadway Lines (TRL), as shown in Figure 2.1.

FIGURE 2.1 PLAN REVIEW OF ROADWAY COVERAGE FOR DIFFERENT TYPES OF LUMINAIRES
(REFERENCE SOURCE NO. 2)



2.1 ROADWAY LIGHTING DESIGN (Continued)

(a) Vertical Light Distribution

Vertical light distributions are divided into three groups, short, medium, and long, as illustrated in Figure 2.1. Classification is on the basis of the distance from the luminaire to where the beam of maximum candlepower strikes the roadway surface. The classifications are:

* Short Distribution - The maximum candlepower beam strikes the roadway surface between 1.0 and 2.25 mounting heights from the luminaire.

* Medium Distribution - The maximum candlepower beam strikes the roadway at some point between 2.25 and 3.75 mounting heights from the luminaire.

* Long Distribution - The maximum candlepower beam strikes the roadway at a point between 3.75 and 6.0 mounting heights from the luminaire.

On the basis of the vertical light distribution, theoretical maximum spacing are such that the maximum candlepower beams from adjacent luminaires are joined on the roadway surface. With this assumption, the maximum luminaire spacings are:

* Short Distribution - 4.5 mounting heights

* Medium Distribution - 7.5 mounting heights

* Long distribution - 12.0 mounting heights

From a practical standpoint, the medium distribution is predominantly used in practice, and the spacing of luminaires normally does not exceed five to six mounting heights. Short distributions are not used extensively for reasons of economy, because extremely short spacing is required. At the other extreme, the long distribution is not used to any great extent because the high beam angle of maximum candlepower often produces excessive glare.

2.1 ROADWAY LIGHTING DESIGN (Continued)

(b) Lateral Light Distributions

The Illuminating Engineering Society established a series of lateral distribution patterns designated as Types I, II, III, IV, and V.

Type I is a two-way lateral distribution having a preferred lateral width of 15 degrees in the cone of maximum candlepower. The two principal light concentrations are in opposite directions along a roadway. This type is generally applicable to a luminaire location near the center of a roadway where the mounting height is approximately equal to the roadway width.

Four-way Type I is a distribution having four principal concentrations at lateral angles of approximately 90 degrees to each other. This distribution is generally applicable to luminaires located over or near the center of 90 degree intersections.

Type II light distributions have a preferred lateral width of 25 degrees. They are generally applicable to luminaires located at or near the side of relatively narrow roadways, where the width of the roadway does not exceed 1.75 times the designed mounting height.

Four-way Type II light distributions, each with a width of 25 degrees. This distribution is generally applicable to luminaires located near one corner of right angle intersection.

Type III light distributions have a preferred lateral width of 40 degrees. This distribution is intended for luminaires mounted at or near the side of medium width roadways, where the width of the roadway does not exceed 2.75 times the mounting height.

Type IV light distributions have a preferred lateral width of 60 degrees. This distribution is intended for side-of-road mounting and is generally used on wide roadways where the roadway width does not exceed 3.7 times the mounting height.

The Type V light distributions have a circular symmetry of candlepower that is essentially the same at all lateral angles. They are intended for luminaire mounting at or near center of roadways, center islands of parkway, and intersections.

2.1 ROADWAY LIGHTING DESIGN (Continued)

For specific classification, luminaires are described on the basis of where the half maximum candlepower isocandela trace falls. This measure, "the half-maximum candlepower trace," describes the direction of the greatest punch of the luminaire better than just simply describing the direction of the beam of maximum candlepower. The ranges of Types I, II, III, and IV are presented in Figure 2.1. As a guide for luminaire lateral light type and placement see Table 2.2.

TABLE 2.2 GUIDE FOR LUMINAIRE LATERAL LIGHT TYPE AND PLACEMENT

SIDE OF THE ROADWAY MOUNTING			CENTER OF THE ROADWAY MOUNTING		
One Side or Staggered	Staggered or Opposite	Local Street Intersection	Single Roadway	Twin Roadways (Median Mounting)	Local Street Intersections
Width up to 1.5 MH	Width beyond 1.5 MH	Width up to 1.5 MH	Width up to 2.0 MH	Width up to 1.5 MH (each pavement)	Width up to 2.0 MH
Types II, III, IV	Types III & IV	Type II (4-way)	Type I	Types II & III	Types I (4-way) & V

NOTE: In all cases, suggested maximum longitudinal spacings and associated vertical distribution classifications are: Short distribution = 4.5 MH, Medium distribution = 7.5 MH, and Long distribution - 12.0 MH.

(c) Control of Distribution Above Maximum Candlepower

Disability and discomfort glare are largely a result of light emission into the driver's eye. For design purposes, it is necessary that luminaires be classified according to their relative glare effects. Thus, luminaires are classified as cutoff, semi-cutoff, and non-cutoff. IES descriptions of these classification categories are as follows:

* Cutoff. A luminaire light distribution is classified as cutoff when the candlepower per 1000 bare lamp lumens does not exceed 25 at an angle of 90 degrees above nadir (a vertical axis through the light source); and 100 at an angle of 80 degrees above nadir.

2.1 ROADWAY LIGHTING DESIGN (Continued)

* Semi-cutoff. A luminaire light distribution is classified as semi-cutoff when the candlepower per 1000 bare lamp lumens does not exceed 50 at an angle of 90 degrees above nadir and 200 at a vertical angle of 80 degrees above nadir.

* Non-cutoff. The classification when there is no candlepower limitation in the zone above maximum candlepower.

In lighting practice, the semi-cutoff control is normally used. Adequate glare control may be accomplished without unduly restricting the spacing of luminaire supports.

D. Selection of Mounting Height

The distance the lamp is mounted above the roadway will affect the illumination intensity, uniformity of brightness, area covered, and relative glare of the unit. Higher mounted units will provide greater coverage, more uniformity, and reduction of glare, but a lower illumination level. It is necessary to weigh the effects of larger lamps against a greater number of smaller units at lower mounting heights with maximum glare potential. The height of luminaires above the roadway surface varies from 15 feet to more than 100 feet. Conventional roadway lighting utilized mounting height of 25 to 50 feet. The lower mounting heights require the use of cutoff or semi-cutoff luminaire distribution to minimize glare.

Figure 2.2 shows minimum mounting heights for various max. candlepower levels and vertical light distributions. Figure 2.3 shows suggested minimum mounting height for various light source sizes.

FIGURE 2.2 MINIMUM LUMINAIRE MOUNTING HEIGHTS FOR VARIOUS MAXIMUM CANDLEPOWER LEVELS AND VERTICAL LIGHT DISTRIBUTIONS
(REFERENCE SOURCE NO. 2)

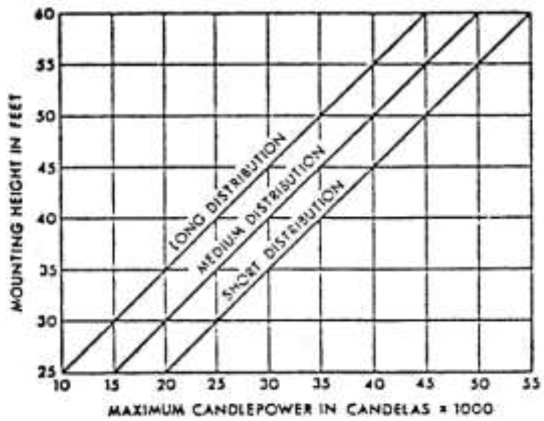
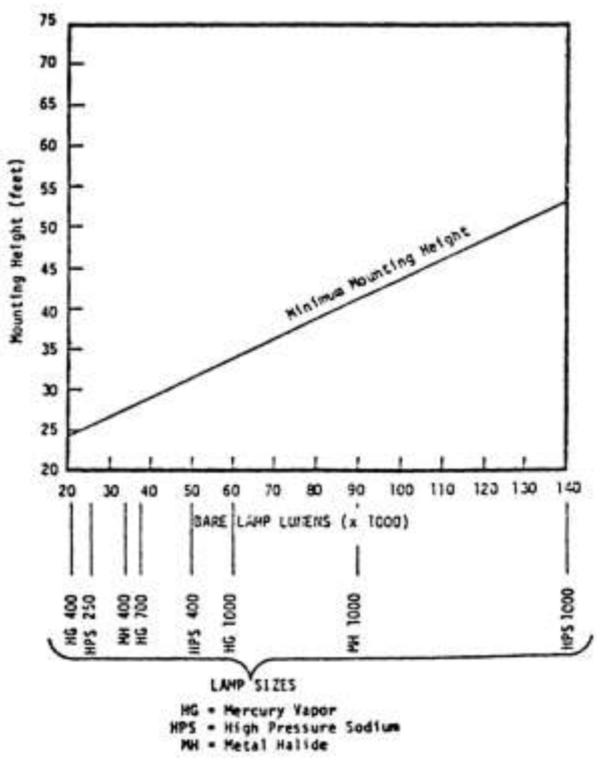


FIGURE 2.3 SUGGESTED MINIMUM MOUNTING HEIGHTS FOR VARIOUS LIGHT SOURCE SIZES
(REFERENCE SOURCE NO. 2)



2.1 ROADWAY LIGHTING DESIGN (Continued)

E. Light System Depreciation

The primary factors of lighting system depreciation are lamp lumen depreciation (LLD) and luminaire dirt depreciation (LDD). A typical range for LLD is from 0.9 to 0.78. A typical range for LDD is 0.95 to 0.78. The product of these two factors is referred to as the Maintenance Factor (MF). Figures 2.4 and 2.5 show lamp lumen and dirt depreciation curves.

FIGURE 2.4 TYPICAL LAMP LUMEN MAINTENANCE CURVE
(REFERENCE SOURCE NO. 2)

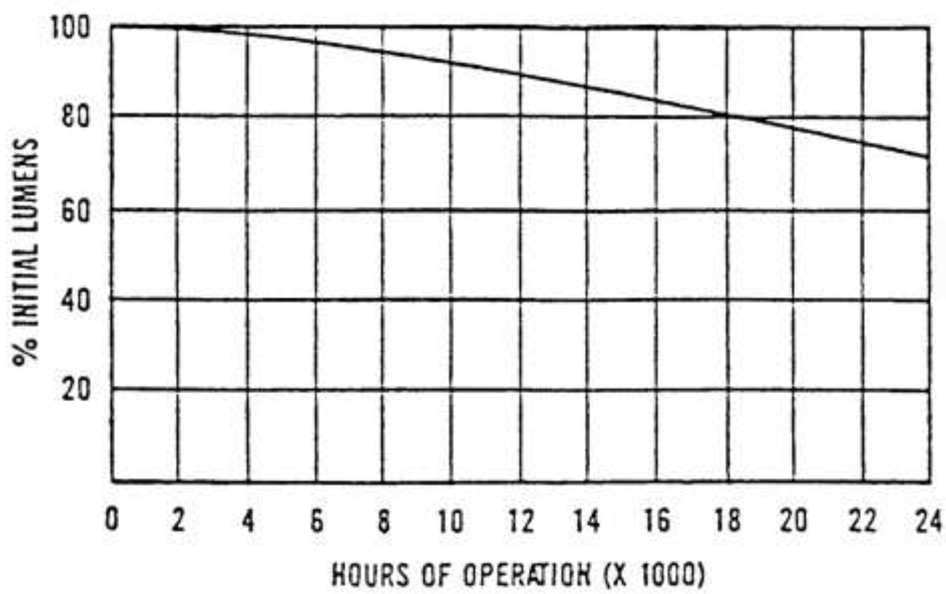
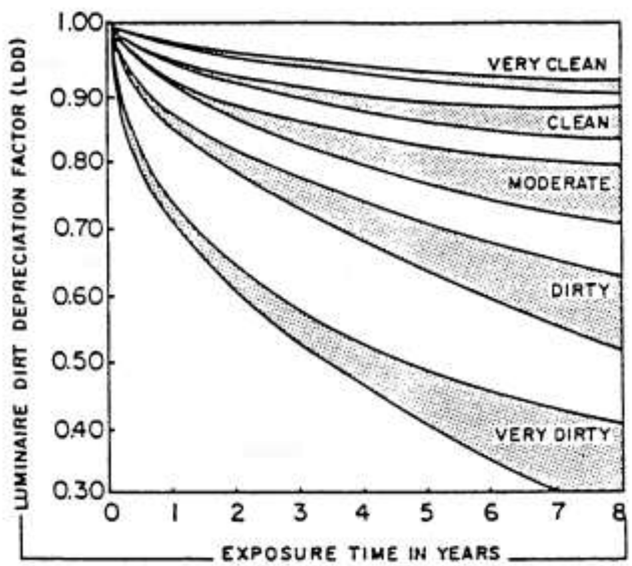


FIGURE 2.5 IES LUMINAIRE DIRT DEPRECIATION (LDD) CURVE
(REFERENCE SOURCE NO. 2)



SELECT THE APPROPRIATE CURVE IN ACCORDANCE WITH THE TYPE OF AMBIENT AS DESCRIBED BY THE FOLLOWING EXAMPLES:

VERY CLEAN - No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. 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. Moderate to heavy traffic. The ambient particulate level is no more than 300 micrograms per cubic meter.

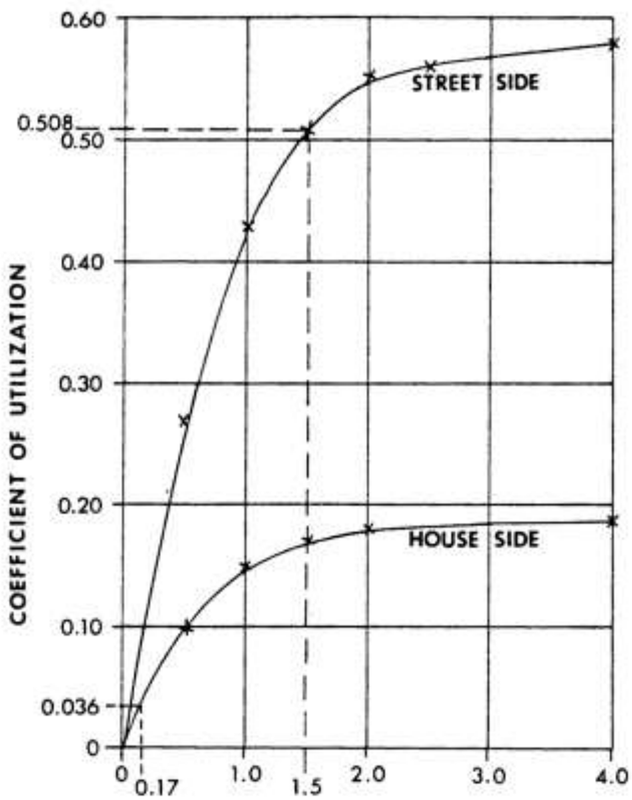
MODERATE - Moderate smoke or dust generating activities nearby. The ambient particulate level is no more than 600 micrograms per cubic meter.

DIRTY - Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.

VERY DIRTY - As above but the luminaires are commonly enveloped by smoke or dust plumes.

F. Coefficient of Utilization (CU) - Measured as the percent of total lamp lumens which are actually delivered to the roadway surface. Utilization differs with each luminaire type, and depends upon mounting height, road width, and overhang. See Figure 2.6.

FIGURE 2.6 EXAMPLE OF COEFFICIENT OF UTILIZATION CURVES FOR LUMINAIRE PROVIDING TYPE III - M LIGHT DISTRIBUTION.
TYPE I, II, III, IV, & V TO BE OBTAINED FROM MANUFACTURER'S PERFORMANCE DATA



G. Luminaire Spacing - Luminaire spacing is often determined by location of utility poles, driveways, property lines, block lengths, or terrain features. It is generally more economical to use lamps with high lumen output, at more reasonable spacings and mounting heights, than to use lamps with lower lumen output at more frequent intervals with lower mounting heights.

In designing a lighting system, maximizing spacing of luminaires consistent with good illumination design, should be emphasized. From the standpoint of economy and safety, the minimum number of luminaires and luminaire supports should be used while satisfying the illumination quantity and quality criteria. The rearrangement of Equation 2.1 is to be used to solve for luminaire spacing.

2.1 ROADWAY LIGHTING DESIGN (Continued)

4. Final Review - Having determined roadway illuminance and uniformity ratios, the design can be compared to the local jurisdictions light level policy or other criteria such as those in Table 2.1. For a specific example refer to the "Roadway Lighting Handbook" of the U.S. Department of Transportation, 1978 (Reference Source No. 2)

2.2 SPECIAL SITUATIONS

1. Road Complexities - There are many roadway areas where the problem of seeing is more complex than on straight and level sections. These areas have three common factors: (i) the vehicle operator is faced with additional visual tasks upon approaching and traversing these areas; (ii) because of vehicle location, roadway geometry, or other reasons, it may be difficult to provide silhouette seeing; and (iii) vehicle headlight illumination may be inadequate since it follows rather than leads the progress of a maneuvering vehicle. These complex areas consist of one or a combination of several of the following basic situations.

    A. Grade Intersections - It is recommended that the illuminance level for an intersection at grade be the sum of the levels for the intersecting roadways. Luminaires should be located so that both vehicles and pedestrians in and near the intersection area are illuminated.

    B. Curves and Grades - Large radius curves and gentle sloping grades may be treated in the same manner as straight, level sections. Sharper curves and steeper grades require closer luminaire spacing in order to provide uniform pavement brightness. Curbs and guardrails should be illuminated.

    C. Underpasses - A short underpass may be illuminated satisfactorily by standard luminaires if those on either side of the underpass are positioned so that their pavement illuminance overlaps underneath the structure. Longer underpasses require special pole or soffit-mounted lighting fixtures for nighttime and possible daytime use.

    D. Converging Traffic Lanes - Good direct lighting should be provided on the vehicles entering the main traffic lanes.

    E. Diverging Traffic Lanes - Curbs, abutments, guardrails, and vehicles in the divergence area should be illuminated. Lighting should also be provided in the deceleration zone.

2.2 SPECIAL SITUATIONS (Continued)

2. Overhead Traffic Signs - Illumination of overhead signs is essential because they will receive little light from vehicle headlights and because other highway lighting, if present in the vicinity, is not designed to illuminate the vertical surface of such signs. California practice is to provide an average illuminance of 30 fc (3 lux) on the surface of the sign, with the sign message having a reflectance of 70% when clean, and the background having a reflectance of less than 10%. Hence, the message appears with a brightness of about 10 times that of the background when clean, but this contrast is reduced as dust collects on the sign. Overhead signs in rural locations, where there is little or no competition from other lighted objects, can be illuminated to a level of 10-15 (1-1.5 lux). Fluorescent and phosphor-coated mercury lamps are used.

3. Railroad Crossings - Grade crossings of streets and railroads should be illuminated to indicate the presence of a train or railroad car within the crossing at night. Luminaires should be placed on both sides so that the train can be seen both by silhouette and by surface detail.

4. Alleys - Street lights are usually not installed in alleys unless special circumstances exist. These circumstances are not standard and will vary between governing authorities.

5. Parking Lots - Parking lots which are used after dark are then lighted to enable drivers to observe pavement markings and see pedestrians, and to deter thefts. Average illumination levels of 0.5-1.0 fc (0.05-0.10 lux) are recommended, but higher levels are sometimes used for public relations values. The illuminance level should be greater than that of surrounding streets.

6. Low Level Lighting - Low level lighting, which is sometimes referred to as streetscape lighting or ornament lighting, is becoming increasingly popular in downtown historical districts, plan unit developments, parking lots, and separate pedestrian pathways. This type of lighting ranges from lighted bollards (posts) to antique reproduction lighting.

   Low level lighting should not become a source of unwanted light and glare. Therefore, the distribution must provide precise control of light with good uniformity and no objectional glare. As an example, parking lot lighting should contain a concealed light source with a cut-off provided to prevent glare as spill over onto adjacent buildings. The Project Engineer or Architect should consult with the Jurisdiction before proceeding with low level lighting. The interchangeability of luminaires and various available posts allows the designer to tailor the amount of light required to meet civic or pedestrian needs. The result is an aesthetic pleasing light sources that conveys a flavor of a specific time period or locale.

DESIGN REFERENCE MATERIAL

3.1 DESIGN REFERENCE MATERIAL

1. "Design of Urban Streets", 1984, ISU.

2. "Roadway Lighting Handbook," Federal Highway Administration, 1978.

3. "Informational Guide for Roadway Lighting," American Association of State Highway and Transportation Officials, 1984

4. "American National Standard Practice for Roadway Lighting", Illuminating Engineering Society of North America, 1977.

5. "Street Lighting Manual", Edison Electric Institute, 1988.

6. "Outdoor Lighting Design Manual", McGraw Edison, 1964.

7. Illuminating Engineering Society Guidelines.

8. American National Standards Institute Guidelines

9. Iowa Department of Transportation Guidelines