General Information

A. General

Darkness brings increased hazards to users of urban streets because it reduces the distance they can see. The nighttime fatal accident rate on unlighted roadways is about three times the daytime rate, based on proportional vehicular miles of travel. This ratio can be reduced when proper fixed street lighting systems are installed.

Good visibility under night conditions is one of the fundamental requirements enabling motorists to move on roadways in a safe and coordinated manner during the nighttime hours. Properly designed and maintained street lighting will produce quick, accurate, and comfortable visibility at night, which will safeguard, facilitate, and encourage both vehicular and pedestrian traffic. Other objectives of street lighting include:

- Improvement of traffic flow at night by providing light, beyond that provided by vehicle lights, which aids drivers in orienting themselves, delineating roadway geometries and obstructions, and determining relationship to other motorists.
- Aid in police protection and enhanced sense of personal security.
- Promotion of business commerce and the use of public facilities during the nighttime hours.

Street lighting design is concerned with the selection and location of lighting equipment to provide improved visibility and increased safety while making the most efficient use of energy with minimum expenditure. This chapter focuses on the street lighting design approach of urban local, collector, and arterial streets. This chapter does not include guidelines for rural or freeway roadway types.

This chapter makes use of state-of-the-art lighting science and internationally and nationally recommended street lighting design practices to facilitate the quality and energy efficient design of street lighting on Iowa's urban roadways. This design guidance relies on roadway lighting guidelines issued by the Illuminating Engineering Society of North America (IESNA). IESNA is considered the nation's technical authority on illumination. The independent, member-based professional organization synthesizes research, investigations, and discussions to develop lighting design recommendations intended to promote good lighting practice. Many of the items in this chapter are references from ANSI / IESNA RP-8-00, *American National Standard Practice for Roadway Lighting,* (RP-8) publication, reaffirmed in 2005.

B. Industry Outlook

At this time, high pressure sodium (HPS) is the predominant type of light source used for street lighting. It is still viewed in many states, including Iowa, as the industry standard for energy efficient street lighting and is used as the benchmark in qualifying other types of lighting sources as energy efficient. However, the practical production of light from energy such as electricity is currently undergoing significant technological change.

On the forefront of the technological development is the advent and use of the light emitting diode (LED) for street lighting purposes. LEDs themselves are currently not as efficient at turning electrical power into light compared to HPS lamps. However, because of the difference in construction of and the control of light from an LED luminaire, LED luminaires used in street lighting

practical applications are realizing energy efficiencies greater than HPS. Also, LEDs are expected to last longer than current lighting sources. Although the approach, appropriate use, and performance standards of LEDs are still being developed by professionals in the lighting industry, it is widely agreed upon that the technology is here to stay. This chapter will touch upon the design considerations, advantages, and potential disadvantages of LED lighting.

As will be discussed in Section 11C-1, there are two basic concepts of lighting design, the illumination concept and the luminance concept. The current edition of RP-8 discusses and supports both design concepts. There are currently discussions by lighting professionals whether the next edition of RP-8 will transition to and favor the luminance concept. However, at this time the illumination design method remains predominant in the United States. For the purpose of this chapter, the illumination method will be the only design concept discussed.

C. Iowa Code

Although there are many options for the type of luminaire to be used for street lighting projects, Iowa Code states all new or replaced luminaires shall be replaced with high pressure sodium lighting or lighting with equivalent or better energy efficiency. Following are excerpts from the current Iowa Code that pertain to publicly owned exterior lighting. Many of the lighting terms used in the following cited Iowa Code sections will be defined in the definition list and detailed further in this chapter.

1. **Facilities Owned By Cities:** Iowa Code Section 364.23 below pertains to facilities owned by cities. It is understood the reference to "era or period lighting" is in relation to architectural or ornamental lighting of historical significance, often found in downtown locations.

   "**364.23 Energy-efficient Lighting Required:** All city-owned exterior flood lighting, including but not limited to street and security lighting but not including era or period lighting which has a minimum efficiency rating of fifty-eight lumens per watt and not including stadium or ball park lighting, shall be replaced, when worn-out, exclusively with high pressure sodium lighting or lighting with equivalent or better energy efficiency as approved in rules adopted by the utilities board within the utilities division of the department of commerce. In lieu of the requirements established for replacement lighting under this section, stadium or ball park lighting shall be replaced, when worn-out, with the most energy-efficient lighting available at the time of replacement which may include metal halide, high-pressure sodium, or other light sources which may be developed."

2. **Facilities Owned By Public Utilities:** Iowa Code Section 476.62 below pertains to facilities owned by public utilities.

   "**476.62 Energy-efficient Lighting Required:** All public utility-owned exterior flood lighting, including but not limited to street and security lighting, shall be replaced when worn-out exclusively with high pressure sodium lighting or lighting with equivalent or better energy efficiency as approved in rules adopted by the board."

3. **Utilities Board Rules:** Iowa Administrative Code (IAC) 199-35.15 (476) contains the rules adopted by the Utilities Board within the Utilities Division of the Department of Commerce that are referenced in the two Iowa Code sections stated above and pertain to exterior lighting energy efficiency. It is understood one of the five conditions of IAC 199-35.14(476) must be met in order to use a light source other than high-pressure sodium for exterior lighting applications.

"**199-35.15(476) - Exterior Flood Lighting**

35.15(1) - Newly Installed Lighting: All newly installed public utility-owned exterior flood lighting shall be high-pressure sodium lighting or lighting with equivalent or better energy efficiency.

35.15(2) - In-service Lighting Replacement Schedule: In-service lighting shall be replaced with high-pressure sodium lighting or lighting with equivalent or better energy efficiency when worn out due to ballast or fixture failure for any other reason, such as vandalism or storm damage. A utility shall file with the board as part of its annual report required in 199-Chapter 23 a report stating progress to date in converting to high-pressure sodium lighting or lighting with equivalent or higher energy efficiency.

35.15(3) - Efficiency Standards: Lighting other than high-pressure sodium has equivalent or better energy efficiency if one or more of the following can be established:

a. For lamps less than 120 watts, the lumens-per-watt lamp rating is greater than 77.1, or
b. For lamps between 120 and 500 watts, the lumens-per-watt lamp rating is greater than 96, or
c. For lamps greater than 500 watts, the lumens-per-watt lamp rating is greater than 126, or
d. The new lighting uses no more energy per installation than comparable, suitably sized high-pressure sodium lighting, or
e. The new lighting consists of solid-state lighting (SSL) luminaries that have an efficacy rating equal to or greater than 66 lumens per watt according to a Department of Energy (DOE) Lighting Facts label, testing under the DOE Commercially Available LED Product Evaluation and Reporting Program (CALiPER), or any other test that follows Illuminating Engineering Society of North America LM-79-08 test procedures."

Prior to the fall of 2010, the language in IAC 199-35.15(3) was different and used strictly the bare lamp efficacy rating of HPS lamps as the basis of comparison to qualify other lighting source types as energy efficient. Because of the way LED lighting is constructed and produces light, the IAC excluded the use of LED lighting even though it could be demonstrated that in many street lighting applications, current LED lighting was more energy efficient. Therefore, the IAC was revised in the fall of 2010 to the language shown above. The IAC still sets HPS lighting as the energy efficient standard; however, other lighting source types can be used if they pass one of the five stated conditions. The first three conditions (a, b, and c) are a modification from the IAC prior to 2010 and generally apply to high intensity discharge (HID) or other single-lamp type luminaires.

Condition 'd' is intended to apply to lighting replacement or retrofit applications. Again, the IAC uses HPS as the comparison standard. Bear in mind the condition says "suitably sized" HPS lighting. For a defined project area, this requires the designer to compare the energy consumption of the proposed lighting system type (other than HPS) to the energy consumption of HPS lighting if it is properly applied meeting the same illumination criteria. The designer should be forewarned to not necessarily use the existing lighting system, particularly if it is HPS, as the basis of energy consumption for the replacement project because the project area may be over lit by the existing lighting. It is generally understood that the illumination criteria published in RP-8 for roadway lighting is to be used in the comparison process.

Condition 'e' is intended to apply strictly to LED lighting when installed in new lighting project applications. This requires the luminaires to have a luminaire efficacy rating of at least 66 lumens per watt as established by a proper industry testing procedure.

D. Definitions

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 footcandles for the pavement area.

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

Bracket or Mast Arm: An attachment to a lighting standard or other structure used for the support of a luminaire.

Candela (cd): The unit of luminous intensity. Formerly the term "candle" was used. Refer to Figure 11A-1.01.

Coefficient of Utilization Curve (CU): This curve shows the percentage of the total light output that will fall on the roadway. Mounting height and horizontal dimensions transverse to the roadway relative to the luminaire position must be known to apply the curve. Refer to Figure 11C-1.02.

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 (l/w).

Footcandle (fc): One footcandle is the illumination incident on a surface one square foot in area on which there is uniformly distributed a luminous flux of one lumen. Footcandle is the English unit for illumination. The metric or SI unit is lux. One footcandle equals 10.76 lux. Refer to Figure 11A-1.01.

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 candelas per square meter.

High Intensity Discharge (HID): A term applied to a category of electric lamps that produce light by means of an electric arc sustained between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube filled with gas and metal salts. The gas facilitates the arc's initial strike. Once the arc is started, it heats and evaporates the metal salts forming a plasma, which greatly increases the intensity of light produced by the arc and reduces its power consumption. High intensity discharge lamps are a type of arc lamp.

Horizontal Footcandle: One lumen distributed uniformly over a horizontal surface one square foot in area. Thus, horizontal footcandle is a measure of illumination from light that strikes a horizontal surface such as the pavement.

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 (measured in footcandles). Refer to Figure 11A-1.01

Initial Lamp Lumens: Manufacturer’s published initial bare lamp lumen output of a new lamp.

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

Isofootcandle Diagram: This diagram is available from the manufacturer of the light source and shows the horizontal footcandles on the pavement surface at various points away from the source. Mounting height must be known to properly use the diagram. Refer to Figure 11C-1.02.

Lamp 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. Refer to Figure 11B-1.01.

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

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

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

Longitudinal Roadway Lines (LRL): A set of horizontal lines running parallel to the curb line or edge of pavement that establish a coordinate system for roadway lighting analysis. Refer to Figure 11B-1.03.

Lumen (lm): A unit of measure of luminous flux or flow of light from a light source. One lumen is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela. Refer to Figure 11A-1.01.

Luminaire: A complete lighting assembly 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.

Luminaire Dirt Depreciation Curves (LDD): These curves give information on the relationship of light output depreciation due to accumulated dirt on the luminaire and lamp optical surfaces. An estimate of the dirt level present in the environment is needed to apply the curves. Refer to Figure 11B-1.02.

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).

Lux (lx): The International System (SI) unit of illumination. One lux is the illumination incident on a surface one square meter in area on which there is uniformly distributed a luminous flux of one lumen. One lux equals .0929 footcandle.

Maintenance Factor (MF): A depreciation factor that 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 footcandles to account for dirt accumulation and lamp depreciation at some predetermined point after installation.

Mean Lamp Lumens: Average quantity of light output (lumens) over the life of the lamp. High pressure sodium, LED, and incandescent lamps are measures for mean lumens at 50% of lamp life. Fluorescent and metal halide lamps are measured for mean lumens at 40% of rated lamp life.

Mounting Height (MH): The vertical distance between the roadway surface and the center of the apparent light source of the luminaire (fixture elevation relative to the roadway surface).

Nadir: A point directly below an observer or object. In lighting, the point vertically below a luminaire's lamp source center with the luminaire mounted in standard position with zero tilt or roll. Refer to Figure 11B-1.05.

Overhang: The transverse horizontal dimension of the position of the luminaire relative to the edge of the roadway or back of curb of the street. Positive overhang is in the direction toward the street center. Negative overhang is in the direction away from the street center.

Roadway Width: The curb to curb width for urban roadway sections and edge to edge pavement width for rural roadway sections.

Steradian: The unit measure of solid angle defined as the conical or pyramid shape that subtends an area on a sphere surface equal to the radius squared. Refer to Figure 11A-1.01.

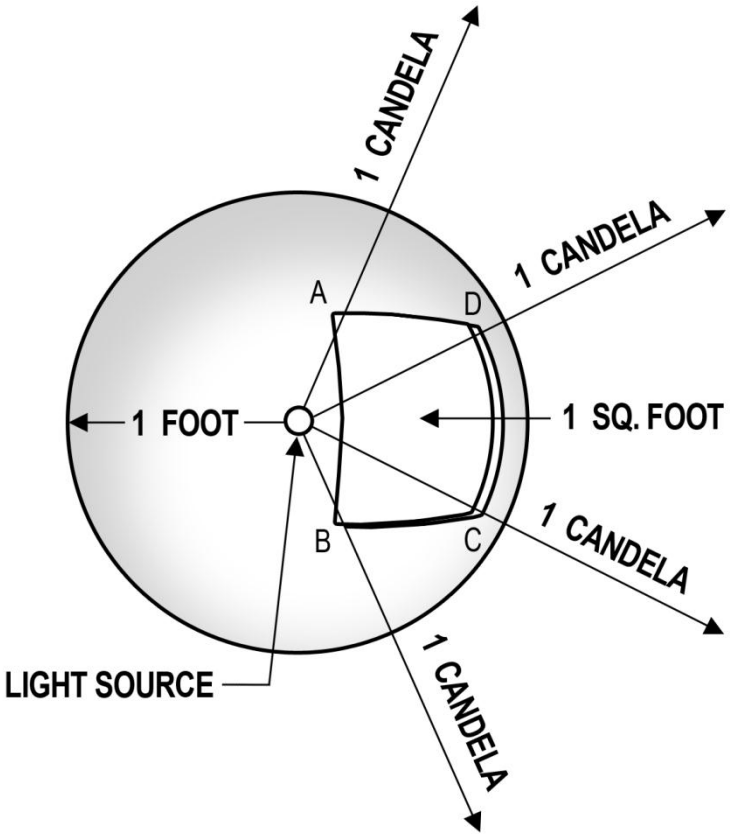
Spacing: The distance between successive lighting units measured longitudinally along the centerline of the roadway.

Transverse Roadway Lines (TRL): A set of horizontal lines running perpendicular to the curb line or edge of pavement that establish a coordinate system for roadway lighting analysis. Refer to Figure 11B-1.03.

Vertical footcandle: One lumen distributed uniformly over a vertical surface one square foot in area. Thus, vertical footcandle is a measure of illumination from light that strikes a vertical surface such as curbs, piers, retaining walls, or other objects with a vertical surface.

Watt: The measure of power or the rate of flow of energy per time. One watt equals the flow of one joule of energy per second. Watts are also equivalent to volts multiplied by amps.

Figure 11A-1.01: Lighting Units Definition Diagram



Relationship between candelas, lumens, and footcandles: A uniform point source (luminous intensity or candlepower equal to one candela) is shown at the center of a sphere of unit radius whose interior surface has a reflectance of zero. The illuminance at any point on the sphere is one footcandle (one lumen per square foot) when the radius is one foot. The solid angle subtended by the area A,B,C,D is one steradian. The flux density is therefore one lumen per steradian, which corresponds to a luminous intensity of one candela as originally assumed. The sphere has a total area of 4π (or 12.57) square feet and there is a luminous flux of one lumen falling on each unit area. Thus, the source provides a total of 12.57 lumens.

Source: Adapted from *ANSI / IES RP-8-00* (R2005)

E. References

Illuminating Engineering Society of North America. *American National Standard Practice for Roadway Lighting*. ANSI / IENSA RP-8-00, (R2005).

Iowa Administrative Codes, 2011.