Luminaires

A. Lighting Sources

Since the development of street lighting, there have been many electrical lighting source types used to illuminate public streets, the first being the incandescent lamp. Other lamp types developed over time were fluorescent, and high intensity discharge (HID) types such as mercury vapor, metal halide (MH), low pressure sodium, and high pressure sodium (HPS). Most recently the solid state light emitting diode (LED) has become a viable choice because of its efficiency to create and apply light in street applications. Because of the enactment of the Iowa Code in 1989 mandating outdoor lighting efficiency, the Code revisions in 2010, and other application considerations, the most practical choices today are metal halide, high pressure sodium, and LED. For a comparison of these source types, refer to Table 11B-1.01.

Table 11B-1.01: Typical Street Lighting Performance Values

Lamp Type and Wattage	Initial Lamp Lumens	Lamp Efficacy (l/w)	Lamp and Ballast Watts	Lamp and Ballast Efficacy (l/w)	Luminaire Optical Efficiency (%)	Overall System Efficacy (l/w)	Average Life (hrs)
250W High Pressure Sodium (HPS)	28,000	112	295	95	85	80.7	24,000
250W Metal Halide (MH)	21,500	86	285	75.5	85	64.2	20,000
180W Light Emitting Diode (LED)	13,100	73	204	64.5	--	64.5	70,000

For HPS and MH, the performance of the light source will vary with wattage size. Typically, the larger the size, the better the efficacy or lumens per watt of the lamp. This is not the case for LED luminaires. Since an LED light assembly is comprised of multiple small LED lamps each having the same efficacy and larger LED luminaires just contain more of the same individual lamps, the efficacy ratio tends to remain the same over the luminaire size range.

For comparison purposes, the table contains a 250 watt HPS lamp, a 250 watt MH lamp, and a 180 watt LED luminaire. The 180 watt LED size was chosen based on application experience. This LED luminaire puts out less total lumens than either of the other two, but because of superior optical efficiency and control, this size luminaire will produce similar street illumination results as a 250W HPS luminaire.

The efficacy ratio suffers as all of the luminaire losses are considered. For the HPS and MH cases, the initial efficacy is based on the lamp input wattage. The efficacy ratio drops when the ballast wattage is included in the calculation. The efficacy ratio drops again when the inherent lumen losses of the luminaire optics are considered. LEDs are rated differently. The initial lumen output is that measured from the entire luminaire assembly at the outset. Therefore, this value has already considered the lamp intensity and any luminaire optical losses. Only the driver wattage needs to be included to arrive at the overall system efficacy.

Another comparison is that LEDs are projected to last significantly longer than HPS or MH. The 70,000 hour life equates to almost 16 years for a street light averaging 12 hours of burn time per night. At this time, LED lighting has not been in practical application for this long. Manufacturers base the rated life on projections from laboratory testing. Due to longer life, LED lighting has the potential for significant maintenance savings.

B. Light System Depreciation

Lighting system depreciation is the loss or degradation of the light output of a luminaire over time with the same power input. The primary factors of lighting system depreciation are lamp lumen depreciation (LLD) and luminaire dirt depreciation (LDD). The light source types considered in this chapter suffer degradation of their light output over their lifetime. A typical range for LLD is from 0.9 to 0.78.

All luminaire assemblies are susceptible to dirt ingress, which absorbs/blocks/disperses light produced by the lamp and prevents it from reaching the intended destination. Some judgment is required to evaluate the luminaire enclosure for contamination protection and the environment to which the luminaire will be exposed. 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). This factor multiplied by the initial light source lumen output gives the maintained lumen output value, which is the expected performance of the lighting system near the end of its rated life. The maintained lumens value is what is used in lighting design photometric calculations. Typical maintenance factors used are:

High Pressure Sodium:	0.75 to 0.80
Metal Halide:	0.70 to 0.78
LED:	0.75 to 0.80

Figures 11B-1.01 and 11B-1.02 depict lamp lumen and dirt depreciation curves.

Figure 11B-1.01: Typical Lamp Lumen Depreciation

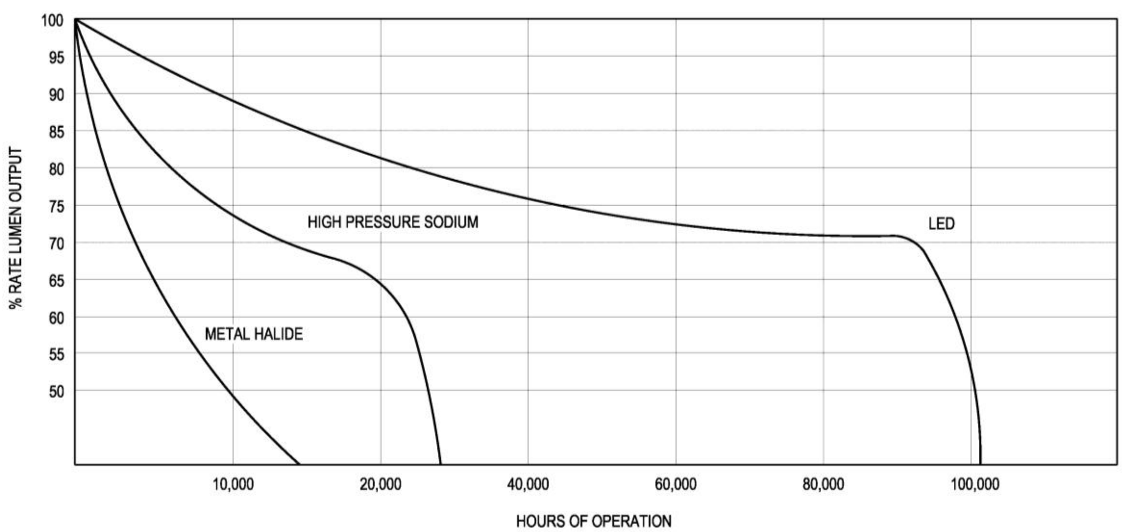
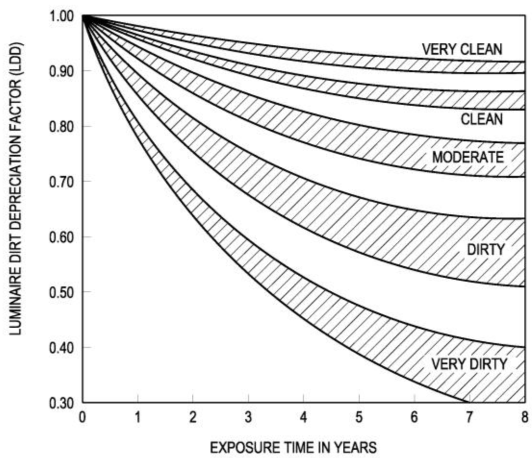


Figure 11B-1.02: Typical Luminaire Dirt Depreciation

Select the appropriate curve according to the type of ambient conditions 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.

Source: Adapted from *Roadway Lighting Handbook*

C. Luminaire Light Distribution Classifications

The Illuminating Engineering Society of North America (IESNA) has developed classification categories and parameters to describe the photometric properties of luminaires. The classifications assist lighting designers in choosing the proper luminaires to accomplish the street lighting task. The categories are lateral light distribution, vertical light distribution, and cutoff rating.

1. **Lateral Light Distribution:** The lateral light distribution classification describes where the light from a luminaire falls into the street surface in relation to the street width, or in other words, how far the light reaches or lands across the street. The classification rating depends on the lateral distance, measured in multiples of luminaire mounting height (mh), where the half-maximum candela trace lands in relation to the location of the luminaire. Refer to Figure 11B-1.03. Following are the IES lateral distribution types and their definitions:

   Type I: Half-maximum candela trace falls between 1 mh on the house side and 1mh on the street side of the luminaire position.

   Type II: Trace falls between 1 mh and 1.75 mh on the street side of the luminaire position.

   Type III: Trace falls between 1.75 mh and 2.75 mh on the street side of the luminaire position.

   Type IV: Trace falls beyond 2.75 mh on the street side of the luminaire position.

   Type V: Has distribution that is circularly symmetrical around the luminaire position.

   The most popular types used for public streets and roads are Types II, III, and IV. Type V distribution is more popularly used in parking or area lighting applications. Type I distribution is used when the luminaire is positioned in the center median of a narrow roadway such as a boulevard driveway.

2. **Vertical Light Distribution:** The vertical light distribution describes where the maximum light intensity (maximum candela) falls longitudinally up and down the street measured in multiples of mounting height in relation to the location of the luminaire (refer to Figure 11B-1.03). Following are the IES vertical distribution types and their definitions:

   Very Short: The maximum intensity point lands 0 to 1.0 mh each way longitudinally from the luminaire position.

   Short: The maximum intensity point lands between 1.0 mh and 2.25 mh each way longitudinally from the luminaire position.

   Medium: The maximum intensity point lands between 2.25 mh and 3.75 mh each way longitudinally from the luminaire position.

   Long: The maximum intensity point lands between 3.75 mh and 6.0 mh each way longitudinally from the luminaire position.

   Very Long: The maximum intensity point lands beyond 6.0 mh each way longitudinally from the luminaire position.

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

   Very Short: 2.0 mounting heights

   Short: 4.5 mounting heights

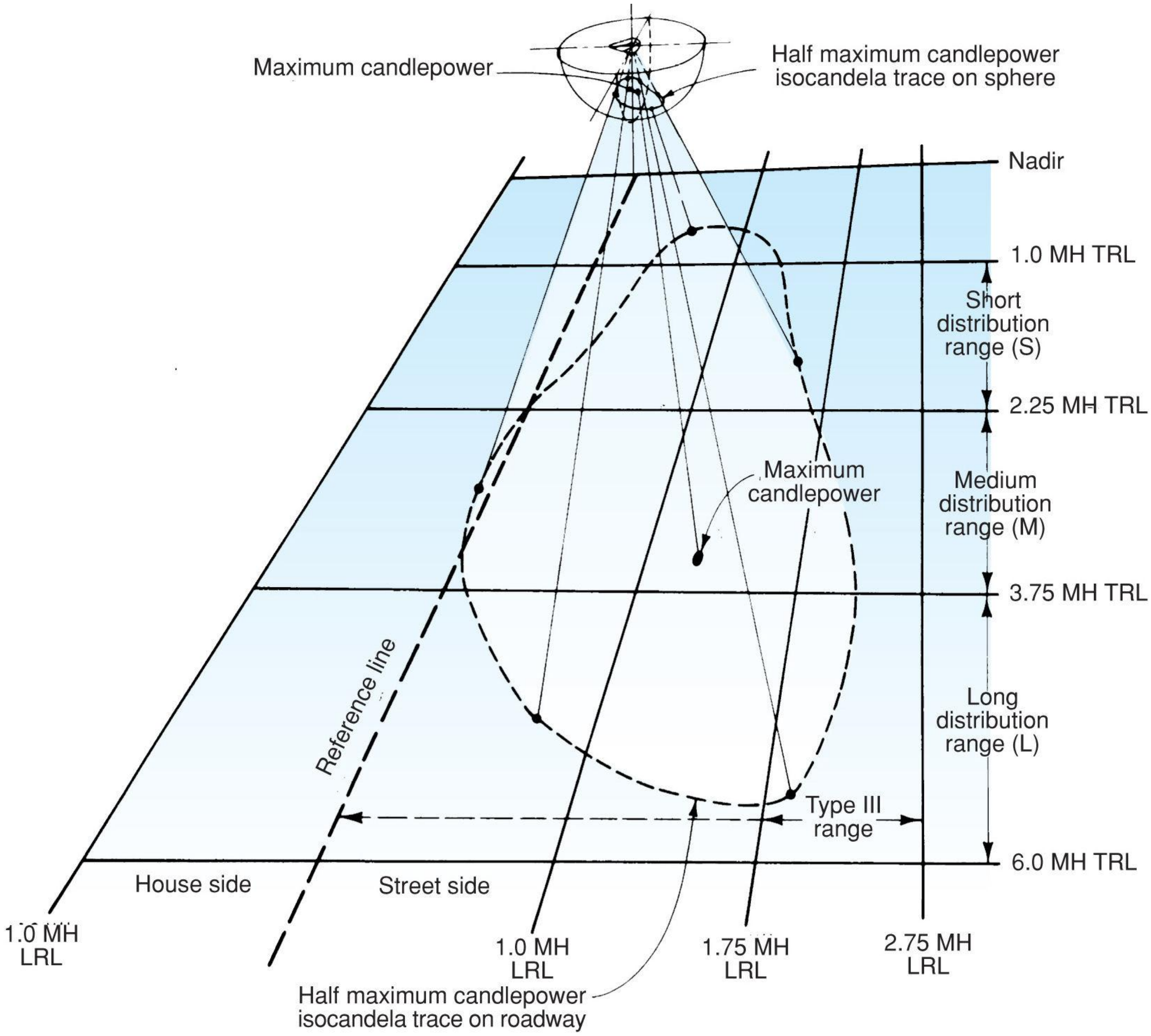
   Medium: 7.5 mounting heights

   Long: 12.0 mounting heights

   Very Long: Beyond 12.0 mounting heights

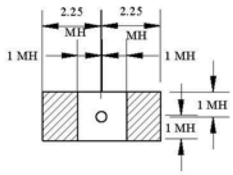
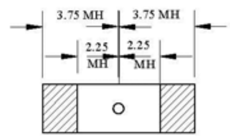
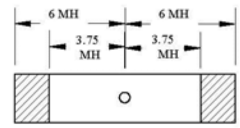
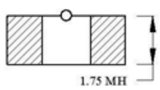
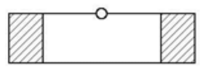
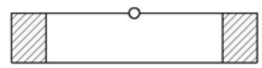
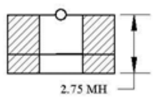
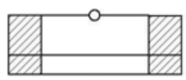
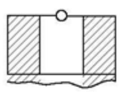
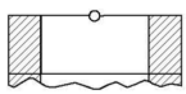
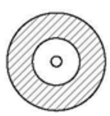
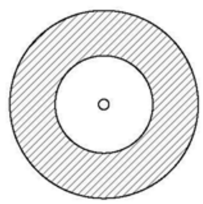
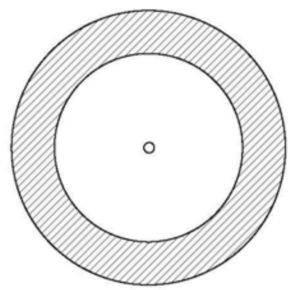
   From a practical standpoint, the medium distribution is predominantly used in practice, and the spacing of luminaires normally does not exceed five to six mounting heights. Short distributions are not used extensively for reasons of economy, because extremely short spacing and more lighting assemblies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

Figure 11B-1.03: IES Light Distribution - Illumination Zone Grid



Source: *IES Lighting Handbook*

Table 11B-1.02: IES Distribution Summary Diagrams

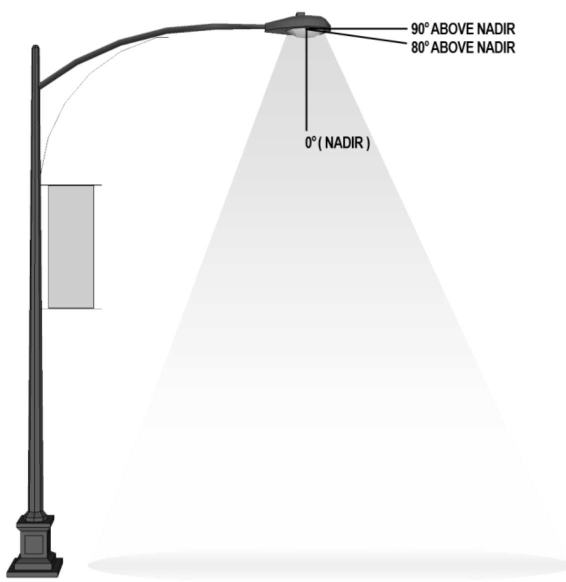
IES Distribution Type	Longitudinal Classification		
	Short "S"	Medium "M"	Long "L"
	Maximum Spacing Is 4.5 Times Mounting Height	Maximum Spacing Is 7.5 Times Mounting Height	Maximum Spacing Is 12.0 Times Mounting Height
Type I For Streets Up to 2.0 Times Mounting Height in Width			
Type II For Streets Up To 1.75 Times Mounting Height in Width			
Type III For Streets Up To 2.75 Times Mounting Height In Width			
Type IV For Streets Up to 2.75 Times Mounting Height In Width			
Type V For General Area Lighting			

3. **Cutoff Rating:** Disability and discomfort glare are largely a result of light emission into the driver's eye. This is largely caused by high-angle light (zone between 80 degrees to 90 degrees above nadir) emanating from a luminaire. Refer to Figure 11B-1.04. Also a concern is the amount of light emanating from the luminaire above 90 degrees from nadir (horizontal plane at the luminaire). This light contributes to sky glow. For design purposes, it is necessary that luminaires be classified according to their relative glare effects. Thus, luminaires are classified by IES as follows:

Full Cutoff: A luminaire light distribution is classified as full cutoff when the luminous intensity (candela) at or above 90 degrees from nadir is zero, and the candela per 1,000 bare lamp lumens does not exceed 100 (10%) at or above a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Cutoff: A luminaire light distribution is classified as cutoff when the luminous intensity (candela) per 1,000 bare lamp lumens does not exceed 25 (2.5%) at or above 90 degrees from nadir, and does not exceed 100 (10%) at or above a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Figure 11B-1.04: Luminaire Cutoff Diagram



Semicutoff: A luminaire light distribution is classified as semicutoff when the luminous intensity (candela) per 1,000 bare lamp lumens does not exceed 50 (5%) at or above 90 degrees from nadir, and does not exceed 200 (10%) at or above a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Noncutoff: A luminaire light distribution where there is no candela limitation in the zone above maximum candela.

As noted above, the metrics related to cutoff classifications for High Intensity Discharge (HID) products are based on candela (intensity) values at specific vertical angles of 80 and 90 degrees when expressed as a percentage of "rated lamp lumens". If LED fixtures are to be evaluated, a problem is developed because LED fixtures are rated in absolute format where there is no lumen rating. This difference can lead to problems if LED luminaires are compared to HID luminaires.

In order to address this difference, the IESNA has published TM-15-11 which uses the parameters of backlighting, uplighting, and glare (BUG) to determine the lumen distributions in specific areas. Design software programs are available that use the BUG rating system. Designers should consult the updated Appendix A of the TM-15-11 document if their design evaluation includes both HID and LED fixtures so the proper comparisons can be made.

D. References

Federal Highway Administration. *Roadway Lighting Handbook*. 1978.

Illuminating Engineering Society of North America (IESNA). *IES Lighting Handbook*. 9th Edition.