Ministry of Transportation Ontario

Electrical Engineering Bulletin

Issue 2018 – 01

January 2018

Table of Contents

1. Light Loss Factors for LED Luminaires

The ministry is expanding its use of LED luminaires and plans to use LED luminaires for all new roadway lighting designs where practical. Therefore, there is a need to identify the light loss factors to apply in LED roadway lighting designs.

The light loss factors for a HPS luminaire are based on the lumen depreciation of the HPS lamp and the relamping cycle. The HPS luminaire is cleaned when it is relamped; therefore, the service life of the lamp and the cleaning cycle are the same (4 years typically).

In contrast, the LEDs are integral to the LED luminaire. Thus, there is typically no periodic replacement or “relamping” of LEDs as there is with high pressure sodium lamps. The service life of the LEDs is the service life of the LED luminaire. The cleaning cycle is specified by the owner and is independent of the LED service life.

The ministry has established the following light loss factors for LED luminaires based on the type of lighting system, LED luminaire cover and the current cleaning cycle. The light loss factors are summarized in Table 1. The development of the light loss factors is summarized in Appendix 1.

Recommended Practice:

It is recommended that minimum maintained lighting levels for LED roadway lighting systems be calculated using the light loss factors summarized in Table 1.

2. Spill Light

Spill light is light from MTO lighting systems that falls onto properties adjacent to or beyond the MTO Right-of-Way. An efficient highway lighting system should direct the light on to the roadway and minimize the amount of light that falls beyond the highway right-of-way.

The maximum spill light level will vary depending on the lighting zone and location (e.g. residential versus commercial). It is of particular importance to minimize spill light levels in residential or environmentally sensitive areas.

The spill light levels shall be calculated for new lighting designs using the “Eye Illuminance” and “Luminous Intensity” criteria described in Appendix 2. The spill light levels should not exceed the maximum values stipulated in Table 2.

Recommended Practice:

For new MTO highway lighting systems it is recommended that spill light levels not exceed the maximum values summarized in Table 2.

Table 1
LED Luminaires: System Attributes and Light Loss Factors

LED Roadway Lighting System	LED Luminaire Expected Service Life (years)	LED Lamp Lumen Depreciation Factor	Cleaning Cycle (years)	LED Luminaire Dirt Depreciation Factor (with or without outer glass cover – Note 1)	Total Light Loss Factor (Note 3)
Conventional (Cobra Head)	20	0.79	4	0.88	**0.70**
High Mast	20	0.79	2 (Note 2)	0.94	**0.74**
Underpass	20	0.79	4	0.7	**0.55**

Note 1: Given the ministry's relatively limited experience with LED lighting, the higher light loss (no cover) dirt depreciation factor was applied.

Note 2: The LED high mast luminaires are assumed to be cleaned each time the luminaire ring is lowered, which is a minimum of once every 2 years.

Note 3: The total light loss factors were rounded to the second decimal place.

Table 2
Lighting Zones and Recommended Spill Light Levels

Lighting Zones	Locations	Land Use	Maximum Eye Illuminance at the Right-of-Way (Note 2)	Maximum Luminous Intensity at the Right-of-Way (Note 2)
LZ1	Environmentally Sensitive Areas (Note 1)	Natural areas identified in local Official Plans including National and Provincial Parks, and designated environmentally sensitive areas	8 lux	10,000 Candela
LZ2	Rural	Rural, Agricultural, or Open Spaces	8 lux	10,000 Candela
LZ3	Urban and Suburban Residential	Low/medium density Residential or Institutional (e.g. Educational Facilities and Churches)	16 lux – Non-residential 8 lux - Residential	20,000 Candela – Non-residential 10,000 Candela - Residential
LZ4	Dense Urban with Mixed Residential, Commercial and Industrial	Commercial, Industrial, and high density Residential and Recreational Mixed Use	24 lux – Non-residential 8 lux - Residential	30,000 Candela – Non-residential 10,000 Candela - Residential

Note 1: Environmentally Sensitive Areas are those areas identified by any agency or level of government which contain natural features, ecological functions or cultural, historical or visual amenities which are susceptible to disturbance from human activities and which warrant protection (Source: Class Environmental Assessment for Provincial Transportation Facilities, MTO 2000).

Note 2: Light levels are based on initial lumens (i.e., Light Loss Factor = 1.0)

Appendix 1

Development of Light Loss Factors

1. LED Lamp Lumen Depreciation (LLD) Factor

Based on the reference documents listed below, specifically Figure E2 in IES TM-21-11, a linear extrapolation of lumen maintenance was developed. Based on the reading of Figure E2 in the MH report, the LED lumen maintenance is 0.95 at 10,000 hours and 0.87 at 50,000 hours (55 C data line).

The characteristics and equation for the line are as follows:

Slope = (0.87 – 0.95)/(50,000 – 10,000) = -2×10^{-6}

Vertical intercept = $0.95 + (2 \times 10^{-6})(10,000) = 0.97$

The equation is thus:

LED lumen maintenance = $0.97 – (2 \times 10^{-6})$(hours of operation)

Hours of operation per year = 365.25 x 12 = 4,383 hours

Therefore, Lumen maintenance = $0.97 - (2 \times 10^{-6})(n)(4383)$

Thus Lamp Lumen Deprecation Factor = LED Lumen maintenance =

$0.97 – (8.766 \times 10^{-3})(n)$

Where n = years of operation and n > 3

For an expected service life of 20 years, the LLD Factor is:

$0.97 – (8.766 \times 10^{-3})(20) = 0.79$

For a 20 year service life, the LED luminaire LLD Factor = **0.79**

2. LED Luminaire Dirt Depreciation (LDD) Factor

2.1 Conventional (Cobra Head) LED Luminaires

Based on the reference documents listed below, specifically the MH report and the conclusions in the IES report RES-1-16, the following linear dirt depreciation factors were identified:

LED luminaire with glass cover: 1 % per year (d = 0.01)

LED luminaire without a glass cover: 3% per year (d = 0.03)

From this the following linear equation was developed:

LED luminaire dirt depreciation (LDD) factor = { 1 – (d)(c) }

Where:

d = linear dirt depreciation factor

c = cleaning cycle in years

For a LED luminaire with a cover and a 4 year cleaning cycle the LDD factor is:

{ 1 – (.01)(4) } = 0.96

For a LED luminaire without a cover and a 4 year cleaning cycle the LDD factor is:

{ 1 – (.03)(4) } = 0.88

2.2 Underpass LED Luminiares

The reference material does not address LED underpass luminaires or LED tunnel luminaires. Therefore, luminaire dirt depreciation for LED underpass luminaires has been assumed to be similar to that for HPS tunnel luminaires.

The MTO Electrical Engineering Manual (Volume 1, Part 4) indicates the following light loss factors for HPS luminaires, based on a 4 year relamping and cleaning cycle:

Conventional: HPS Lamp Lumen Depreciation Factor (Chapter 6) = 0.85

Conventional HPS Luminaire Dirt Depreciation Factor (Chapter 6) = 0.7

Conventional HPS Maintenance Factor = (0.85)(0.7) = 0.6

Tunnel HPS Maintenance Factor (Chapter 11) = 0.25 to 0.6

This implies that for a tunnel the HPS Luminaire Dirt Depreciation Factor would be:

Low End: LDD factor = 0.25/0.85 = 0.3

High End: LDD factor = 0.6/0.85 = 0.7

An underpass is a very short tunnel. Therefore, in general it should be less dirty than a tunnel and typically have a LDD factor at the high end. Based on this, the maintenance factor for a LED underpass luminaire would be = (0.79)(0.7) = 0.55

3. LED Luminaire Component Deprecation (LCD) Factor

Based on the MH report, the depreciation in light output because of degradation in optical components (other than the LEDs themselves) was assumed to be negligible. That is, the LCD factor is assumed to be 1.0.

4. Total Light Loss Factor (Maintenance Factor)

Total light loss factor = LLD factor x LDD factor x LCD factor

Minimum Maintained Lighting Level = Initial Lighting Level x Total Light Loss Factor

5. References

1. IES TM-21-11, Projecting Long Term Lumen Maintenance of LED Light Sources
   Illuminating Engineering Society of North America, 2011

2. IES RES –16, Measure and Report Luminaire Dirt Depreciation (LDD) in LED Luminaires for Street and Roadway Lighting Applications
   Illuminating Engineering Society of North America
   VirginiaTech Transportation Institute, 2016

3. Report on a Design Guide and Maintenance Standards for LED Luminaires
   Morrison Hershfield Report for Ministry of Transportation Ontario, 2017

4. Electrical Engineering Manual (Volume 1, Part 4)
   Ministry of Transportation Ontario, 2001

Appendix 2

Calculation of Spill Light Levels

Definitions:

Eye illuminance means the illuminance generated by a light source on a plane perpendicular to the line of sight.

Luminous intensity means the luminous flux per unit solid angle in a specific direction, expressed in candela (cd). That is, it is the luminous flux on a small surface normal to that direction, divided by the solid angle (in steradians) that the surface subtends at the source.

Eye illuminance shall be calculated at the observer's eye, at a height of 1.5 m above ground, every 10 m along the Right-of-Way (ROW) property line.

At each calculation point, the calculation of eye illuminance shall include the contribution from all ministry luminaires within the visual field. The eye illuminance is the maximum eye illuminance encountered by an observer at that location (i.e. the observer is looking towards the Right-of-Way in the direction that results in maximum illuminance at the observer's eye). Note that maximum eye illuminance can occur when the observer is looking directly at the closest light source.

Luminous intensity shall be calculated at each grid point where eye illuminance is calculated. The luminous intensity shall be calculated using the luminous intensity values in the photometric file and the appropriate interpolation for the given geometry. The calculation at each point shall be performed for all ministry light sources within the observer's visual field and the resultant intensity from the most objectionable light source (luminaire or cluster of luminaires) shall be recorded.

References

1. CSA C811-13, Performance of highmast luminaires for roadway lighting, Canadian Standards Association, 2013

2. CIE 150:2003, Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, International Commission on Illumination, 2003

3. Development of Policy and Standards for Spill Light beyond the MTO Right-of-Way and for Light Trespass onto the MTO Right-of-Way, Morrison Hershfield Report for Ministry of Transportation Ontario, 2007.