# INDIANA DEPARTMENT OF TRANSPORTATION

*Driving Indiana's Economic Growth*

**Design Memorandum No. 13-12**
**Technical Advisory**

June 12, 2013

**TO:** **All Design, Operations, and District Personnel, and Consultants**

**FROM:** ***/s/ David Boruff***
**David Boruff**
**Manager, Office of Traffic Administration**
**Traffic Engineering Division**

**SUBJECT:** **Lighting Design Procedure**

**REVISE:** **Indiana Design Manual Sections 78-3.04, 78-5.0, 78-6.0, and 78-7.0.**

**EFFECTIVE:** **Stage 2 Plan Submission On or After July 1, 2013**



Through this time INDOT has been using High Pressure Sodium roadway, high mast, and underpass luminaires. With developing technology, other types of light sources, e.g., LED, plasma, and induction, are now available and can provide acceptable light levels while reducing energy consumption and maintenance costs. Due to varying photometric (light distribution) patterns, installation costs and maintenance schedules it is necessary for the designer to consider and compare various light source types to generate the optimal, most cost effective design. Therefore, the subject *Indiana Design Manual* sections have been revised and two new worksheets, Figures 78-5B and 78-5C, have been developed to facilitate the light source type selection process.

Please note that sections 807.03, 807.13, 807.19, and 920.01(d) of the *INDOT Standard Specifications* are being revised through a recurring special provision to complement the use of light sources other than HPS as determined and specified by the designer. This recurring special provision will be effective with September 2013 lettings.

Revisions to Chapter 78 are attached to this memo.

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**78-3.04 Luminaire**

A luminaire is defined as a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute light. The following and the INDOT *Standard Specifications* provide the Department's criteria for luminaire hardware. Section 78-6.03 discusses the various light distributions for a luminaire. For additional information, the designer should contact the ~~Highway Operations Division's Office of Traffic Engineering~~ *Traffic Administration Manager, Traffic Engineering Division* for the latest products and specifications.

**78-3.04(01) Light Source**

There are numerous light sources for highway lighting. However, there are only a few practical choices when considering availability, size, power requirements, and cost effectiveness. Only a high-intensity discharge light source should be used. The following provides information on the recommended light sources that may be used.

1. High-Pressure Sodium (HPS). Due to its excellent luminous efficiency, power usage, and long life, ~~HPS is the only light source that INDOT is using for each new installations of conventional or high-mast lighting~~. The HPS lamp produces a soft, pinkish-yellow light by passing an electric current through a sodium-and-mercury vapor.

2. Low-Pressure Sodium (LPS). Low-pressure sodium is considered one of the most efficient light sources. Its disadvantage is that it requires long tubes and has poor color quality. INDOT does not allow the use of LPS in a State-controlled system. However, a local agency may consider the use of an LPS lighting source. The LPS lamp produces a yellow light by passing an electrical current through a sodium vapor.

3. Mercury Vapor (MV). Prior to the introduction of HPS, mercury vapor was the most commonly used light source. ~~A local agency may still install the MV light source for a new installation to match an existing installation. However, INDOT does not allow the use of MV for conventional or high-mast lighting in a new installation. MV usage by INDOT is limited to overhead-sign lighting. The mercury-vapor lamp produces a bluish white light~~. *New installations of Mercury Vapor lamps are prohibited by the Energy Policy Act of 2005.*

4. Metal Halide (MH). A metal-halide lamp produces better color at higher efficiency than an MV lamp. However, life expectancy for an MH lamp is shorter than for HPS or MV. An MH lamp is also more sensitive to lamp orientation than another light source. The MH lamp is used for lighting a sports arena or major sports stadium, for high-mast lighting, or for lighting a downtown area or park. Metal halide produces good color rendition. Light is produced by passing a current through a combination of metallic vapors.

5. *Light Emitting Diode (LED). LEDs are arranged in clusters which are attached to a panel. Various designs utilize different LED types Heat sinks are built into the housing to facilitate heat dissipation and maximize luminaire service life. Light is directly emitted from the lens, so reflectors are not required, resulting in the light being delivered more efficiently than the HPS type and also resulting in less light pollution. LEDs are energy efficient, have a long life, and generate a full color spectrum resulting in good color*

*rendition. Due to the manner in which light is emitted the arrays must be carefully arranged to provide sufficient light distribution and yet be energy efficient. Properly arranged LEDs can provide energy efficient, effective light distribution*.

*LED retrofits are available for existing high mast luminaires. LED modules are attached to a threaded rod which is fit into the existing housing. Luminaire dimensions should be verified as housing diameters less than 16 inches may require an attachment plate as well as the threaded rod, pending the retrofit manufacturer's specific design.*

*6. Plasma. Plasma lamps generate light by exciting gas with radio frequency power. They produce visible light without phosphor conversion which results in a higher luminaire efficiency and which eliminates color shift. The point-source light they generate results in an even distribution of light through highly efficient optics. Plasma luminaires have no electrodes which reduces maintenance requirements. They are highly efficient, have a long life, and generate a full color spectrum resulting in good color rendition. Heat sinks are built into the housing to facilitate heat dissipation and maximize luminaire service life.*

*7. Induction Lighting. Magnetic induction lamps also contain no electrodes resulting in an extended service life. The power used to generate light is transferred from outside the lamp to inside via electromagnetic fields. Induction lamps are also efficient light generators compared to HPS lamps.*



**78-3.04(02) Optical System**

The optical system consists of a light source, *usually* a reflector, and usually a refractor. The following discusses the optical system of a luminaire.

1. Light Source. Section 78-3.04(01) discusses the recommended high-intensity light sources that ~~should be considered~~ *may be used*.

2. Reflector. The reflector is used in optical control to change the direction of the light rays. Its purpose is to take that portion of light emitted by the lamp that otherwise would be lost or poorly utilized, and to redirect it to a more desirable distribution pattern. A reflector is designed to work either alone or with a refractor. Reflectors can be classified into two types, specular or diffuse. A specular reflector is made from a glossy material that provides a mirror-like surface. A diffuse reflector is used where the intent is to spread the light over a wider area.

3. Refractor. The refractor is another means in optical control to change the direction of the light. A refractor is made of a transparent, clear material, usually high-strength glass or plastic. Plastic is used in a high-vandalism area. However, plastic may yellow over time due to heat and ultraviolet exposure. The refractor, through its prismatic construction, controls and redirects both the light emitted by the lamp and the light reflected off the reflector. It can also be used to control the brightness of the lamp source.

**78-3.04(03)** ***Regulation of Input Voltage*/Ballast**

Each luminaire must *operate with an input voltage variation of ±10% of the rated operating voltage specified, with most technologies this is done by* ~~include~~ a built-in ballast. A ballast is used to regulate the voltage to the lamp to ensure that the lamp is operating within its design parameters. It also provides the proper open-circuit voltage to start the lamp. INDOT uses the auto-regulator type ballast. ~~with an input voltage variation of ±10% of the rated operating voltage specified~~. Figure 78-5A, Lamp Data, provides the approximate expected operating wattage for a ballast based on the lamp wattage.

**78-3.04(04) Housing Unit**

Luminaire housing requirements are dependent upon the application type. When selecting a luminaire housing, the designer should consider the following.

1. <u>Roadway-Lighting Luminaire</u>. A roadway-lighting-luminaire housing or specular reflector holder is made of aluminum with a weatherproof finish. The housing unit should allow access from the street side and allow for adjustments to the light. The luminaire should also have a high-impact, heat-resistant, glass *or plastic*, prismatic refractor. The unit should be sealed to ensure that dust, moisture, and insects will not be able to enter the inside of the luminaire.

2. <u>Sign Luminaire</u>. A sign luminaire requires the same housing as a roadway-lighting luminaire, except that it should also provide a durable, plastic, vandal-resistant shield and an aluminum shield that blocks the view of the refractor from an approaching motorist. The unit is attached to the sign walkway as shown on the INDOT *Standard Drawings.* The mounting attachment is adjustable to allow for directing the light onto the sign.

3. <u>Underpass Luminaire</u>. An underpass luminaire requires the same housing as a roadway lighting luminaire, except that it should also provide a durable, plastic, vandal-resistant shield. The ballast may be placed as shown on the INDOT *Standard Drawings*. An underpass luminaire may be attached to the vertical-side surface of a bridge bent structure, or may be suspended by the use of a pendant.

4. <u>High-Mast Luminaire</u>. A high-mast luminaire is an enclosed aluminum unit with a reflector and a borosilicate glass refractor. The unit should be sealed to ensure that dust, moisture, or insects will not be able to enter the inside of the luminaire. The luminaire is attached to the mast ring. The mounting attachment is adjustable to allow for directing the light.

**78-5.0 DESIGN PROCEDURE**

The following provides guidelines on the lighting-design procedure used by INDOT. For additional design information, the designer should also review the references listed in Section 78-1.01. Lighting-system design *should consider various light sources and* may require several iterations *for each type of light source* to produce an acceptable design. After the first run, if the design criteria are not satisfied the designer will need to change the initial parameters (e.g., pole spacing, mounting height, *light source*, and luminaire wattage/*lamp lumen output*) and recheck the design to determine if it then satisfies the criteria. This process is repeated until the design is optimized and all criteria are satisfied.

*As part of the scope of work on certain project the designer may be given specific parameters for the lighting system, e.g. tower or conventional, pole height, luminaire type to supplement or supersede the guidance provided in this section.*

**78-5.01 Computerized Design**

~~To determine an acceptable lighting system requires numerous iterations using numerous variables. The chance for error in manually solving its equations is high. Therefore, the designer should use one of the commercial computer software packages that are available.~~
~~Each software package requires the same input and performs the same calculations. However, the method of input may vary significantly. With the proliferation of software programs, the user should first determine which programs are currently acceptable to INDOT. The Department is using the PC-based program ILLUM$, developed by General Electric, or Visual, developed by Acuity Brands Lighting for its lighting calculations. These programs are used to generate templates for design and to check lighting levels and uniformity. For a lighting design prepared by a consultant, it should provide the Production Management Division's Traffic Review Team with the design data inputs and reports.~~

*To determine an acceptable lighting system requires iterations using variables. The chance for error in manually solving its equations is high. Therefore, one of the commercial computer software packages that are available should be used.*

*Each software package requires the same input and performs the same calculations. However, the method of input can vary. The user should first determine which programs are currently acceptable to INDOT. The PC-based program VISUAL, developed by Holophane, should be used for its lighting calculations. VISUAL is used to generate templates for design and to check lighting levels and uniformity.*

*The design data inputs and reports for a lighting design prepared by a consultant, should be provided to the Office of Traffic Design and Review, Traffic Engineering Division.*



**78-5.02 Design Process**

*Lighting may be designed under four different scenarios*. The following provides the procedural steps in designing a lighting system *for each.*

***78-5.02(01) Spot Lighting (new)***

*Spot lighting comprises no more than one or two lights at an intersection or other particular spot along the roadway where it is deemed necessary to identify that roadway feature at nighttime.*

*In this circumstance AASHTO design criteria need not be applied so it is not necessary for the designer to perform a light level computations.*

*The design should be done as follows:*

*1. Coordinate with the utility company to determine the availability of electric service and to identify the location of the service point. Re-imbursement costs to the utility company should be identified in a special provision and the cost incorporated into the bid estimate.*

*2. Develop a plan sheet for the location. The plan sheet should include the roadway geometry, the location of the service point (indicating the voltage being supplied), location of the pole(s), the orientation of the luminaire(s), the light source type and luminaire wattage, as well as any underground wiring, conduit, handholes, cable duct markers that are needed.*

***78-5.02(02) Luminaire Replacement or Partial Modernizations***

*This type of project involves the replacement of luminaires on existing poles. Other equipment may also be replaced.*

*The design should be done as follows:*

1. *Assemble Information. Obtain a plan of the existing lighting system*

2. *Plan Verification. Verify that the geometrics and lighting system are accurately detailed on the existing plan sheet*

3. *Confirm Scope. Confirm what elements in the system are to be modernized. This should be coordinated with the District Traffic Office.*

4. *Select Design Criteria Select the appropriate AASHTO design criteria- see 78-6.02. based on the type of roadway.*

5. *Select Light Source Type Select the optimal light source type and wattage to satisfy the design criteria in a cost effective manner. Because calculations by computer are relatively quick and easy, the designer should try a number of alternative light source types even if the first design satisfies the criteria as more than one alternative may be satisfactory. Typically systems with 40-ft height poles will typically utilize a luminaire that provides approximately 28,000 or 50,000 lumens of initial light output in a M-S-Type II, III or Type IV IES distribution classification- see Figure 78-6D for information on the IES classification system.*

   *At minimum the alternatives should include one HPS, one LED, one Plasma, and one Induction model- other light source types may also be considered. Only luminaire types/models that have an accessible IES light distribution file can be used. For a list of manufacturer's that have approached INDOT about use of their luminaires go to Y:\TrafficManagement\Luminaire Manufacturers. Consultants and local agencies may contact their Project Manager or the Office of Traffic Administration to obtain this information.*

   *Design optimization should include an analysis for the purpose of minimizing service costs. The lowest service cost per year alternative should be selected. The service cost is defined as:*

*Service Cost per Year =*
*Annual Energy Cost + Annual Routine Luminaire Maintenance Costs*
*+ Installation Cost/Warranty Period*

*Where:*

*Annual Energy Costs are the total luminaire wattage of the system x hours per year operated x cost of electricity*

*Hours operated per year will be defined as 4380*

*Cost per kWh can be estimated at $0.08 (the electric provider or district may have a more location specific unit cost)*

*Maintenance Cost for HPS should be based on re-lamping the entire system every 3 years as well as other miscellaneous work. Currently this cost is estimated at $60 per year for each 250 watt or 400 watt luminaire- and $105 per year for each 1000 watt high mast luminaire. Confer with the manufacturer for routine maintenance costs of other light source types..*

*Recent bid history as obtained on INDOT website should be used to estimate the cost of HPS luminaires. Cost of luminaires utilizing alternative light sources should be obtained from the manufacturer along with an estimate of the cost to install about 1 hour of labor per luminaire. A $75 estimate can be used for labor cost.*

*Warranty period is defined as 5 years or the manufacturer specific warranty period if greater than 5 years The designer should verify the warranty period as some manufacturers provide longer coverage periods.*

*See Figure 78-5B, Service Costs Analysis for Luminaire Modernization, for the worksheet that should be used to perform this computation (see www.in.gov/dot/div/contracts/design/dmforms/ for an editable version). A worksheet should be completed for each alternative considered and placed in the project file. If the service cost analysis does not yield a clear choice, other factors such as the light color or district preferences should be weighed into the decision making on the type of light source.*

6. *Electric Design. Once the luminaire model is selected, the designer will need to determine the voltage drop for the system. Section 78-6.07 provides information on how to determine the voltage drop for the lighting system. If the most cost effective model results in too much voltage drop the designer may either check the voltage drop of the second most cost effective design for use or may try additional luminaire models.*

7. *Prepare Plans. The plan sheet should indicate the average illumination level and uniformity ratio and should show the location of the existing equipment being reused and indicate what is being replaced or added. Equipment includes the service point (indicating voltage being supplied), pole(s), the orientation of the luminaire(s), underground wiring, conduit, handholes, and cable duct markers. The light source type. luminaire wattage, initial lumen output, and the IES file type used will be given on the*

*plans with a note that the distribution pattern of the actual luminaire to be supplied will be equivalent (e.g. luminaire shall provide a light distribution equivalent to IES distribution type GE 452918.IES). This distribution pattern is based on how a specific luminaire model distributes light (how it is designed) and also corresponds to the lumen output and power draw of the fixture. The luminaire table, service point amp table, and the lighting ID numbers should also be included in the plans,*

8. *Utility Notification. If there is a change in service location or an increase in the power requires the designer needs to coordinate with the electric provider. Re-imbursement costs to the utility company should be identified in a special provision and the cost incorporated into the bid estimate.*

9. *Working (Shop) Drawing Check. As part of the working (shop) drawing approval the contractor will submit the IES photometric distribution file for each model where the IES file number varies from that which is indicated on the plans. In these cases, the IES files will be provided to the design engineer of record for their review and concurrence that the design light level criteria will be satisfied.*

### *78-5.02(03) New Lighting System or Full Modernizations*

*This procedure should followed when designing a new system or when modernizing and the existing poles and foundations will not be reused*

1. Assemble Information. Assemble all necessary information. This includes the following:

    a. contact the Traffic Review Team for the current design policies and procedures applicable to the project, sample plans, schedules, pay quantities, and example calculations;

    b. gather roadway and bridge plans including plan and profile sheets and details sheets (e.g., those for overhead signs);

    c. determine existing and expected utility locations;

    d. discuss special considerations with the road or bridge designer

    e. conduct field reviews; and

    f. if a local-agency project, hold discussions with local officials.

2. Determine Classifications. Determine the roadway classification and environmental conditions. If not already included in the project report, this information can be obtained from the Environmental Policy Team. The roadway classifications, for lighting purposes, are defined in Section 78-6.01.

3. Select Design Criteria. Based on the above information, the designer will select the pertinent design methodology (see Section 78-4.0) and the appropriate criteria based on the classification selected in Step 2; see Section 78-6.02. For an INDOT-route lighting

project, only the illuminance design methodology should be used.

4. Select Optimum Design *and Light Source Type* . Because recalculations by computer are relatively quick and easy, the designer should try several alternatives even if one design satisfies the criteria. There is often more than one satisfactory alternative.

*At minimum the alternatives should include one HPS, one LED, one Plasma, and one Induction model- other light source types may also be considered. Only luminaire types/models that have a published IES light distribution can be used. For a list of manufacturer's that have approached INDOT about use of their luminaires go to Y:\TrafficManagement\Luminaire Manufacturers. Consultants and local agencies may contact their Project Manager or the Office of Traffic Administration to obtain this information.*

*Design Optimization should include an analysis for the purpose of minimizing service costs. The lowest service cost per year alternative should be selected. The service cost is defined as:*

*Service Cost per Year =*
*Annual Energy Cost + Annual Routine Luminaire Maintenance Costs*
*+ Installation Costs/Warranty Period*

*Where:*

*Annual Energy Costs are the total luminaire wattage of the system x hours per year operated x cost of electricity*

*Hours operated per year will be defined as 4380*

*Cost per kWh can be estimated at $0.08 (the electric provider or district may have a more location specific unit cost)*

*Maintenance Cost for HPS should be based on re-lamping the entire system every 3 years as well as other miscellaneous work. Currently this cost is estimated at $60 per year for each 250 watt or 400 watt luminaire- and $105 per year for each 1000 watt high mast luminaire. Confer with the manufacturer for routine maintenance costs of other light source types..*

*Installation Cost should include poles and foundations as well as the luminaires. Recent bid history as obtained on INDOT website should be used. Cost of luminaires utilizing other light sources should be obtained from the manufacturer along with an estimate of the cost to install about 1 hour of labor per luminaire. A $75 estimate can be used for labor cost.*

*Warranty period is defined as 5 years or the manufacturer specific warranty period if greater than 5 years The designer should verify the warranty period as some manufacturers provide longer coverage periods.*

*See Figure 78-5C, Service Costs Analysis for New or Fully Modernized Lighting, for the worksheet that should be used to perform this computation (see [www.in.gov/dot/div/contracts/design/dmforms/](www.in.gov/dot/div/contracts/design/dmforms/) for an editable version). A worksheet should be completed for each alternative considered and placed in the project file. If the service cost analysis does not yield a clear choice other factors, such as the light color or district preferences, should be weighed into the decision making on the type of light source..*

a. Select ~~Equipment~~ *Light Output Characteristics*. In the preliminary design, the designer will need to make some initial assumptions regarding the ~~equipment composition~~ *light output*. This includes mounting height, pole setback distance, light source, mast-arm length, *light source type*, lamp wattage, etc. INDOT's practice is to use *either* a *30-ft, 35-ft, or* 40-ft height pole ~~with HPS lamps of 250-W or 400-W~~ *with a luminaire that provides approximately 28,000 or 50,000 lumens of initial light output in a M-S-Type II, III or Type IV IES distribution classification- see Figure 78-6D for information on the IES classification system.* ~~Figure 78-5A, Lamp Data, provides the information on lighting levels for various HPS, LPS and Metal Halide~~. See Sections 78-3.0 and 78-6.03 for additional details. ~~on equipment selection~~. ~~After selecting the luminaire equipment, the designer will also need to obtain the photometric data sheet from the manufacturer for the luminaire selected.~~

*Normally mounting heights and mast arm lengths will be uniform through the project limits. If the project ties into adjacent lighting systems consideration should be given to matching these considerations.*



b. Select Layout Arrangement. Section 78-6.04 provides information on the commonly used lighting arrangements. The selection of the appropriate layout design depends upon local site conditions and the engineer's judgment. Section 78-6.05 provides the roadside safety considerations in selecting the lighting arrangements. Section 78-6.06 provides other layout considerations.

c. Luminaire Spacing. For an INDOT-route lighting project, use the illuminance methodology to determine the appropriate luminaire spacing. This step is conducted by the computer. ~~For hand calculation, Equation 78-5.1 should be used. Sections 78-1.02 and 78-6.03 define the variables used in the equation.~~

$$S = \frac{(LL)(CU)(LLD)(LDD)}{(W)(E_h)} \qquad \text{(Equation 78-5.1)}$$

~~Where:~~
~~*S* = Luminaire Spacing (ft)~~
~~*LL* = Initial Lamp Lumens~~
~~*CU* = Coefficient of Utilization~~
~~*LLD* = Lamp Lumen Depreciation Factor~~
~~*LDD* = Lamp Dirt Depreciation Factor~~
~~$E_h$ = Average Maintained Level of Illumination (ft-cd)~~
~~*W* = Width of Lighted Roadway (ft)~~

d. Check Uniformity. Once the spacing has been determined, the designer should check the uniformity of light distribution and compare this to the criteria selected in Step 3. Use Equation 78-5.2 to determine the uniformity ratio. Section 78-7.0 provides an example for calculating the uniformity ratio.

5. Electric Design. Once the *type*. number, size, and location of the luminaires are determined, the designer will need to determine the ~~appropriate~~ electric voltage drop for the system. Section 78-6.07 provides information on how to determine the voltage drop for the lighting system.

6. INDOT Pre-Design Approval. For a consultant-designed project, the consultant should *submit the service cost analysis worksheets and* discuss the optimum alternatives with the Traffic Review Team prior to preparing the plans in order to expedite project development. Upon approval from INDOT, FHWA if necessary, and the local utility company, the final development of the plans may proceed.

7. Prepare Plans. Once the final design has been selected, the lighting designer will prepare and submit to the Traffic Review Team the plan sheets, , quantities, cost estimate, voltage drop calculations, circuit schematic layouts, and special provisions that are required for review. *The light source type, luminaire wattage, initial lumen output, luminaire table, service point amp table, and the lighting ID numbers should be included on the plans Additionally the IES file type used in the design will be given on the plans with a note that the distribution pattern of the actual luminaire to be supplied will be equivalent (e.g. luminaire shall provide a light distribution equivalent to IES distribution type GE 452918.IES).*

*8. Working (Shop) Drawing Check. As part of the working (shop) drawing approval the contractor will submit the IES photometric distribution file for each model where the IES file number varies from that which is indicated on the plans. In these cases, the IES files will be provided to the design engineer of record for their review and concurrence that the design light level criteria will be satisfied.*

***78-5.02(04) Design-Build Projects***

*The following provides the procedural steps in designing a lighting system as part of a roadway design-build project. The design-build team will:*

*1. Assemble Information. Assemble all necessary information. This includes the following:*

*a. contact the Traffic Review Team for the current design policies and procedures applicable to the project, sample plans, schedules, pay quantities, and example calculations;*

*b. gather roadway and bridge plans including plan and profile sheets and details sheets (e.g., those for overhead signs);*

*c. determine existing and expected utility locations;*

*d. discuss special considerations with the road or bridge designer;*

e. conduct field reviews; and

f. if a local-agency project, hold discussions with local officials.

2. Determine Classifications. Determine the roadway classification and environmental conditions. If not already included in the project report, this information can be obtained from the Environmental Policy Team. The roadway classifications, for lighting purposes, are defined in Section 78-6.01.

3. Select Design Criteria. Based on the above information, the designer will select the pertinent design methodology (see Section 78-4.0) and the appropriate criteria based on the classification selected in Step 2; see Section 78-6.02. For an INDOT-route lighting project, only the illuminance design methodology should be used.

4. Select Equipment. In the preliminary design, the designer will need to make some initial assumptions regarding the equipment composition. This includes mounting height, pole setback distance, mast-arm length, light source type, luminaire wattage, photometric distribution pattern (INDOT typically uses M-S-Type II, III, or IV), and initial lumen output (typically 28,000 or 50,000),. See Sections 78-3.0 and 78-6.03 for additional details on equipment selection.

   Normally mounting heights and mast arm lengths will be uniform through the project limits. If the project ties into adjacent lighting systems consideration should be given to matching these considerations.

   At minimum the alternatives should include one HPS, one LED, one Plasma, and one Induction model- other light source types may also be considered. Only luminaire types/models that have an accessible IES light distribution file can be used For a list of manufacturer's that have approached INDOT about use of their luminaires go to Y:\TrafficManagement\Luminaire Manufacturers. Consultants and local agencies may contact their Project Manager or the Office of Traffic Administration to obtain this information.

5. Select Layout Arrangement. Section 78-6.04 provides information on the commonly used lighting arrangements. The selection of the appropriate layout design depends upon local site conditions and the engineer's judgment. Section 78-6.05 provides the roadside safety considerations in selecting the lighting arrangements. Section 78-6.06 provides other layout considerations.

6. Luminaire Spacing. For an INDOT-route lighting project, use the illuminance methodology to determine the appropriate luminaire spacing. This step is conducted by the computer.

   Normally for tangent alignment where roadway width is constant, spacing will be uniform through the project limits. If the project ties into adjacent lighting systems consideration should be given to matching the spacing.

7. Check Uniformity. Once the spacing has been determined, the designer should check the uniformity of light distribution and compare this to the criteria selected in Step 3. Use

*Equation 78-5.2 to determine the uniformity ratio. Section 78-7.0 provides an example for calculating the uniformity ratio.*

8. *Select Optimum Design. Because recalculations by computer are relatively quick and easy, the designer should try several alternatives even if the first design satisfies the criteria. There is often more than one satisfactory alternative. Design Optimization should include an analysis for the purpose of minimizing service costs. The service cost is defined as:*

   *Service Cost per Year =*
   *Annual Energy Cost + Annual Routine Luminaire Maintenance Costs*
   *+ Installation Cost/Warranty Period*

   *Where:*

   *Annual Energy Costs are the total luminaire wattage of the system x hours per year operated x cost of electricity*

   *Hours operated per year will be defined as 4380*

   *Cost per kWh can be estimated at $0.08 (the electric provider or district may have a more location specific unit cost)*

   *.*
   *Maintenance Cost for HPS should be based on re-lamping the entire system every 3 years as well as other miscellaneous work. Currently this cost is estimated at $60 per year for each 250 watt or 400 watt luminaire- and $105 per year for each 1000 watt high mast luminaire. Confer with the manufacturer for routine maintenance costs of other light source types..*

   *Estimated Cost of the system should include poles, foundations, wiring, conduit, handholes, service points as well as the luminaires. Recent bid history as obtained on INDOT website should be used. Cost of alternative technology luminaires should be obtained from the manufacturer along with an estimate of the cost to install about 1 hour of labor per luminaire. A $75 estimate can be used for labor cost.*

   *Warranty period is defined as 5 years or the manufacturer specific warranty period if greater than 5 years The designer should verify the warranty period as some manufacturers provide longer coverage periods.*

   *See Figure 78-5C, Service Costs Analysis for New or Fully Modernized Lighting, for the worksheet that should be used to perform this computation (see www.in.gov/dot/div/contracts/design/dmforms/ for an editable version). A worksheet should be completed for each alternative considered and submitted with the plans. If the service cost analysis does not yield a clear choice other factors, such as the light color or district preferences, should be weighed into the decision making on the type o flight source.*

9. *Electric Design.* Once the type, number, size, and location of the luminaires are determined, the designer will need to determine the appropriate electric voltage drop for the system. Section 78-6.07 provides information on how to determine the voltage drop for the lighting system. For light source types other than HPS, the design current (amperage) requirement should be obtained from the manufacturer.

10. *Prepare Plans.* Once the final design has been selected, the lighting designer will prepare and submit to the Traffic Review Team the plan sheets, design criteria, initial lumen output, photometric files, service cost analysis worksheets, luminaire shop drawing, quantities, cost estimate, voltage drop calculations, circuit schematic layouts for review. The plan sheet shall indicate the IES photometric distribution file number used in the design, the luminaire type and initial lumen output and should include the luminaire table, service point amp table, and the lighting ID numbers .

11. *Plans submission.* Plans should be submitted in accordance with the project witness and hold point schedule.

**78-6.02 Design Criteria**

The lighting criteria vary according to the design methodology, highway classification, area classification, and pavement type. The following provide AASHTO and INDOT lighting design criteria.

1. Figure 78-6B provides the recommended INDOT roadway-illuminance-design criteria
.
2. The AASHTO *An Informational Guide for Roadway Lighting* provides the recommended illuminance-design criteria for a pedestrian walkway, bikeway path, or local-agency project.

3. *NCHRP Report 672, "Roundabouts: An Informational Guide", provides the recommended illuminance-design criteria for roundabout lighting.*

**78-6.03(04) Light-Loss Factor (Maintenance Factor)**

The efficiency of a luminaire is reduced over time. The designer must estimate this reduction to properly estimate the light available at the end of the lamp-maintenance life. The maintenance factor *for HPS lighting* may range from 0.50 to 0.90, with the optimum range from 0.65 to 0.75. Figure 78-6A, INDOT Lighting Design Parameters, provides the factors used for designing a lighting system.

The maintenance factor is the product of the following.

1. Lamp/*LED* Lumen Depreciation Factor (LLD). As the lamp progresses through its service life, the lumen output of the lamp decreases. The initial lamp lumen value is adjusted by means of a lumen depreciation factor to compensate for the anticipated lumen reduction. This ensures that a minimum level of illumination will be available at the end of the assumed lamp life, even though lamp lumen depreciation has occurred. This information should be provided by the manufacturer. *Typically* the LLD factor is 0.90.

~~should be used. If deemed necessary, another value may only be used with approval from the Office of~~ ~~Traffic Engineering~~. *For a more precise value the designer should use the manufacturer's recommendations. The LLD should be based on a standard lamp life expectancy or service life.*

2. Luminaire Dirt Depreciation Factor (LDD). Dirt on the exterior and interior of the luminaire, and to some extent on the lamp, reduces the amount of light reaching the roadway. Various degrees of dirt accumulation may be anticipated depending upon the area in which the luminaire is located. Industry; exhaust of vehicles, especially large diesel trucks; dust; etc., all combine to produce dirt accumulation on the luminaire. A higher mounting height, however, tends to reduce vehicle-related dirt accumulation. Information on the relationship between the area and the expected dirt accumulation is shown in Figure 78-6H. An LDD factor of 0.87 should be used. This is based on a moderately-dirty environment and three years' exposure time. If deemed necessary, another value may only be used with approval from the ~~Office of Traffic Engineering~~ *Traffic Administration Office.*

**78-6.07 Voltage Drop Determination**

A highway-lighting distribution circuit consists of two 240-V circuits provided by a multiple conductor armored cable. Power supply to the lighting system is 240/480 V, single phase, 60-cycle alternating current. The lights are alternately connected to each side of the four-wire circuit. Ground rods are provided at each light standard. Voltage drop should not be over 10% to the last light in the circuit. Figure 78-6N provides the design amperages for ~~various~~ typical *HPS* luminaires, *check with the manufacturer for other light source types*. Figure 78-6 O provides resistances for various wire types. Equation 78-6.1 should be used to determine the voltage drop between two adjacent luminaires.

$E = IR$ (Equation 78-6.1)

Where:

$E$ = voltage, or electric potential (volt)
$I$ = current (ampere/mile)
$R$ = resistance (ohm)



**78-7.0 HIGH-MAST LIGHTING DESIGN [Rev. Jan. 2011]**

The design of a high-mast lighting system consists of the same design procedures as discussed in Section 78-5.02. The following should also be considered:

1. Lighting Source. *For HPS designs a 130,000 lumen (1000 watt)* ~~A 1000-W high pressure sodium~~ light source should be used. *For LED and plasma design the lumen and wattage requirements may vary.* The number of required luminaires*, and in the case of LED and plasma the lumen and wattage,* should be determined based on the area to be lighted *and target design criteria* as shown in Figure 78-7A. *At a minimum the designer should consider one HPS, one LED, and one plasma model for determining the optimal design.*

2. Estimated Mounting Height. This can range from 100 to 200 ft. Once determined, it

should be specified to the higher 5-ft increment. An EMH of 100 to 160 ft has proven to be the most practical. An EMH of 165 ft or greater requires more luminaires to maintain the illumination level. However, such an EMH allows for fewer towers and provides better uniformity. Use of such an EMH should be confirmed with the district traffic engineer.

3. Location. In determining the location for a tower, the plan view of the area should be reviewed to determine the more critical areas requiring lighting. In selecting the appropriate location for a tower, the following should be considered.

   a. Critical Area. A tower should be located such that the highest localized level of illumination occurs within a critical-traffic area, e.g., freeway/ramp junction, ramp terminal, merge point.

   b. Roadside Safety. A tower should be located a sufficient distance from the roadway so that the probability of a collision is virtually eliminated. It should not be placed at the end of a long tangent.

   c. Sign. A tower should be located so that it is not within a motorist's direct line of sight to a highway sign.

4. Design. The methodologies for checking the adequacy of uniformity are the point-by point method and the template method. The point-by-point method checks illumination by using the manufacturer’s Isolux diagram. The total illumination at a point is determined as the sum of the contributions of illumination from all luminaire assemblies within the effective range of the point. The template methodology uses isolux templates to determine the appropriate location for each tower. The templates may be moved to ensure that the minimum-maintained illumination is provided, and that the uniformity ratio has been satisfied. Section 78-8.0 provides an example of using the template methodology.

   A retaining wall should be included with the concrete pad at the base of the tower if the surrounding ground’s slope is steeper than 5:1. The height of the retaining wall should be determined from Figure 78-7B.

5. Foundation and Soil Test. After the final location of each tower is determined, a geotechnical investigation should be requested from the Office of Geotechnical Engineering. The standard foundation of 20-ft depth and 4-ft diameter should be specified for each tower with the soil properties as follows.

   a. Soft Clay. Undrained shear strength of 750 $lb/ft^2$, density of 120 $lb/ft^3$, and strain of 0.01 at half the maximum stress for an undrained triaxial test. The soil should not include excess rock.

   b. Sand. Angle of internal friction of 30 deg, density of 115 $lb/ft^3$, and modulus of subgrade reaction of 20 $lb/in^3$. The soil should include a minimum of gravel or clay.

   If a tower of 180 ft or higher is required where soil is sandy, a foundation of 22-ft depth and 4.5-ft diameter should be specified, and its details should be shown on the plans. The standard foundation has been designed with the assumption that no groundwater is present. The Office of Geotechnical Engineering should be contacted if groundwater is present or if excess rock is present in clay soil.

For other soil conditions or properties, the Office of Geotechnical Engineering may recommend an alternate foundation. Such alternate foundation should be shown on the plans.

6. Information to be Shown on Plans. This includes the tower location, foundation details if not standard, estimated mounting height, retaining-wall height if applicable, *the light source type*, number of luminaires, *and the luminaire wattage. The IES file type used in the design will be given on the plans with a note that the distribution pattern of the actual luminaire to be supplied will be equivalent (e.g. luminaire shall provide a light distribution equivalent to IES distribution type GE 452918.IES). The plans should also include the luminaire table, service point amp table, and the lighting ID numbers.*

*When a high mast luminaire retrofit is selected as the best option, the designer should include a unique special provision that incorporates any needed changes to the standard specifications on High Mast Luminaires, as well as information on the existing high mast luminaire since the housing will be re-used. At a minimum this information should include manufacturer, model name/number, and dimensions of the housing. Additionally the designer should include a pay item for Luminaire, High Mast, Retrofit, ___ (watts),….each. The unique special provision should include a basis of payment section indicating that in addition to the cost of the LEDs and mounting hardware, the cost of all work necessary to remove, disassemble, re-assemble with the new LED modules, and then reinstall the existing luminaire is included in the Retrofit pay item.*

Location: __________________          Project Number: __________

Light Source Type: __________          IES Light Distribution Type: __________

------------------------------------------------------------------------------------------------------------------------

Service Cost per Year for Luminaire Replacement or Partial Modernization

= Annual Energy Cost + Annual Maintenance Cost + (Installation Cost/Warranty Period)

------------------------------------------------------------------------------------------------------------------------

Annual Energy Cost

= [(No. of Luminaires x Wattage per Luminaire x Operational Hours)÷1000] x Unit Cost of Electricity

No. of Roadway Luminaires = _____ (1)

Roadway Luminaire Wattage = _____ (2)

No. of High Mast Luminaires = _____ (3)

High Mast Luminaire Wattage = _____ (4)

Operational Hours = 4380

Unit Cost of Electricity = _____ (5) ($0.08 per kWh or location specific rate)

Annual Energy Cost =

[{(_____ x _____) + (_____ x _____ )} x 4380 ÷ 1000] x _____ = _____

(1) (2) (3) (4) (5) (A)

---

Annual Maintenance Cost

= No. of Luminaires x Maintenance Cost per Luminaire

No. of Roadway Luminaires = _____ (1)

Maintenance cost per Roadway Luminaire,

for 250W or 400W HPS = $60 (6)

for other light source types = _____ (7) (per manufacturer's info)

No. of High Mast Luminaires = _____ (3)

Maintenance Cost per High Mast Luminaire,

for 1000W = $105 (8)

for other light source types = _____ (9) (per manufacturer's info)

Annual Maintenance Cost = {(_____ x _____) + (_____ x _____)} = _____

(1) (6) or (7) (3) (8) or (9) (B)

---

**SERVICE COST PER YEAR**
**FOR LUMINAIRE REPLACEMENT OR PARTIAL MODERNIZATION**

**Figure 78-5B**
**(Page 1 of 2)**

Installation Costs

= No. of Luminaires x Furnish & Install Cost per Luminaire

No. of Roadway Luminaires = _____ (1)
Furnish/Install Cost per Roadway Luminaire = _____ (10) (for HPS use bid history)

Roadway Luminaire Warranty Period = (choose one) years (11)

No. of High Mast Luminaires = _____ (3)
Furnish/Install Cost per High Mast Luminaire = _____ (12) (for HPS use bid history)

High Mast Luminaire Warranty Period = (choose one) years (13)

Installation Cost = [(_____ x _____ ÷ _____) + (_____ x _____ ÷ _____)/= _____
(1) (10) (11) (3) (12) (13) (C)

-------------------------------------------------------------------------------------------------------------------

Service Cost per year = _____ + _____ + _____ = _____
(A) (B) (C)



**SERVICE COST PER YEAR**
**FOR LUMINAIRE REPLACEMENT OR PARTIAL MODERNIZATION**

**Figure 78-5B**
**(Page 2 of 2)**

Location: __________ Project Number: __________

System Configuration: _____ Pole Spacing: _____ Mounting Height: _____

Light Source Type: _____ IES Light Distribution Type: _____

---

Service Cost per Year for New Installations or Complete Modernization
= Annual Energy Cost + Annual Maintenance Cost + (Installation Cost/Warranty or Service Period)

---

Annual Energy Cost
= [(No. of Luminaires x Wattage per Luminaire x Operational Hours)÷1000] x Unit Cost of Electricity

No. of Luminaires = _____ (1)

Luminaire Wattage = _____ (2)

No. of High Mast Luminaires = _____ (3)

High Mast Luminaire Wattage = _____ (4)

Operational Hours = 4380

Unit Cost of Electricity = _____ (5) ($0.08 per kWh or location specific rate)

Annual Energy Cost =
[{(_____ x _____) + (_____ x _____ )} x 4380 ÷ 1000] x _____ = _____
(1) (2) (3) (4) (5) (A)

---

Annual Maintenance Cost
= No. of Luminaires x Maintenance Cost per Luminaire

No. of Luminaires = _____ (1)

Maintenance cost per luminaire,
for HPS = $60 (6)
for other light source types = _____ (7) (per manufacturer's info)

No. of High Mast Luminaires = _____ (3)

Maintenance Cost per High Mast luminaire,
for 1000W = $105 (8)
for other light source types = _____ (9) (per manufacturer's info)

Annual Maintenance Cost = {(_____ x _____) + (_____ x _____)} = _____
(1) (6) or (7) (3) (8) or (9) (B)

---

**SERVICE COST PER YEAR FOR NEW OR FULLY-MODERNIZED LIGHTING**
**Figure 78-5C**
**(Page 1 of 2)**

Installation Costs

= [Cost of Luminaires ÷ Warranty Period] +
[Cost of Poles/Foundations ÷ Pole Service Life] +
+ [Cost of Towers/Foundations ÷ Tower Service Life]

No. of Roadway Luminaires = _____ (1)
Furnish/Install Cost per Roadway Luminaire = _____ (10) (per mfr. for non-HPS)
Warranty Period = (choose one) years (11)

No. of Poles Foundations = _____ (12)
Furnish/Install Cost of Pole = _____ (13)
Furnish/Install Cost of Pole Foundation = _____ (14)
Pole Service Life = 20 years

No. of High Mast Luminaires = _____ (3)
Furnish/Install Cost per High Mast Luminaire = _____ (15) (per mfr. for non-HPS)
Warranty Period = (choose one) years (16)

No. of High Mast Towers Foundations = _____ (17)
Furnish/Install Cost of Tower = _____ (18)
Furnish/Install Cost of Tower Foundation = _____ (19)
Tower Service Life = 40 years

Installation Cost =

[(_____ x _____) ÷ _____] = _____ (20)
(1) (10) (11)

+ [(_____ x (_____ + _____)) ÷ 20] = _____ (21)
(12) (13) (14)

+ [(_____ x _____) ÷ _____] = _____ (22)
(3) (15) (16)

+ [(_____ x (_____ + _____)) ÷ 40] = _____ (23)
(17) (18) (19)

/= _____ + _____ + _____ + _____= _____
(20) (21) (22) (23) (C)

---

Service Cost per year = _____ + _____ + _____ = _____
(A) (B) (C)

**SERVICE COST PER YEAR FOR NEW OR FULLY-MODERNIZED LIGHTING**
**Figure 78-5C**
**(Page 2 of 2)**