LIGHTING OF TRAFFIC FACILITIES

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CHAPTER 10 - LIGHTING OF TRAFFIC FACILITIES

10-1.00 INTRODUCTION

10-1.01 Purpose

The purpose of this chapter is to present MnDOT's practice for the lighting of traffic facilities. The chapter also presents the step by step procedure for initiating, designing, and letting a contract for the construction of an electric lighting system.

10-1.02 Scope

This chapter is meant to be a guideline rather than a standard. Together with other documents, this chapter gives guidelines and procedures for lighting installations on MnDOT roadways, underpasses, tunnels, rest areas, weigh stations, parking lots, lighted signs, and bridges. Refer to the MnDOT Roadway Lighting Design Manual when a detailed lighting design description is needed. This chapter references the Lighting Design Manual when appropriate.

The principal reference for lighting design is the Roadway Lighting Design Guide published by the American Association of State Highway and Transportation Officials (AASHTO). The AASHTO Roadway Lighting Design Guide is an essential document to accompany this chapter and is a frequent reference within the chapter.

Other important documents include the American National Standard Practice for Roadway Lighting RP-8 published by the Illuminating Engineering Society, hereafter referred to as RP-8, and the National Electrical Code published by the National Fire Prevention Association. Other references are listed at the end of the chapter.

10-2.00 GLOSSARY

"A" Base
Base plate joined to the pole shaft with continuous exterior and interior welds and fastened directly to the foundation anchorages or to the top of a transformer base.

Ambient Light
Illumination at, near, or around a traffic facility, but outside of the right-of-way.

Average Initial Illumination
The average level of horizontal illumination on the pavement area of a traveled roadway at the time the lighting system is installed, when lamps are new, and luminaires are clean; expressed in footcandles (lux).

Average Maintained Illumination
The average level of horizontal illumination on the pavement area of a traveled roadway when the illuminating source is at its lowest output allowed and when the luminaire is in its dirtiest condition; expressed in footcandles (lux).

Ballast
An auxiliary device used with high intensity discharge (HID) lamps to provide proper starting and operating characteristics. It limits the current through the lamp and may also regulate the voltage.

Bent Straw Pole
A tapered pole with a straight mast arm off the top at an approximately 90 degree angle

Breakaway
A design feature that allows the lighting unit support to yield, fracture, or separate near ground level on impact.

Breakaway Support Coupling
A high strength coupling specifically designed to yield quickly and cleanly on impact.

BUG Rating
Backlight, uplight, and glare rating of a luminaire.

Candela
The unit of luminous intensity (the force generating the luminous flux). Formerly the term “candle” was used.

Complete Interchange Lighting
The lighting of the freeway through traffic lanes through the interchange, the traffic lanes of all ramps, the acceleration and deceleration lanes, all ramp terminals, and the crossroad between the outermost ramp terminals.

Davit Pole and Mast Arm
A shaft that curves from vertical to horizontal.

Edge Line
A line that indicates the edge of the roadway.

Electronic Control Module (ECM)
A module in LED luminaires that controls dimming and monitors luminaire performance.

Electronic Driver
Power supply used in LED luminaires to power the LED light modules.

Feedpoint
A source of AC power that distributes AC power to individual lighting units in a lighting system.

Fog Line
Also known as the right lane edge.

Footcandles (lux)
The unit of illumination when the foot is taken as the unit of length. It is the illumination on a surface one square foot in area on which there is a uniformly distributed flux of one lumen, or the illumination produced on a surface, all points of which are at a distance of one foot from a directionally uniform point source of one candela.

Frangible base
An aluminum transformer light pole base designed to readily or easily break on impact. The frangible base is fastened with bolts to the “A” base that is welded to the light pole shaft.

Glare
The brightness of a light source which causes eye annoyance, discomfort, or loss in visual performance and visibility.

Gore
On a freeway or expressway, the area where the mainline of the roadway and the ramp diverge or converge.

High Base
A tapered transformer base that attaches to a galvanized or stainless steel pole by slip fitting inside the pole shaft.

High Intensity Discharge (HID) Luminaire
A complete lighting fixture consisting of a HID lamp together with the ballast, reflector, refractor, a photocell when required, and the housing. An example of an HID lamp type would be High Pressure Sodium (HPS) or Metal Halide (MH).

Horizontal Lux
Lux measured in a horizontal plane.

Illuminance
The density of luminous flux incident on a surface; it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated, expressed in lumens per square meter.

IP Rating (International Protection Rating)
Sometimes interpreted as Ingress Protection Marking, this classifies and rates the degree of protection provided against intrusion, dust, accidental contact, and water.

Isolated Intersection
The general area where two or more non-continuously lighted roadways join or cross at the same level.

Lamp
A source of light. The device within a luminaire that converts the electrical energy to light.

LED Luminaire
A complete lighting fixture consisting of light-emitting diodes (LEDs) that connect to a power supply as well as internal and external designed parts necessary for operation and distribution of light.

Light-Loss Factor (LLF)
A depreciation factor which is applied to the calculated initial average luminance or illuminance to determine the value of depreciated average illumination at a predetermined time in the operating cycle. The light loss factor reflects the decrease in effective light output of a lamp and luminaire during its life.

Lighting Unit
Includes the light pole, luminaire, lamp (if needed), wire holder, fuse holder, and all other miscellaneous equipment required for a complete lighting unit installation.

Lumen
The unit of luminous flux (time rate of flow of light). A lumen is defined as the luminous flux emitted by a point source having a uniform luminous intensity of one candela.

Luminance
The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction, expressed in candela per square meter.

Lux
The International System (SI) unit of illuminance. One lux is defined as the illuminance incident on a surface of one square meter, all points of which are one meter from a uniform source of one candela.

Partial Interchange Lighting
Lighting consisting of a few luminaires located in the vicinity of some or all ramp terminals, intersections, or other decision making areas.

Pavement Reflection Factor (or Reflectance)
The ratio of the light reflected by a pavement surface to the light incident upon it.

Post Top Lighting Unit
A light pole with a short vertical shaft for mounting the luminaire.

Progressive-Shear Base
A high base that is riveted or spot-welded to a base plate designed to shear progressively on impact. Most commonly found on stainless steel breakaway poles.

Shoe Base
A low profile casting that connects the shaft to the pole base plate.

Slip Base
A pole base plate designed to slide off a lower plate on impact.

Tenon
A smooth tapered piece on the top end of the pole shaft or davit for slip fit mounting of the luminaire.

Transformer ("T") Base
A box-like structure with access door between the foundation and pole "A" base plate used to accommodate the wiring splice connections.

Truss Mast Arm
A horizontal bracket used to support the luminaire.

Uniformity Ratio
Average to minimum uniformity ratio is the ratio of average footcandle (lux) of illumination on the design area to the footcandle (lux) at the point of minimum illumination on the area. Maximum to minimum uniformity ratio is the ratio of the maximum footcandle (lux) value at any point on the design area to the point of lowest footcandle (lux) value.

Veiling Luminance
A luminance superimposed on the retinal image that reduces its contrast. It is this veiling effect produced by bright sources or areas in the visual field that results in reduced visual performance and visibility.

Vertical Lux
Lux measured in a vertical plane.

10-3.00 LIGHTING PROJECT PROCEDURES

This section describes the process involved in bringing a state administered lighting project from its inception to its completion. The section lists the steps involved and then describes each step separately.

For projects that utilize state funds but are not administered by the state, the MnDOT Office of State Aid will request from the District Traffic Engineer any assistance needed to handle the project. Local jurisdictions may also, with proper permits, administer lighting projects on state trunk highways at their sole expense, as when the local jurisdiction desires lighting that is determined by the state to be unwarranted. Form 2525, the utility permit application, is obtainable from the district office for this purpose. Any lighting on state trunk highways must be approved by MnDOT regardless of the agency installing it.

The district initiates state administered lighting projects. The following steps are necessary for completing a lighting project:

1. Scoping the project
2. Programming the project
3. Negotiating with local authorities and utilities
4. Implementing a work authority
5. Preparing plans
6. Preparing special provisions
7. Preparing agreements
8. Letting the project

10-3.01 Warrants

The primary purpose of warrants is to assist administrators and designers in evaluating locations for lighting needs and selecting locations for installing lighting. Warrants give conditions that should be satisfied to justify the installation of lighting. Meeting these warrants does not obligate the State to provide lighting. Conversely, local information in addition to that reflected by the warrants, such as roadway geometry, ambient lighting, sight distance, signing, crash rates, or frequent occurrences of fog, ice, or snow, may influence the decision to install lighting. The warrants are applicable to all lighting projects where the State participates in the cost, whether the contract is administered by the State or by a local governmental agency.

Warrants for freeway lighting are contained in the AASHTO Roadway Lighting Design Guide and the MnDOT Lighting Design Manual.

The AASHTO Roadway Lighting Design Guide also contains guidelines on special considerations for roadway lighting.

The AASHTO Roadway Lighting Design Guide gives no specific warrants for continuous lighting of roadways other than freeways (roads with fully controlled access, no at-grade intersections), but does suggest some general criteria that may apply when considering the installation of lighting.

Lighting of at-grade intersections is warranted if the geometric conditions mentioned in the AASHTO Roadway Lighting Design Guide exist or if one or more of the conditions listed in the MnDOT Lighting Design Manual exists.

Intersection lighting is a strategy for reducing fatal and serious injury crashes at isolated intersections and has been recommended in the Minnesota Strategic Highway Safety Plan (SHSP) and other companion documents such as the District Safety Plans and the County Road Safety Plans. If a nighttime crash issue is identified, illuminating the intersection is a strategy that should be considered. However, if all impacted jurisdictions agree, intersection lighting can be installed proactively even though no formal crash warrants have been satisfied. Lighting may be installed in the form of full intersection lighting, meeting recommended light levels, or delineation lighting, intending to mark an intersection for approaching traffic, but not meeting light level recommendations. Intersection lighting installations should be data driven and take into consideration risk factors associated with crashes. Effort should be made to make sure that lighting deployments are not arbitrary in nature. Lighting is one of many strategies that can be used to improve safety and should be compared with other alternatives to determine what strategy is most effective for the location under consideration.

Warrants covering lighting for roundabout intersections, tunnels, underpasses, rest areas, and signs are contained in the AASHTO Roadway Lighting Design Guide.

10-3.02 Programming

The District Traffic Engineer is responsible for requesting planning and programming to encumber funds for lighting installations.

10-3.03 Negotiations

Lighting installations involve coordination with electric utility companies and may involve other agencies. The responsibility for negotiating with municipalities, counties, railroads, and electric utility companies rests with the District. The Utility Agreements Unit of the Office of Technical Support, the Office of Freight and Commercial Vehicle Operations (OFCVO), and the Central Office (CO) Lighting Unit may all be available to assist the District in such negotiations.

10-3.04 Work Authorities

Work authorities are required before design or construction is started.

Function 1 work authority is for preliminary design.

Function 2 work authority is for detail design.

Function 3 work authority is for construction.

Where the lighting design is part of the road plans, the Road Design Engineer should implement the work authority, including the lighting design work, and a separate work authority for the lighting portion of the plan is unnecessary.

10-3.05 Preparation of Plans

The District Traffic Office is responsible for the designs of the lighting system that will be installed under a State contract. Assistance may be requested from the CO Lighting Unit.

The lighting plans should include a title sheet showing the following:

1. Project location and description,
2. State and federal project number(s),
3. The area and job number(s),
4. Appropriate signature lines,
5. Roadway design values,
6. Legends and symbols,
7. A list of scales, and
8. A plan index.

When a municipality is participating in the cost for installing or maintaining the lighting system, the title sheet should include a signature line for the appropriate authority from the municipality. The District Traffic Engineer should submit a final copy of the plan to the municipality for review and approval before the project is let.

Lighting System Pay Items

The lighting system pay items may be itemized showing items for conduit, cable, light standards, etc., in which case a statement of estimated quantities is included, or, the lighting plan may be shown as a lump sum. Any notes pertaining to any of the items in the estimated quantities should be included on the estimated quantities sheet. Paying for the lighting system as a lump sum item may be more convenient than itemizing in certain situations. To simplify estimating and bidding when a lump sum pay item is used, the plans should include a tabulation of the individual items that are part of the lump sum.

Detail Sheets

Detail sheets should show pole details for each type of pole used in the project, details for mounting the service cabinets and photoelectric controls, any special anchorage details, conduit attachment to bridges for underpass lighting, and any other necessary details.

Layout Sheets

Each layout sheet should include a layout of the roadway and locations of light poles, cable, service cabinets, conduit, junction boxes, and handholes or pull boxes. All of these items should be properly labeled and identified. A tabulation should list stations, locations, and types of lighting units.

Lighting Unit Labels

Lighting units indicated in the plans should be labeled with a unique identification number. The top number, which is assigned by the CO Lighting Unit, is called the feedpoint number. The number below the feedpoint number indicates the individual lighting unit number (pole number) being serviced by that specific feedpoint. Light poles should be labeled with the entire assigned feedpoint number and the lighting unit number as stated in the plan. Tunnel and underpass luminaires should be labeled with the last letter of the assigned feedpoint number above the number indicating the lighting unit on that feedpoint. Lighting units should be numbered consecutively according to the plan.

Wiring Diagrams

The plans should include wiring diagrams to detail the wiring of the lighting circuits such as wire sizes, identification colors, splices and handholes, conduits, and type of wiring (direct buried lighting cable or single conductors).

Information sheets should be included when appropriate.

Sources of Power and Meter Address

The designer must contact the appropriate electric utility company to establish source of power(s) (SOP) and the meter address. The electric utility company may require an Application for Service, extra equipment, and have an electrical service charge. All communications with the electric utility company should be confirmed in writing.

10-3.06 Preparation of Special Provisions

The special provisions for a lighting project should give any necessary information that is not already given in the plans or in the MnDOT Standard Specifications for Construction, as well as information that is especially in need of the bidders' attention. This information may include an explanation of the electrical distribution system, materials specifications for materials, construction requirements that are not included in the Standard Specifications for Construction, a statement of items that are to be furnished by the state, and an explanation of what is included in each pay item.

The District Lighting Designer normally prepares the Lighting Special Provisions for the project. The CO Lighting Unit may provide assistance if requested.

10-3.07 Preparation of Agreements

An agreement is a legal document detailing the responsibilities of the various parties involved regarding cost, installation, maintenance, and providing power to a lighting system. The District prepares the agreements for lighting projects that are not a part of a road construction project.

Lighting agreements that are part of a road construction project are normally prepared by the Municipal Agreements Unit of the Office of Technical Support.

An agreement may be between the State, the electric utility company, a railroad, or a municipality (city or county). There may be several agreements with different agencies. In rare instances there may be a three-party agreement. The terms of the agreement will be project specific. Information regarding agreements with a railroad, an electric utility company, and a municipality are shown below. Only general considerations are given in these descriptions.

10-3.07.01 Agreement with a Railroad

Agreements and permits may be necessary for power cables over or under railroad tracks.

10-3.07.02 Agreement with an Electric Utility Company

MnDOT typically meters all roadway lighting, therefore an agreement with the local electric utility company is not needed. Only in rare instances when MnDOT will not be metering a lighting system an agreement with the local electric utility company is required.

An agreement with an electric utility company details the method of payment and certain maintenance functions of the lighting system along with the possibility for providing electric utility owned lights. Rates for maintaining the lighting system may include maintenance such as LED luminaire replacement, luminaire and glassware maintenance and cleaning, lamp replacement, ballasts, photocells, and maintaining the above ground wiring supplying power to the luminaire in addition to supplying electrical energy. The service cabinet, direct buried lighting cable, and pole knockdowns are almost always maintained by the State and are not part of an agreement with the electric utility company. Agreements with power electric utility companies should be open ended to include additions or changes to the number and types of lighting units on the lighting system covered and may be made by processing a CADD lighting plan sheet showing the addition or changes. A flat rate is then charged for each lighting unit based on the type.

With the exception of municipal utilities, the rates charged by electric utility companies are regulated by the Minnesota Public Utilities Commission (PUC). The electric utility company must set forth these conditions in a letter to the PUC when filing a new proposed rate schedule or when filing a change of the rate schedule. The rates set forth in the schedule may be put into effect by the utility 30 days after the letter is filed with the PUC. Municipal utilities are not regulated by the PUC, but rather by the residents of the municipalities that own and operate them.

On the rare occasion that local electric utility company owned lights are to be provided, the District Traffic Office should prepare a lighting plan containing the name of the electric utility company, location, type, and number of lights. If the State does not have an open ended agreement with the electric utility company to provide electric utility owned lights, the District must write one. Agreements for electric utility owned lights should include maintenance by the electric utility company.

Agreements with the electric utility company may be required for extending power lines to the electrical service point of the lighting system. Costs for extending power lines should not be included in the open ended agreements with the utility for providing power and maintenance for lights.

Lighting plan layout sheets are necessary for additions and changes to existing open ended agreements. A lighting plan layout includes the highway, the city (if applicable), the electric utility company, the feedpoint number, and the total number of lights of each type after the addition or change. Attached to the layout is the Signature Sheet indicating the number and date of the open ended agreement that is being altered by the lighting plan layout sheet and a summary of the changes. The District notifies the electric utility company of the date of effect of the change once the lights have been turned on.

Two copies of all lighting plan layout sheets are sent to the Electrical Services Unit (ESU) and the District Office to update their location files.

10-3.07.03 Agreement with a Local Road Authority - Cost Participation Policy

An agreement with a local road authority details the cost responsibility for the design, installation, maintenance, power cost, and ownership of a roadway lighting system.

- **Cooperative Agreement** - An agreement that includes participation by the local road authority in the installation cost as well as detailing the maintenance and ownership responsibility.
- **Maintenance Agreement** - An agreement that only involves the maintenance responsibility, with no participation by the local road authority for installation.

The roadway lighting system may be installed as a State contract or a local government contract. The local road authority or the State may pay the entire cost or part of the cost of any of these items. The negotiations between the District and the local road authority shall be in accordance with the Cost Participation for Cooperative Construction Projects and Maintenance Responsibilities between MnDOT and Local Units of Government, hereafter referred to as Cost Participation Policy.

Such factors as the location of the lighting units, the agency administering the contract, the types of light poles and luminaires used, the jurisdiction of the intersection roadways, warrants met, and past practice all may influence the negotiated cost splits.

A Long Form Utility Permit (Form 2525) is required for all lighting systems that are to be owned and operated by the local road authority regardless of cost splits.

The following are guidelines for lighting installations. See the Cost Participation Policy for more information on cost splits.

1. **Trunk Highways - Freeway (Limited Access Including Interstate)**
   The State determines what portions of freeways and highways will be lighted. Light levels should meet the requirements in this chapter, the AASHTO Roadway Lighting Design Guide, and the MnDOT Lighting Design Manual. Roadways considered for lighting are the main line, ramps, and the intersections of ramps with cross streets (ramp terminals).

   The lighting of frontage roads not concurrent with ramps is the responsibility of the local road authority.

Lighting of every interchange is not deemed necessary, but is recommended in most areas. The State will install lighting units where engineering and economic studies indicate the existence of appropriate justification in accordance with the requirements in this manual. Per the Cost Participation Policy, a local road authority may request the installation of unjustified lighting on an interchange . If approved by the District Traffic Engineer, the system may be installed in accordance with MnDOT's Standards as indicated in this chapter.

2. **Trunk Highways (Arterial and Expressway)**
The State will determine what portions of trunk highways will be lighted and the light levels to be provided in accordance with the requirements in this chapter.

   A local authority may request to install a lighting system on a trunk highway per the Cost Participation Policy that meets MnDOT's standards indicated in this chapter and the MnDOT Lighting Design Manual

   Isolated intersection lighting may be installed per the Cost Participation Policy, this chapter, and the MnDOT Lighting Design Manual.

   Preparing an agreement involves several steps. Using the Cost Participation Policy, the District and the municipality must agree on the percentage of the total cost that each agency will pay and the method of payment. The District or Municipal Agreement Unit of Technical Support will prepare the agreement. The agreement should be processed in a similar fashion as the traffic signal agreements, detailed in Chapter 9, "Highway Traffic Signals" of this manual.

3. **Aesthetic Bridge Designs**
Refer to the Cost Participation Policy.

10-3.08 Project Letting

Upon completion of the plans, special provisions, cost estimate, and agreement, the project will be turned in, advertised, bid, and awarded to the contractor with the lowest qualified bid.

MnDOT may also use a Design-Build process on larger projects that may include lighting as part of the project.

10-4.00 LIGHTING SYSTEM DESIGN

Once the decision is made to install lighting, the design stage can begin. This section describes typical MnDOT designs. The design must be appropriate for the site and must provide the level and uniformity of light suggested in the AASHTO Roadway Lighting Design Guide. The lighting described in this section is a product of the illuminance method of lighting design. Lighting may also be designed using the luminance method described in the AASHTO Roadway Lighting Design Guide. Both methods produce satisfactory results. A detailed description of MnDOT's lighting design standards can be found in the MnDOT Lighting Design Manual.

Minnesota Statute Chapter 16B.328, Subd. 3 provides information regarding the use of state funds for outdoor lighting fixtures. With a few exceptions, state funds may not be used for luminaires that do not meet the cutoff definition or are more restrictive.

Certain luminaire manufacturers and independent companies offer computer programs to analyze light levels for a user-defined roadway with user-defined lighting installed. These programs are excellent tools for determining the correct luminaire, mounting height, and pole spacing necessary to provide the proper light levels and uniformity of light on a roadway. Any consultant doing a lighting design for MnDOT must have lighting design software. The CO Lighting Unit also has lighting design software and can provide assistance to a district. This can be either laying out the pole spacing or verifying the design provided by others.

10-4.01 Typical Lighting Systems

10-4.01.01 Continuous Freeway Lighting

Lighting on MnDOT roadways must meet the recommended 0.6 to 1.1 footcandles light levels, and the 3:1 to 4:1 average to minimum uniformity ratio, and the maximum veiling luminance as indicated for freeways in the AASHTO Roadway Lighting Design Guide and the MnDOT Lighting Design Manual. To meet these requirements, MnDOT lighting systems may be median barrier mounted lighting units, roadside mounted lighting units, or a combination of both.

Lighting units mounted on a median barrier are typically double 6- to 9-foot, davit-type mast arms. Roadside mounted lighting units typically are a single 9-foot, davit-type mast arms placed 19 to 26 feet behind the right edge line of the traveled roadway depending on pole height and luminaire rated light output.

The advantages of median barrier mounted lighting units with double mast arms are:

- They provide the same number of luminaires with fewer poles than roadside mounting requires,
- They are less likely to be knocked down than roadside mounted lighting units, and
- Electrical wiring for the lighting units do not need to be located because it is in the barrier therefore reducing man hours for locating and eliminating the possibility of cable hits due to excavators.

Median barrier mounted lighting units are discouraged in high volume areas where shoulders inside the left yellow edge line are less than 10 feet wide. They are difficult to access and maintain due to traffic, and require lane control. In most cases, roadside lighting units do not require lane control because of wide outside shoulders.

The lights for a roadway with two lanes in each direction are typically 40-foot poles spaced approximately 250 feet apart with a luminaire of adequate luminous intensity to achieve the required light level. On a mainline roadway with three lanes in each direction, 49-foot poles spaced approximately 275 feet with a luminaire of adequate luminous intensity to achieve the required light level are typically used. Pole spacing for both 40- and 49-foot poles may be reduced on ramps and interchanges compared to those on the mainline roadway.

Roadways with more than three lanes in each direction may require reduced spacing or both median barrier mounted lights and roadside mounted lights to achieve the desired light level and uniformity.

10-4.01.02 Partial Interchange Lighting

Figure 10-1:Typical Luminaire Locations Partial Interchange Lighting Davit Arm Poles shows typical luminaire locations for partial interchange lighting. This figure is a modification of similar figure in the AASHTO Roadway Lighting Design Guide. The lights are typically the same as those described above for continuous freeway lighting with two lane roadways.

10-4.01.03 Complete Interchange Lighting

Complete interchange lighting places lights in the merging traffic and gore areas in the same locations as partial interchange lighting. In addition, it places lights along the ramps, the mainline roadway through the interchange, and on the crossroad between the ramp terminals.

10-4.01.04 Tunnel Lighting

The AASHTO Roadway Lighting Design Guide contains information related to tunnel lighting warrants and guidelines. A more detailed guideline along with light level guidelines is located in the Illuminating Engineering Society's (IES) Tunnel Lighting publication.

A short tunnel may only need lighting at night. A very long tunnel may require separate lighting controls for nighttime, clear days, and cloudy days. These requirements are discussed in the AASHTO Roadway Lighting Design Guide.

10-4.01.05 Underpass Lighting

Where the AASHTO Roadway Lighting Design Guide indicates that underpass lighting is desirable, underpass luminaires for each direction of travel on the roadway are mounted on the bridge abutment or pier. If such mounting would set back the luminaire more than 20 feet from the edge of driving lane or more than 17 feet above the roadway surface, then the luminaire is typically mounted on a bracket or plate that attaches to the bottom of the bridge diaphragm to meet acceptable light levels.

10-4.01.06 Rest Area Lighting

The AASHTO Roadway Lighting Design Guide gives light levels and uniformity values for use in rest areas. The luminaires and poles for the entrance and exit ramps of a rest area are the same as those described above for continuous freeway lighting with two lane roadways.

Poles in the parking area of the rest area are typically 30-foot, non-breakaway, single or double davit or bent straw mast arm poles with LED luminaires. Approved poles can be found on the MnDOT Approved Products List under Roadway Lighting.

The pedestrian lighting around rest area buildings and walkways are typically 15-foot decorative bronze painted poles with LED luminaires. Approved LED luminaires can be found on the MnDOT Approved Products List under Roadway Lighting.

The spacing of poles for these areas varies with the geometrics of the parking areas and walkways. The lighting must be designed to meet AASHTO recommended light levels using MnDOT approved products.

10-4.01.07 Lighting for Other Streets and Highways

Lighting levels and uniformity ratios for streets and highways other than freeways are contained in the AASHTO Roadway Lighting Design Guide. The design for these roadways is often matched to existing lighting in a city rather than to freeway design standards.

10-4.01.08 Bridge Lighting

The roadway on a bridge is normally treated the same as other parts of the roadway. If there is no lighting on the adjacent roadway, there is normally no need for lighting on the bridge. An exception is a very long bridge, which may be lit even though the roadway is not lit at other locations.

The desirable locations for the lighting units on a bridge are at abutments and pier locations, or at a distance from an abutment or pier not to exceed 25 percent of the length of the span. This placement of the lighting units reduces the effects of vibration. The light poles should have a davit arm that is an integral part of the pole shaft so there are no joints to be weakened by vibration. Bolted on mast arm attachments to pole shaft should not be used. The bridge light pole base should have a 4-bolt or 6-bolt high base with dual access doors commonly used on barrier to house the wiring splices.

If a local governmental agency or aesthetic committee requests ornamental lighting on a new MnDOT bridge or bridge replacement project, MnDOT will participate in funding in accordance with MnDOT Policy Guideline: Highways (including Bikeways) 6.1G-1 Policy and Procedures for Cooperative Construction Projects with Local Units of Government.

The installation of marine lanterns (navigation lights) and air obstruction lights are an integral part of the bridge design. Navigation lights are required to meet the light level performance requirements as indicated in the U.S. Coast Guard (USCG) Publication “A Guide to Bridge Lighting” and be compliant with the Code of Federal Regulations (CFR), Title 33, Part 118.

Air obstruction lights will be installed in accordance with the requirements of the Federal Aviation Administration (FAA), Advisory Circular AC 70/7460-1K. A Notice of Proposed Construction or Alteration” (FAA Form 7460-1) must be filed with the Federal Aviation Administration in such instances.

The Office of Bridges and Structures may ask the Lighting Unit to coordinate electrical service points for the roadway lighting and navigational/air obstruction lighting.

10-4.01.09 Airport Impacts on Roadway Lighting

Where an airport or heliport is close enough to a highway lighting project that clearances are at or near minimum requirements, a sketch showing airport runways with all pertinent vertical and horizontal measurements should be done. A Notice of Proposed Construction or Alteration" (FAA Form 7460-1) must be filed with the Federal Aviation Administration in such instances. The location near the airport may (1) limit the height allowable for the poles, (2) may mandate the use of luminaires with no up-light, (3) require L810 air obstruction lights, or may require a combination of all three. If required by the FAA, Form 7460-2, Supplemental Notice, may also need to be filed.

The impact to the airport will vary depending on the type of lighting and the proximity to airports. For example, a high mast tower lighting system would impact an airport at a greater distance than would a lighting system utilizing 40-foot light poles.

10-4.01.10 Weigh Station Lighting

Weigh station lighting level and uniformity values are the same as those for the lighting of rest areas. Because of the variety of weigh station designs, there is no typical weigh station lighting. Weigh station lighting should provide a manual means to turn off all lights except for necessary security lights when the weigh station is not in use.

10-4.01.11 Lighting of Roadways with Median Barriers

Median barrier lighting is described in Section 10-4.01.01 Continuous Freeway Lighting.

10-4.01.12 Intersection Lighting

Roadway lighting for at-grade intersections is shown in Figure 10-2: Standard Illumination Plan for Intersections. The poles and luminaires may be selected according to the guidelines given previously, may be selected to match existing street lighting in the city where the intersection is located, or may be a part of a traffic control signal system. The local agency will be required to maintain anything other than MnDOT standard luminaires.

Lighting should be provided at all signalized and flashing beacon intersections. A signal pole shaft extension with a luminaire davit should be utilized whenever possible to avoid adding more poles at the intersection. Roadway lights on traffic control signal poles should be fed from the traffic signal service point. Additional light poles may be necessary when the intersection has channelization or complex turning lanes. The level of illumination of a signalized intersection is dictated by the area classification of the roadway. Suggested levels of illumination and average horizontal footcandles for roadway lighting are given in the IES RP 8.

The level of illumination at an intersection should be greater than that between intersections where there is continuous lighting.

Where the level of illumination is low between intersections, such as 0.6 footcandles, the light intensity at the intersection should be doubled as a rule.

10-4.01.13 Roundabout Intersection Lighting

Roundabout intersection light levels are similar to that of a standard intersection. Warrants and guidelines are given in the AASHTO Roadway Lighting Design Guide and the MnDOT Lighting Design Manual.

10-4.02 Roadway Lighting System Components

10-4.02.01 Poles

The latest version of the "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals", published by AASHTO, specifies structural requirements for light poles. The MnDOT Standard Specification for Construction Book has additional MnDOT requirements for poles.

The designer must determine the pole height, type and length of mast arm(s), material and finish, and method of mounting based on MnDOT standard products and luminaires on the MnDOT Approved Products List. Whenever possible, these choices should conform to standard products offered by manufacturers.

Pole height affects the illumination intensity, uniformity, area covered, and relative glare of the unit. Higher mounted units provide greater coverage, more uniformity, and a reduction of glare, but a lower footcandle level. By using higher poles, fewer poles are required and they can be set back farther from the traveled roadway. Typical pole heights are 30 feet, 40 feet, and 49 feet. The applications of the different heights are indicated in Section 10-4.01: Typical Lighting Systems. Power lines, nearby airports, and nearby residential neighborhoods may limit the height of poles used for lighting.

Where pole height is not restricted, high mast tower lighting may replace conventional lighting units at locations with complex roadways, such as at freeway interchanges. High mast tower lighting is a lighting system that includes 3 to 6 foot high wattage luminaires mounted on a stainless steel luminaire ring that is hoisted atop high towers, 100 to 140 feet, to illuminate a large area. A mechanical lowering system is used to lower and raise the luminaire ring to perform maintenance on luminaires.

Advantages of high mast tower lighting systems vs. conventional lighting systems:

- There are fewer towers used than poles on a conventional lighting system.
- Traffic control requirements are reduced because towers can be placed farther from the traveled roadway than poles on a conventional lighting system.
- Provides a more uniform light distribution on roadway surfaces than conventional lighting.
- There are no knockdown lighting units to replace.

Disadvantages of high mast tower lighting systems vs conventional lighting systems:

- The cost to install a high mast lighting system is considerably higher than that of a conventional lighting system.
- High mast lighting systems are not desirable near residential neighborhoods due to discomfort glare and light intrusion.
- If placed in the clear zone they must be protected from impact by guard rail or other barriers.
- The luminaire mounting ring must be lowered and raised on an annual basis if an integral powered lowering unit is installed.

Conventional lighting units should have davit type arms or a tenon-type mounting assembly unless a desire for decorative lighting dictates another type of arm, or the lights must match existing light poles with a different type of arm.

Barrier mounted light poles should be galvanized steel and non-breakaway. Roadside light poles located in the clear zone must be breakaway when on higher speed roads and are unfinished aluminum or stainless steel. Decorative poles should be painted steel or aluminum. A municipality may want painted poles or poles of a specific material to match its existing lighting.

Where traffic speeds exceed 40 mph, any poles located within the "clear zone" (See the MnDOT Road Design Manual for the definition of "clear zone") must either be breakaway devices, or must be protected by a suitable traffic barrier (guardrail). A breakaway pole has a special base and has been tested as a complete unit to show that it will "break away" when hit and will not impede a vehicle's movement more than a maximum set amount. In urban areas with speeds less than 30 mph and pedestrians present, a knocked down pole may present a greater hazard to traffic and pedestrians than would a non-breakaway device. In such locations, non-breakaway poles should be used. In urban areas with speeds between 30 mph and 40 mph, the designer may choose either breakaway poles or non-breakaway poles. These criteria for the use of breakaway poles apply regardless of the State's participation in the project.

Types of MnDOT pole bases include the tapered high base, the anchor base, the shoe base, and the standard transformer base. Types of MnDOT breakaway poles include the stainless steel progressive sheer base with a stainless steel shaft, the frangible cast aluminum transformer base with an aluminum pole shaft and arm, a slip base pole, and an aluminum shoe base pole.

Roadside light poles up to and including 40 feet in height should mount on the Design E light foundation. Light poles higher than 40 feet and up to 49 feet in height should mount on the Design H light foundation. Light poles on a bridge or median barrier are typically mounted on a six bolt anchor bolt cluster. Six bolt anchor bolt cluster requires a specially widened section of the barrier, called an AL section, to be itemized in the road plans. MnDOT light pole foundations and six bolt anchor bolt cluster are detailed in the MnDOT Standard Plates Manual.

The designations for the various pole types are given in Figure 10-3: Pole Type Designations.

Pole placement is an engineering decision that should be based upon:

- Geometry,
- Character of the roadway,
- Physical features,
- Environment,
- Available maintenance,
- Economics,
- Aesthetics, and
- Overall lighting objectives.

Physical roadside conditions may require adjustment of the spacing determined from the base levels of illumination, indicated in the AASHTO Roadway Lighting Design Guide. Higher levels of illumination are justified when overhead structures, safety, and object clearances restrict the placement of poles. It is advisable to provide the higher illumination levels at diverging and merging areas.

Site considerations affecting pole placement include the presence at the site of noise walls, fences, guard rail, rock, narrow roadside clearances, ditches, steep slopes, standing water, power lines, nearby airports, traffic signals and nearby residential neighborhoods. Poles should be placed behind noise walls if the site permits and coordination is needed to be sure access, such as a doorway, is provided to the poles. Poles should not be placed directly next to a fence and care must be taken that the base of the pole has a minimum of three feet clear area for maintenance personnel. Poles should be placed at least three feet behind any existing guard rail to allow the guard rail to properly deflect upon impact but no more than seven feet to allow for a bucket truck to reach the luminaire for maintenance. Light poles should not be placed in ditch bottoms. When roadway lights are installed in conjunction with traffic signals, the lights should be installed on the same poles as the traffic signals, if possible.

Light pole placement on a long radius curve should be spaced the same distance as poles on a straight roadway. Pole placement on a short radius curve should be placed on the inside of the curve and require closer spacing in order to produce adequate pavement brightness on the curved section. Light poles on the inside of a banked curve should be placed such that they will not be hit by vehicles. Light pole placement should consider maintenance. Bucket trucks must be nearly level to operate and are limited in the height and distance from the roadway that the bucket can reach. Different types of trucks may have different working ranges. Poles should also be placed to minimize knockdowns.

10-4.02.02 Luminaires

A luminaire consists of an LED array with a power supply or a lamp, reflector, lens, and ballast, and a photocell (if required), and housing. There are several factors in choosing the type of luminaires that MnDOT approves. Some of those factors include:

- Efficiency of the luminaire in converting electrical energy to light,
- Ability of the luminaire to maintain light output over the course of the lamp life,
- Length of the LED or lamp life,
- Light color,
- Distribution of the light area.

All factors affect the cost and effectiveness of installing, operating, and maintaining the lights, and, therefore, affect the choice of light source. The luminaires are approved by the CO Lighting Unit and can be found on the MnDOT Approved Products List under Roadway Lighting.

In determining the light output for a luminaire, the lighting system designer must consider the luminaire light loss factor (LLF). This is a factor that is applied to the light output of a new luminaire (initial light output) to determine the light output of the luminaire after a fixed period of time (maintained light output). The AASHTO Roadway Lighting Design Guide discusses the different aspects of the light loss factor. With these considerations, the actual factor to apply to arrive at a maintained light output value for the luminaire is an educated guess. The LLF is different for each type of light source and is also dependent on how dirty the luminaires may become in a given area. LED light loss factors will vary by luminaire manufacturer. A standard LLF for an HPS lamp is .81. The LLF for LED luminaires is determined by luminaire testing. MnDOT's approved method of determining the LLF for an LED luminaire is in the luminaire specification found on the approved products list website. The value for MnDOT approved luminaires is located on the MnDOT Approved Products List.

The most commonly used luminaires for MnDOT roadway lighting typically has been the HPS "cobra head" style. MnDOT is now installing LED luminaires as a standard on our roadways. There are several advantages with using LED luminaires such as:

1. LED luminaires have a longer life expectancy than HPS, which may provide maintenance savings because of a reduction in the frequency of service of the luminaire.
2. LED Luminaires provide a white light that is often more desirable.
3. LED luminaires provide significant energy savings.
4. With some LED luminaires there is a reduction in upward lighting and glare.

Luminaires should only have a photocontrol receptacle and device when the lighting service cabinet does not provide photoelectric control or a lighting control system is used. Lighting control systems at each luminaire may replace the standard photocell on the cabinet if a control system is being utilized.

10-4.02.03 Electrical Service Point

The electrical service point (feedpoint) consists of a lighting service cabinet complete with circuit breakers and photoelectric control where applicable, a concrete foundation or wood pole for mounting, electrical connections to the electric utility service conductors, provisions for grounding, and a meter and meter socket when necessary. The District Traffic Office locates feedpoints from the electric utility company serving the area. The CO Lighting Unit should then be contacted to assign a feedpoint number.

The local electric utility company should be contacted early in the planning stage to determine the various locations where power is available for the project. The electric utility company should be given the voltage, lighting load (sum of the wattages of all the luminaires connected to the system), and any other pertinent information in the form of a letter to a electric utility company representative. The transformers necessary to provide the correct voltage and current are usually furnished and installed by the electric utility company. A sample copy of a letter is available in the MnDOT Roadway Lighting Design Manual.

It is always desirable to have the source of power located at a point nearest the center of the load. Service cabinets should be located:

1. Where they can be easily accessible for maintenance,
2. Will not obstruct the view of motorists,
3. Will not be prone to flooding,
4. Will not be prone to being hit, and
5. Located where highway electrical equipment currently exists or will probably be installed in the future.

Gates should be provided through the right-of-way fence where necessary. If the service cabinet is located at ramp terminals or at intersections on a one-way street, the best locations are in the far left quadrant or far right quadrant of the intersection.

The electric utility company may bring power of the proper voltage to a wood pole, or it may bring its primary voltage underground to a transformer on the concrete foundation with the service cabinet. When the electric utility company brings power to its wood pole, service to the cabinet comes through a weatherhead on the wood pole, through a conduit with drainage provisions, and into the cabinet. When the electric utility company comes to its transformer on the service cabinet foundation, service conductors come through conduit directly from the transformer to the cabinet.

The service cabinet should be a pad mounted type cabinet except for temporary lighting systems or where there is not space for a pad mounted cabinet, in which case a pole mounted cabinet would be installed. MnDOT approved cabinets are on the MnDOT Approved Products List.

A meter should be installed on the wood pole for wood pole service points, or mounted directly on the lighting service cabinet for cabinet foundation mounted transformer service points. The meter should be installed in an accessible location where the safety of personnel is not jeopardized, such as at the side of the road or on a frontage road, rather than in the median of a divided roadway. For some temporary systems, typically in rural areas, the district may request an agreement with the county or utility to pay a fixed monthly rate. This is becoming more uncommon.

Where available, the electrical service should be three-wire, 240/480 volts, 60-cycle alternating current. By using 240/480 volt service rather than 120/240 volt service, smaller wires can be used on the lighting branch circuits for the same lighting load.

For installations consisting of only 3 or 4 lights the smaller RLF cabinet mounted on the pad would be used instead of the larger Type L cabinet.

The branch circuit breakers in the standard Type L1, Type L2, Type A Type B or Type RLF lighting service cabinets are 20 ampere, 2 pole. The National Electrical Code allows circuit breakers to be loaded to only 80 percent of their ampere rating for loads that will be on for more than three hours. This means that the circuits should be designed so that there is no more than 16 ampere current on each phase wire. If it is not possible to limit the current to this value, additional branch circuits must be included to reduce the load current to an acceptable level.

10-4.02.04 Lighting Branch Circuits

The lighting branch circuits normally consist of three-wire single phase circuits, with two phase wires, one shared neutral wire, and a ground conductor. Each luminaire should be wired between a phase conductor and the neutral conductor, not between the two phase conductors. This means that on a 240/480 volt system, the luminaires should operate at 240 volts. On 120/240 volt systems, the luminaires should operate at 120 volts.

Where lighting is installed along the side of a roadway in a grassy area, the lighting branch circuits should utilize direct buried armored cable. Where the direct buried cable passes under roadways, it should pass through a Schedule 80 rigid PVC or HDPE conduit for protection and to avoid the need to break up the pavement to trench the cable in. See Figure 10-4: Typical Conduit Placement (Cloverleaf Interchange) and Figure 10-5: Typical Conduit Placement (Diamond Interchange). Conduit size under roadways should be a minimum of three inches to allow space for future conductors to be run under the roadway and should have bell ends on each end to prevent damage to the cable jacket. The conduit should be installed as part of the roadway paving plan.

Where the lighting is installed on a median barrier, a bridge, a tunnel wall, or an underpass, the lighting branch circuits should be individual conductors run through conduit and junction boxes. The conduit and junction boxes will normally be installed as part of the median barrier, bridge, tunnel, or underpass. Conduit installed in a median barrier will usually be Schedule 80 rigid PVC conduit, and conduit installed as part of a bridge or tunnel will usually be rigid steel conduit. Other types of conduit are currently being explored for use in a bridge. All conduit systems require an equipment grounding conductor that must be indicated in the plans along with the phase and neutral wires in the conduit.

Continuous lighting systems should include a standby cable and, if appropriate, conduit between the adjacent end lights on branch circuits from adjacent sources of power for flexibility in the wiring of the lighting units, for temporary wiring during future construction, or for maintenance purposes.

For the main lighting branch circuits, the conductors should be number 4 wires as defined by the American Wire Gage (AWG). The direct buried lighting cable that the State uses is normally manufactured in the number 4 AWG wire size. Because of its availability, the number 4 AWG should be used when direct buried lighting cable is used, even if a smaller wire size would be sufficient. If number 4 AWG wires result in a voltage drop in the wiring system (measured at the farthest light on the lighting branch circuit) of more than 3 percent of the system voltage, a larger wire size is necessary. The procedure for calculating voltage drop in a system is located in the MnDOT Lighting Design Manual.

Lighting circuits that serve an underpass light may be single conductors no smaller than number 10 AWG run in conduit.

Lighting branch circuits are frequently spliced to provide the necessary circuits to operate all of the lights in the system. Splices should be avoided where possible. When splices are necessary because of the layout of the system, they should be made only in light pole bases. A handhole and splices are acceptable in a permanent lighting system for underpass lighting if there is no good way to make the splice in a light pole base. Splices in handholes must be the approved two-way and three-way direct buried handhole splices found on the MnDOT Approved Products List under Roadway Lighting.

Direct buried splices should not be utilized in a permanent lighting system installation. Every splice in a wiring system is a potential point for wiring system failure. Splicing lighting branch circuit wires in the light pole bases are considered above ground and does not add extra splices since a splice is already required at each light pole base to connect the light to the system.

A 15-foot ground rod should be indicated in the plans at every alternate light base, and at the first and last light base on each lighting branch circuit.

10-4.03 Temporary Lighting

Providing temporary lighting may be desirable in construction areas or near at-grade intersections on highways where the warrants mentioned previously are met. The District Traffic Engineer may request the installation of temporary lights from an electric utility company, or the temporary lights may be installed by the contractor or State.

Lighting installed by the electric utility company is maintained by the electric utility company, and, while it may be their standard design, it must meet all the State's safety requirements. Temporary lighting installed by the State or the contractor may be maintained by the electric utility company, the State, or the contractor and is the State's or the contractor's design. Temporary lights in a construction zone are subject to being frequently moved, and so maintenance by the contractor is often the simplest to implement in that the State and the electric utility company do not have to keep track of what lights are where at any given time. When the contractor maintains the system, the contract documents should indicate that the contractor also is responsible for paying for the power. If temporary lighting is to be left in place at the end of a project, to be removed as part of a later project, it may be better for the state to maintain the system and pay for the power. Temporary lighting that is not part of an agreement with the electric utility company should be metered.

Power distribution to temporary lighting units is typically by means of self-supporting ACSR messenger quadplex aluminum cable. Quadplex cable should be used to provide the two phase wires, the neutral wire, and the ACSR messenger equipment ground wire. Aluminum wire should not be used if the lighting will be in place for a long period of time.

10-4.04 Sign Lighting

In general, MnDOT no longer uses sign lighting, however, there may be some instances when it is still desirable. LED luminaires will be used for lighting the signs. The spacing of the lighting units depends upon the width of the sign panel being illuminated.

A roadway lighting unit is the normal power source for a sign light. A means for disconnecting the light for maintenance is provided.

10-5.00 CONSTRUCTION

10-5.01 Field Placement of Light Poles

The exact locations of light poles may be adjusted to avoid obstructions encountered in the field. Such items as solid rock, power lines, slopes, existing guard rail, fences, ditches, standing water, etc., may make it necessary or desirable to locate the pole differently than is indicated in the plans - maintain a 3-foot clear area around the base of the light pole. The project engineer may stake the poles up to 10 feet along the direction of the roadway from the locations indicated in the plans. If a farther change is required, the project engineer should consult with the lighting system designer to determine if such a change requires changing the placement of other light poles in the system. The plans typically place the poles 19 to 26 feet behind the edge of the traveled roadway for davit. If this distance cannot be achieved, contact the District Traffic Office. If a noise wall exists at the location and is not indicated in the plans, light poles should be placed behind it if possible and a door installed in the wall for access to the light pole. If guardrail exists, clearance between the back of the guardrail and the front of the light pole should be at least 2 to 3 feet and no more than 7 feet. Do not place light poles in ditch bottoms. Poles should not be closer than 20 feet in any direction from power lines. If 20 feet cannot be maintained, contact the electric utility company.

10-5.02 Documentation

The project engineer should notify the District Traffic Engineer of the date the lights are energized. The district should then notify the electric utility company of this date, in writing for billing purposes, with a copy to the District Lighting Unit.

The project engineer should document any field changes to the lighting system on final “as-built” plan sheets. These “as-built” plans should be kept by the District Lighting Unit with a copy being sent to the Electrical Services Unit Locate Office.

The Automated Facility Management System (AFMS) must also be updated to show the new lighting and the parties responsible for operation and maintenance.

The MnDOT Standard Specifications for Construction requires the electrical distribution system to be tested for insulation resistance and short circuits to ground. The contractor should document the results of these tests and deliver the documentation to the project engineer.

When a municipality is participating in the cost of installing or maintaining the lighting system, the city utility engineer should attend the final inspection of the lighting system.

10-6.00 OPERATION AND MAINTENANCE

10-6.01 General

Operation of the lights involves supplying power to the light and paying all power costs. Maintenance of the lights includes maintaining everything within the system from the point of attachment to the power source or utility, to the last light from the feed point and is described in the Cost Participation Policy.

Responsibility for operating and maintaining lighting systems is detailed in the agreement and may fall upon the electrical utility company, the local governing body, and/or the State. Responsibility may include performing maintenance, paying for maintenance, and/or paying for power. If a different party performs maintenance work than is responsible for its cost, the cost should be reimbursed.

The following are some definitions for lighting maintenance including power cost. See the Cost Participation for more information:

Power Cost

All energy costs associated with the lighting system after the system has been turned on.

Hook Up Fees

This includes charges from the electric utility for hooking up the service.

Luminaire Maintenance

This includes, but is not limited to, relamping lighting units or replacing of LED luminaires, repair or replacement of all damaged luminaire glassware, loose connections, luminaires when damaged or when the ballast fails, photoelectric controls on luminaires defective starter boards or drivers, and cleaning glassware.

Luminaires must be replaced when they no longer provide required light levels. This will be based on the light loss factor used during design. Current design requires luminaires to be replaced in 18 to 20 years from installation.

Pole or Knockdown Maintenance

This includes, but is not limited to, replacing damaged fuse holders and blown fuses, repairing or replacing the pole when knocked down (including the wiring within the pole), replacing damaged poles, and painting poles when applicable.

Underground Maintenance (including all wiring from the line side of the fuse kit to the source of power)

This includes, but is not limited to, repairing or replacing handholes or pullboxes when needed, repairing underground wire, locating underground wire, installing approved splices or replacing wires, and repairing or extending conduit.

Light Foundation Maintenance

This includes repairing damaged foundations, repairing or replacing bolts, repairing concrete, and repairing conduits.

Cabinet and Pad Maintenance

This includes a complete lighting cabinet, maintenance including photoelectric cell, repairing the equipment pad or anything located on the pad, and repairing the electrical distribution system.

10-6.02 Budgeting (MnDOT)

Payment for Energy - The district should budget for the energy bills for roadway lighting for which the State has responsibility.

Payment for Painting of Poles - Where the department has the responsibility of pole maintenance, the painting of light poles and bases should be arranged for, budgeted, and paid for by the district.

10-6.03 Maintenance (MnDOT)

10-6.03.01 Maintenance Procedures

The District Traffic Engineer is responsible for the monitoring and asset management of all lighting owned by MnDOT within their district. The District and the Electrical Services Unit are responsible for entering all lights that are either inoperable or knocked down into AFMS.

When either the Metro or Regional Electrical Services Unit is responsible for the repair they will update AFMS when they complete work. When the work is entirely complete the work order should be closed out.

10-6.04 Obtaining Electrical Power from MnDOT Lighting or Signal Systems

Other MnDOT offices as well as non-MnDOT agencies are discouraged from obtaining electrical power from MnDOT Lighting and Signal equipment. Only in rare circumstances, and after all other options have been exhausted with the local electric utility company, the requester may request to obtain power from a MnDOT Lighting or Signals system. All costs incurred by the new installation should be paid for by the requester.

In order to assure safe and efficient operation of all equipment and to monitor electrical power sharing and billing, approval must be obtained from the District Traffic Office, MESU or ESU before installation and certain procedures must be followed.

The following procedures vary depending on what agency requests the power and the type of equipment involved.

10-6.04.01 Lighting Cabinet or Unit

Process

1. The requester seeking electrical power should submit a scaled CADD plan sheet, signed by a professional engineer or master electrician, of the proposed installation to the District. The drawing shall include the reason for the request as well as the intended electrical loading.
2. The District Traffic Engineer will review the information with ESU, and will work with the requester to develop an acceptable proposal.
3. The requester shall contact the local electric utility company to notify them of the installation and set up a billing procedure. Documentation of this agreement shall be sent to the District prior to the start of construction.
4. If the request is approved, the applicable requirements from the following list and the general requirements must then be fulfilled.

Requirements

- If a MnDOT lighting unit is the power source, a 6 amp in-line fuse on a 240v system or an 8 amp fuse on a 120v system must be provided in the lighting unit. This fuse holder must be a MnDOT approved breakaway type and be labeled as to its use. If the MnDOT lighting unit is operated from a photocontrol device at the lighting cabinet, the circuit is only energized at night. If the lighting unit is part of a metered system you will not be able to separate power use when doing this. The District Traffic Office will be charged for the power of the system being powered using the lighting unit. If this is undesirable then other options must be used.
- If a MnDOT lighting cabinet is the power source, a separate circuit breaker shall be provided and labeled as to its use. Power to the circuit breaker must bypass the photocontrol device unless the new installation is intended to be photocontrolled.
- For metered lighting systems the lighting cabinet may be used as a power source and a separate meter will be required. The conductors that supply the service shall be sized to supply both meters. This will be done by the requester at no cost to MnDOT.

- The installation must be inspected by ESU and the required electrical permits be obtained from the local electrical inspector to insure code compliance and safety to maintenance personnel and the public. ESU shall be notified as soon as a construction date is determined.
- All additional conductors and cables shall be labeled within the Mn/DOT lighting system.

10-6.04.02 Signal System

A signal system is defined as any cabinet containing traffic signal, traffic management, or traffic recording equipment.

The signal system refers to any cables that lead into or out of the signal cabinet. Power shall not be obtained from inside the signal cabinet. Power can be obtained from the service equipment/service cabinet or from the unmetered lighting conductors in the signal bases. If the lighting conductors are to be used as the power source, follow the requirements for obtaining power from a lighting unit as follows:

Requirements

- A separate circuit breaker shall be provided and labeled as to its use. Power to the circuit breaker must be obtained from the unmetered side of the load center or ahead of the meter. A separate meter will be required by the electric utility company.
- All additional conductors and cables shall be labeled within the MnDOT signal system.
- The installation must be inspected by ESU and the required electrical permits be obtained from the local electrical inspector to insure code compliance and safety to maintenance personnel and the public. ESU should be notified as soon as a construction date is determined.

General

- MnDOT may disconnect the system without prior notice if the installation interferes with the operation of the MnDOT system.
- If MnDOT relocates or moves the system providing power, it is the requesting office's responsibility to reconnect to MnDOT's system or to find an alternate source of power.
- The requester shall submit as-built plan sheets, signed by a professional engineer or master electrician, to the District within 48 hours of connection into a MnDOT system.
- Only a certified electrician will be allowed access to the systems used as the power source. Prior notification must be given to the District or ESU.
- The requesting office will be responsible for maintaining all equipment after the power source.
- The requesting office shall provide the District and ESU or MESU with contact information for the party who will be performing maintenance on the system.
- The requesting office shall identify a contact person within the office.
- The requesting office must be, or become, a registered owner with Gopher State One Call and be responsible for locating the cable from the MnDOT power source to the location being served.

10-6.04.03 Special Additional Requirements for a Non-MnDOT Agency

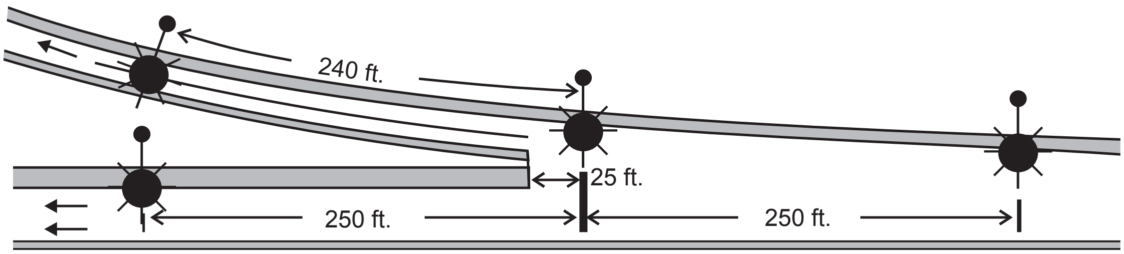
A MnDOT permit will be required for any installation request.

10-7.00 REFERENCES

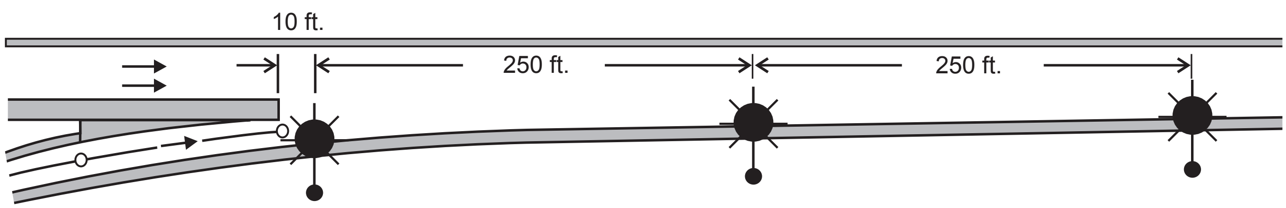
The AASHTO Roadway Lighting Design Guide and the IES American National Standard Practice for Roadway Lighting RP-8 contain many additional references, including references for high mast tower lighting and tunnel lighting.

1. American National Standard Practice for Roadway Lighting, ANSI/IES RP-8, Current Edition. Illuminating Engineering Society, 120 Wall Street, New York, New York 10005.
2. American National Standard Practice for Tunnel Lighting, ANSI/IES RP 22, Current Edition.

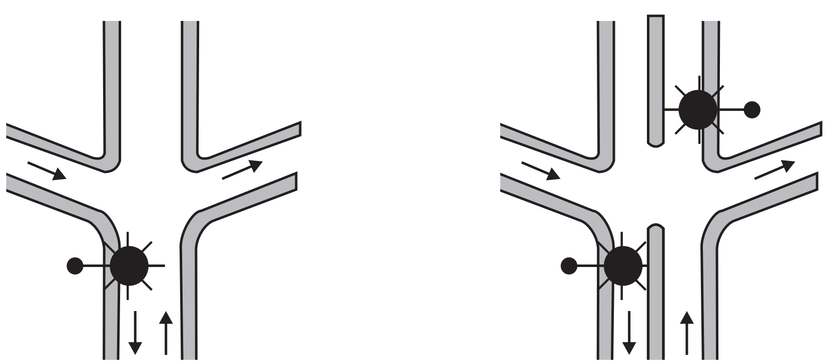
1. Illuminating Engineering Society, 345 East 47th Street, New York, New York 10017.
2. The Roadway Lighting Design Guide, October, 2005 and Current Edition. American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, D.C. 20001.
3. Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD), Current Edition.
4. A Policy on Geometric Design of Highways and Streets, Current Edition American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, D.C. 20001.
5. Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, Current Edition. AASHTO, 444 North Capitol St. N W., Suite 225, Washington, D.C. 20001.
6. Illuminating Engineering Society of North America Lighting Library.



DECELERATION LANE



ACCELERATION LANE

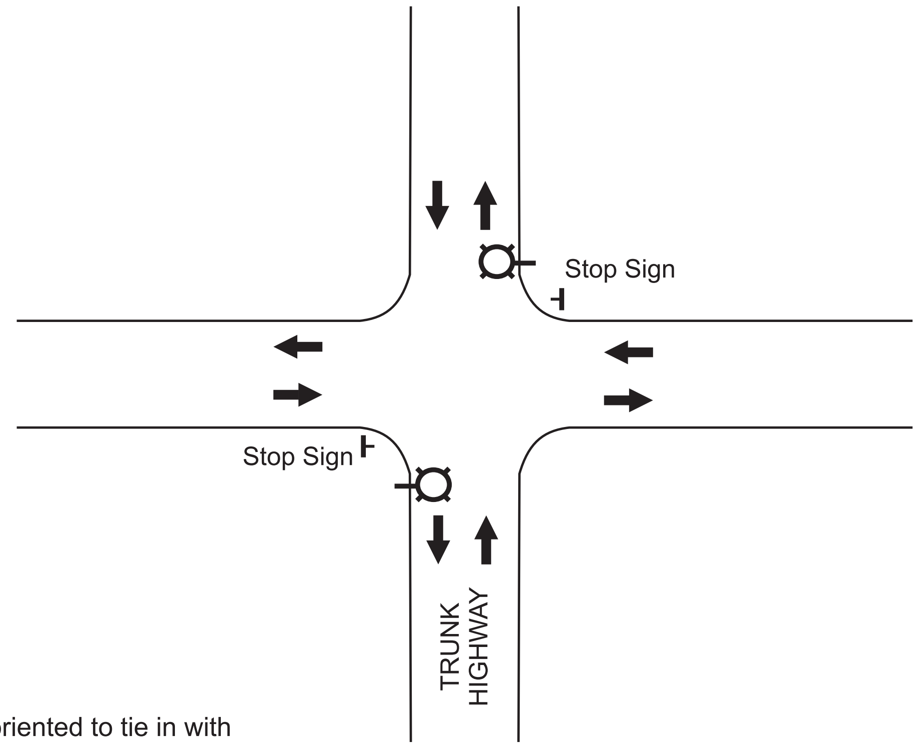


SIMPLE CROSSROAD RAMP TERMINALS

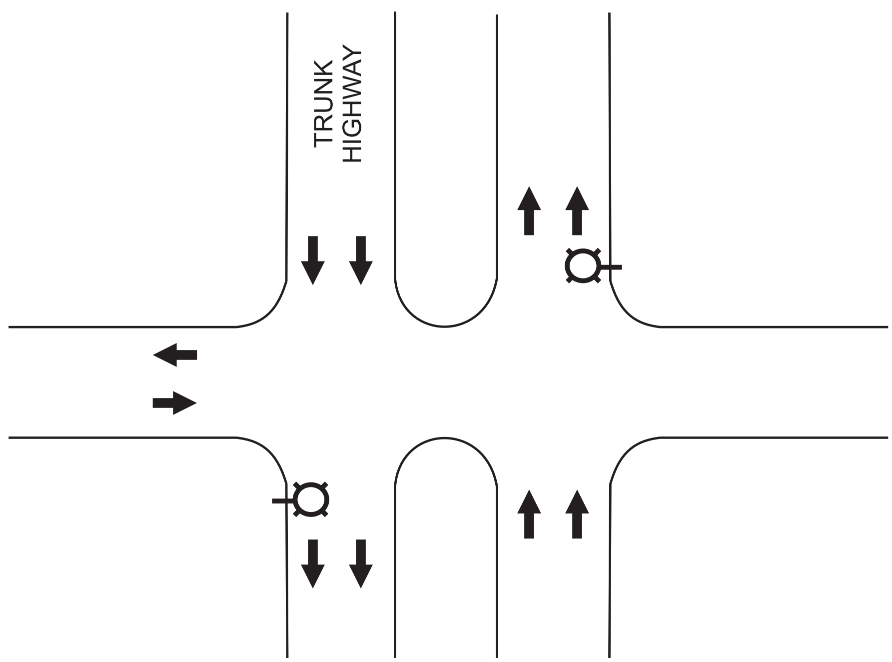
DIVIDED CROSSROAD RAMP TERMINALS

Text Ref.: 10-4.01.02

January 1, 1996	TYPICAL LUMINAIRE LOCATIONS PARTIAL INTERCHANGE LIGHTING DAVIT ARM POLES	FIGURE 10.1



NOTE:
Luminaires may be oriented to tie in with existing or proposed city or county lighting systems.



Text Ref.: 10-4.01.12

January 1, 1996	**STANDARD ILLUMINATION PLAN FOR INTERSECTIONS**	**FIGURE 10.2**

Pole Type Designations generally contain:

1. Mast Arm Length,
2. Type of Pole, and
3. Nominal Pole Height.

The designation appears in the following order:

Mast Arm Length, Type of Pole - Nominal Pole Height

1. Mast Arm Length

The first character before the dash is the mast arm length, usually 6 feet, 9 feet, or 12 feet.

2. Type of Pole

The character(s) just preceding the dash indicate the type of pole used, see the list below. If no characters are in this position, the pole has a transformer base or high base, is intended for mounting on a light base, and has no finish for an aluminum or stainless steel pole or is galvanized for a steel pole.

The pole type characters are as follows:

A - Anchor bolt pole (no transformer base)
B - Barrier or bridge mounting (6 bolt cluster)
C - Corten steel (no finish applied)
D - Double mast arms
M - Ornamental style pole
P - Painted pole
S - Combination traffic signal and street light pole
W - Wood pole lighting unit (for temporary lighting)
X - Decorative pole (usually square arms)
VM - Vertical mount

3. Nominal Pole Height

The characters after the dash give the nominal pole height.

<u>**EXAMPLES:**</u>

9-40

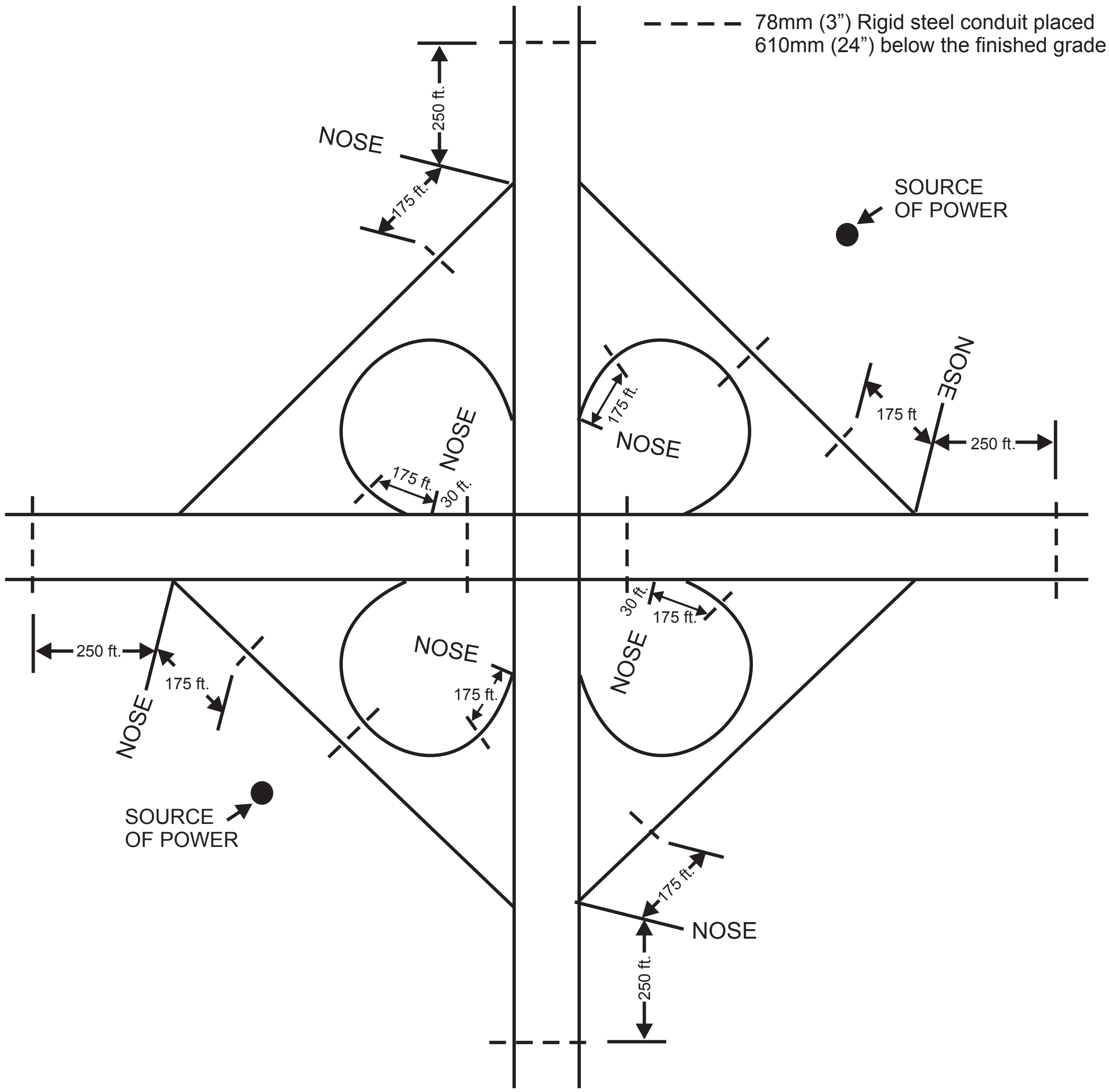
9 foot mast arm with 40 foot mounting height, transformer base or high based, and aluminum or stainless steel as indicated in the plans.

6BD-40

6 foot double mast arms with 40 foot mounting height, provisions for barrier mounting.

VMD-45

Tenon mount double vertical luminaire with 45 foot mounting height.



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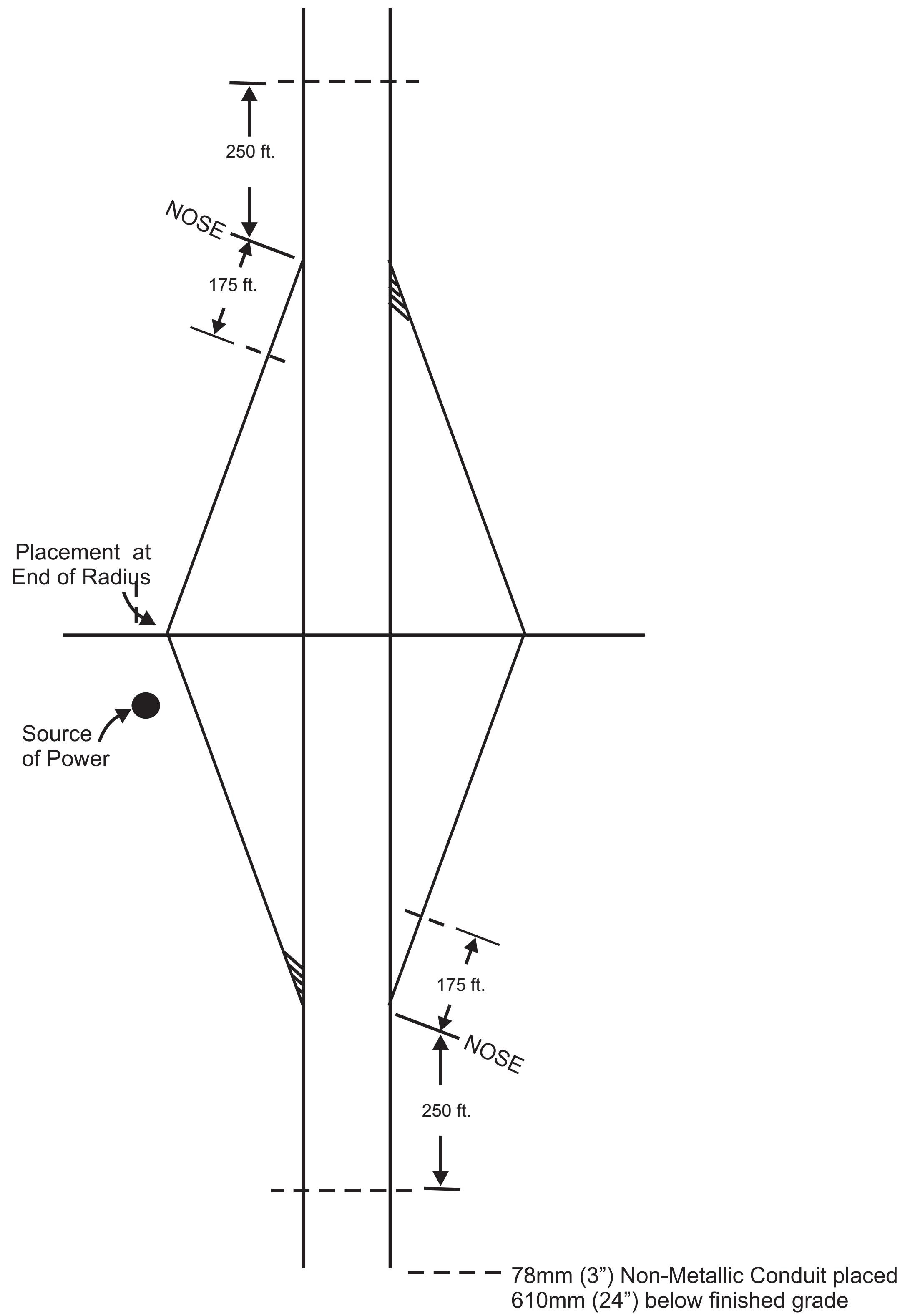
January 1, 1996	**TYPICAL CONDUIT PLACEMENT (CLOVERLEAF INTERCHANGE)**	**FIGURE 10.4**



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January 1, 1996	TYPICAL CONDUIT PLACEMENT (DIAMOND INTERCHANGE)	FIGURE 10.5

LIGHTING OF TRAFFIC FACILITIES

Appendix A
Voltage Drop Calculations

10-8.00 APPENDIX A: VOLTAGE DROP CALCULATIONS

VOLTAGE DROP CALCULATIONS

A voltage drop calculation shows the amount of voltage that will be present at the farthest luminaire on a lighting branch circuit. The voltage drop is of concern in order to assure that the voltage at all luminaires will be sufficient for the luminaires to operate properly, and also to avoid inefficient operation of the lighting system due to a large amount of power being dissipated in the electrical distribution system (wires).

The wires carrying current to the luminaires in the lighting system have a small amount of resistance. The resistance of the wire depends on the size (gauge) of the wire, the material of the wire, and the length of the wire. When current flows through the wires on its way to the luminaires, a voltage proportional to the resistance and to the current is developed along the length of the wire. This voltage subtracts from the voltage at the source of power and results in a lower voltage at the luminaire. If the resistance of the wire is too high for the amount of current flowing through it, the voltage dropped along the wire will be too high to allow sufficient voltage at the luminaire. The National Electrical Code suggests a value of 3 percent of the system voltage to be a reasonable limit to the amount of voltage drop to allow in the lighting branch circuit. The voltage along the wire multiplied by the current flowing through the wire yields the power dissipated in the wire. The higher the resistance of the wire, the higher the voltage dropped along the wire, and the more power is used up by the wiring system. The voltage drop calculation determines the size (gage) of wire of a specified material that is necessary to carry the required current the required distance without creating too large of a loss in the wire.

The basic equation that is used to determine the voltage drop in a lighting branch circuit is Ohm's Law

E = I x R, where:

- E is the voltage drop along a segment of wire,
- I is the current through the same length of wire, and
- R is the resistance of the length of wire.

This equation is only completely accurate for direct current systems. With the current in the branch circuits limited to 20 ampere by the circuit breakers, and the frequency of the power at 60 hz, the equation is fairly accurate for the lighting branch circuits also.

E is the unknown value that is sought. I (for any segment of wire) is calculated by adding the currents for each luminaire the particular segment of wire feeds (i.e. all the luminaires downstream on that wire). R (for a particular segment of wire) is calculated by multiplying the length of the wire (in thousands of feet) in that segment by the resistance per 1000 feet of wire for that particular size and material of wire. The total voltage drop to the farthest luminaire is calculated by adding the voltage drops for each segment of wire from the service cabinet to that luminaire. The current for a single luminaire of various types and the resistance values for several types of wire is given in Figure 10.7, "Voltage Drop Calculation Values"

The voltage drop must be calculated for the phase wire (hot wire, ungrounded wire) and for the neutral wire (grounded wire), and these voltages must be added together to arrive at the total voltage drop. In a two-wire circuit, the current that travels out in the phase wire must return in the neutral, and so the current in the neutral wire is the same as the current in the phase wire. The total voltage drop in the two-wire circuit, then, can be calculated by figuring the voltage drop in just the phase wire and multiplying that number by 2.

Most of the lighting branch circuits in lighting systems designed by the state are three-wire single phase circuits. A three-wire circuit consists of two phase wires and a neutral wire instead of one phase wire and one neutral wire as in the two-wire circuit. In a three-wire circuit, the neutral is at approximately zero volts with respect to the ground. The two phase wires share the same neutral and are at opposite voltages with respect to the neutral wire For example, if at some given time the voltage in one phase wire was 240 volts with respect to the neutral wire, then the voltage in the other phase wire at that same time would be -240 volts with respect to the neutral wire. The significance of this voltage arrangement is that the current returning in the neutral wire from one of the phase wires will cancel out the current returning in the neutral wire from the other phase wire.

Thus, if the loads on the two phase wires are exactly balanced, there will be no current in the neutral wire, and, therefore, no voltage drop in the neutral wire In this case, the total voltage drop to the farthest luminaire is simply the total voltage drop in the phase wire, and the neutral wire can be disregarded.

Two examples of a voltage drop calculation are shown below. One example is for single luminaires wired to alternate phase wires as is typically done. The second example is for double luminaire poles such as might be found on a median barrier. Two different voltages are used in the examples to illustrate the application of the voltage drop at different voltages.

EXAMPLE ONE: SINGLE LUMINAIRES

The system in this example consists of 250 watt high pressure sodium luminaires on poles 130 feet apart. The wires are number 4 gage single conductor wires in a conduit system. This is a 120/240 volt lighting system. There are 9 lights total on the lighting branch circuit, with the lights wired to alternate phase wires. A circuit such as this might be found in a downtown city street light system.

A wiring diagram for the lighting branch circuit is shown in Figure 10.9 “Voltage Drop Calculation Examples.” The wire segment labels and the distances between the lights are also shown on the diagram.

From Figure 10.8, “Voltage Drop Calculation Values,” the current for a 250 watt high pressure sodium luminaire at 120 volts is 2.9 ampere. The resistance for number 4 gage copper wire is 0.259 ohms per 1000 feet. The following table calculates the voltage drop in the phase wire for each wire segment and gives the total voltage drop. The distance is a given from the layout of the system. The resistance is calculated by multiplying the distance in thousands of feet by the resistance per thousand feet. The current is calculated by multiplying the number of luminaires downstream of each wire segment by 2.9 ampere per luminaire The voltage drop in each segment of wire is calculated by multiplying the current in each wire segment by the resistance of each wire segment The total voltage drop is calculated by adding the voltage drops of all the wire segments. The current in the neutral wire is disregarded for this calculation. Depending on the system layout, the voltage drop in the neutral may add to the total voltage drop or subtract from the total voltage drop as calculated. The contribution of the voltage drop in the neutral wire is negligible compared to the voltage drop in the phase wire if the system is reasonably balanced

Wire Segment	Distance	Resistance	Current	Voltage Drop
A	0.06	0.051	14.5	0.7395
B	0.09	0.0765	11.6	0.8874
C	0.09	0.0765	8.7	0.6656
D	0.09	0.0765	5.8	0.4437
E	0.09	0.0765	2.9	0.2219
TOTAL				**2.958**

Since 3 percent of 120 volts is 3.6 volts, this value is acceptable, and the number 4 wires can be used. The calculation would be identical if three conductor number 4 armored cable were used instead of the single conductor number 4 gauge wires. Had number 6 gage wires been used, the resistance would be 0.410 ohms per 1000 feet and the voltage drop would have been 4.2805 volts. This is more than 3 percent of 120 volts, and so number 6 gauge wires are too small.

EXAMPLE TWO: DOUBLE LUMINAIRES

The system in this example consists of 250 watt high pressure sodium luminaires on poles 75 m apart with two luminaires on each pole. The wires are number 4 gage single conductor wires in a conduit system. This is a 240/480 volt lighting system. There are 16 lights total on the lighting branch circuit, with one light wired to each phase wire at each pole. A circuit such as this might be found in the median of a freeway.

A wiring diagram for the lighting branch circuit is shown in Figure 10.9. “Voltage Drop Calculation Examples.” The wire segment labels and the distances between the lights are also shown on the diagram.

From Figure 10.8, “Voltage Drop Calculation Values,” the current for a 250 watt high pressure sodium luminaire at 240 volts is 1.4 ampere. The resistance for number 4 gage copper wire is 0.259 ohms per 1000 feet. The following table calculates the voltage drop in the phase wire for each wire segment and gives the total voltage drop. The voltage drop in each segment of wire is calculated in the same manner as in example one. The current in the neutral wire is disregarded for this calculation. If only double luminaire poles are on the branch circuit, the load is exactly balanced at all points on the circuit, there is no current anywhere in the neutral, and the voltage drop is correct as calculated.

Wire Segment	Distance	Resistance	Current	Voltage Drop
A	0.06	0.051	11.2	0.5712
B	0.075	0.06375	9.8	0.62475
C	0.075	0.06375	8.4	0.5355
D	0.075	0.06375	7	0.44625
E	0.075	0.06375	5.6	0.357
F	0.075	0.06375	4.2	0.26755
G	0.075	0.06375	2.8	0.1785
H	0.075	0.06375	1.4	0.08925
TOTAL				**3.0700**

Since 3 percent of 240 volts is 7.2 volts, this value is acceptable, and the number 4 wires can be used. Had number 6 gauge wires been used, the resistance would be 0.410 ohms per 1000 feet and the voltage drop would have been 4.7757 volts. This value is still less than 3 percent, and so number 6 gauge wire could have been used. Had number 8 gauge wire been used, the resistance would be 0.6404 ohms per 1000 feet and the voltage drop would have been 7.4594 volts. Therefore, number 8 gauge wire should not be used.

Current in AMPS for High Pressure Sodium Luminaires

Luminaire Voltage	Lamp Wattage			
	150	200	250	400
120	1.7	2.1	2.9	4.1
240	0.9	1.1	1.4	2.1

Resistance of Conductors in Ohms Per 1000 Feet

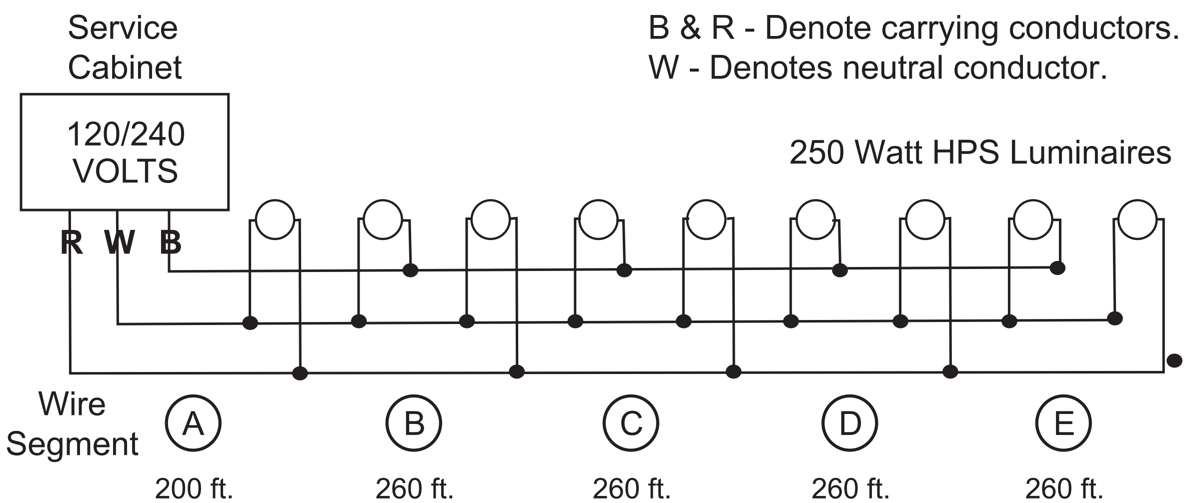
Conductor Material	Conductor Size (AWG)			
	12	10	8	6
Copper	5.31 (1.62)	3.44 (1.018)	2.10 (0.6404)	1.35 (0.410)
Aluminum	8.73 (2.66)	5.48 (1.67)	3.44 (1.05)	2.21 (0.674)

Conductor Material	Conductor Size (AWG)			
	4	2	0	00
Copper	0.85 (0.259)	0.53 (0.162)	0.33 (0.102)	0.27 (0.0811)
Aluminum	1.39 (0.424)	0.84 (0.266)	0.55 (0.168)	0.11 (0.133)

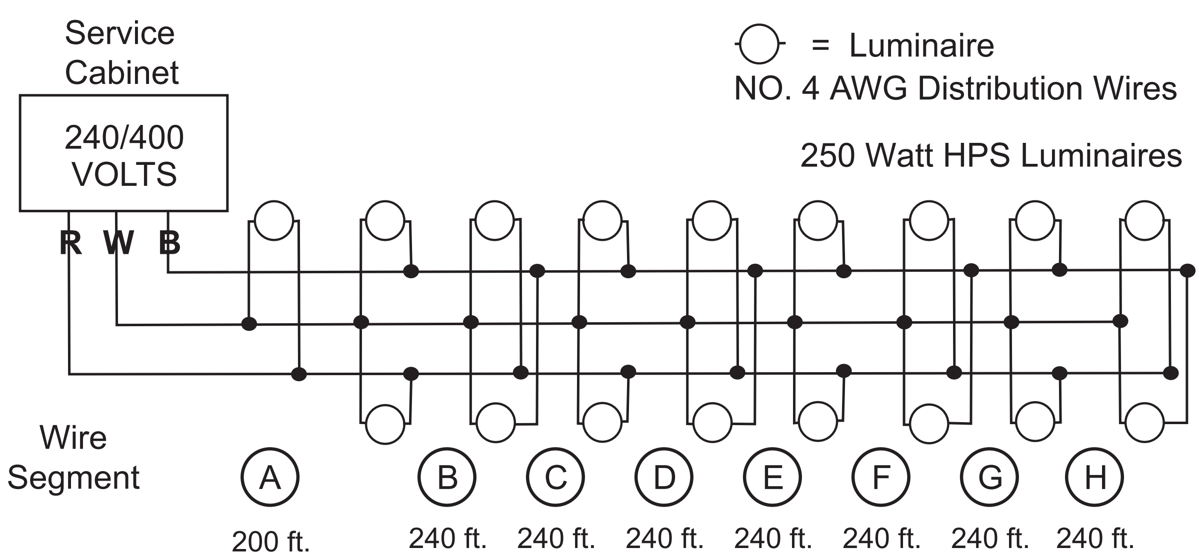
Text Ref.: Chapter 10 Appendix

June 2015	VOLTAGE DROP CALCULATION VALUES	FIGURE 10.6

EXAMPLE ONE



EXAMPLE TWO



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June 2015	VOLTAGE DROP CALCULATION EXAMPLES	FIGURE 10.7