Chapter 10
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 the preferred practice in Minnesota 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 to be a guideline rather than a standard. Together with other documents, this chapter gives guidelines for lighting installations on roadways, underpasses, tunnels, rest areas, weigh stations, parking lots, lighted signs, and bridges.

The principal reference for lighting design is the "Roadway Lighting Design Guide" published by the American Association of State Highway and Transportation Officials (AASHTO), hereafter referred to as the AASHTO Guide.

The AASHTO 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" published by the Illuminating Engineering Society and the National Electrical Code" published by the National Fire Prevention Association. Other references are listed at the end of the chapter.

10-1.03 Chapter Organization

Following this introduction is a glossary. Following the glossary are step by step procedures for producing a lighting project. Next follows detailed information about the design of lighting systems. A section discussing the construction of lighting systems is included followed by operation and maintenance considerations. A listing of references follows. The appendix details the method for calculating voltage drops in lighting system wires. Figures are included throughout the text.

10-2.00 GLOSSARY

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 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.

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 roadway 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 Mast Arm - One-piece shaft which curves from vertical to horizontal.

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.

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 - Transformer base which tapers from a base plate to a smaller shaft.

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.

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

Light-Loss Factor - A depreciation factor which is applied to the calculated initial average footcandle (lux) to determine the value of depreciated average illumination at a predetermined time in the operating cycle, usually just prior to relamping, and which reflects the decrease in effective light output of a lamp and luminaire during its life.

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.

Luminaire - A complete lighting fixture consisting of a lamp or lamps together with the ballast, reflector, refractor, photocell when required, and the housing.

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 which consists of a few luminaires located in the vicinity of some or all ramp terminals. The usual practice is to light those general areas where the exit and entrance ramps connect with the through traffic lanes and those areas where the ramps intersect the crossroad.

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.

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.

Specular Glare - Glare resulting from light being reflected from polished or glossy surfaces.

Transformer Base - A box-like structure between the foundation and pole base plate which can be used to accommodate the ballast and the underground wiring 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.

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 it 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 Office of State Aid will request the District Traffic Engineer for any assistance it needs it to handle the project. Local jurisdictions may also, with proper permission, 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 the Mn/DOT regardless of the agency installing

The district initiates state administered lighting projects.

The following steps are necessary for completing a lighting project:

1. Programming the project
2. Negotiating with local authorities and utilities
3. Implementing a work authority
4. Preparing plans
5. Preparing special provisions
6. Preparing agreements
7. 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 which 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 for which 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 Guide, with the modifications and additions indicated below:

Continuous Freeway Lighting

Case CFL-1 - Continuous freeway lighting is considered to be warranted on those sections in and near cities where the current ADT is 40,000 or more.

Case CFL-2 - Continuous freeway lighting is considered to be warranted on those sections where three or more successive interchanges are located with an average spacing of 1-1/2 miles or less, and adjacent areas outside the right-of-way are substantially urban in character.

Case CFL-3 - Continuous freeway lighting is considered to be warranted where for a length of 2 miles or more, the freeway passes through a substantially developed suburban or urban area in which one or more of the following conditions exist:

a. local traffic operates on a complete street grid having some form of street lighting, parts of which are visible from the freeway;

b. the freeway passes through a series of developments such as residential, commercial, industrial and civic areas, colleges, parks, terminals, etc., which includes roads, streets and parking areas, yards, etc., that are lighted;

c. separate cross streets, both with and without connecting ramps, occur with an average spacing of one-half mile or less, some of which are lighted as part of the local street system; and

d. the freeway cross section elements, such as median and borders, are substantially reduced in width below desirable sections used in relatively open country.

Case CFL-4 - Continuous freeway lighting is considered to be warranted on those sections where the ratio of night to day crash rate is at least 2.0 or higher than the state wide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate.

Continuous lighting should be considered for all median barriers on roadway facilities in urban areas. In rural areas each location must be individually evaluated as to its need for illumination.

Complete Interchange Lighting

Complete interchange lighting generally is warranted only if the mainline freeway has continuous lighting.

Partial Interchange Lighting

Case PIL-1 - Partial interchange lighting is considered to be warranted where the total current ADT ramp traffic entering and leaving the freeway within the interchange areas exceeds 5000 for urban conditions, 5000 for suburban conditions, or 2500 for rural conditions.

Case PIL-2 - Partial interchange lighting is considered to be warranted where the current ADT on the freeway through traffic lanes exceeds 25,000 for urban conditions, 20,000 for suburban conditions, or 10,000 for rural conditions.

Case PIL-3 - Partial interchange lighting is considered to be warranted where the ratio of night to day crash rate within the interchange area is at least 1.25 or higher than the state wide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate.

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

The AASHTO 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 Guide exist or if one or more of the following conditions exists:

1. **Volume -** The traffic signal warrant volumes for the minimum vehicular volume warrant, the interruption of continuous traffic warrant, or the minimum pedestrian volume warrant are satisfied for any single hour during conditions other than daylight, excluding the time period between 6:00 a.m. and 6:00 p.m. See the "Traffic Signals" chapter of this manual and the "Signals" chapter of the "Minnesota Manual on Uniform Traffic Control Devices" (MN MUTCD) for further information about traffic signal warrants.

2. **Crashes -** There are three or more crashes per year occurring during conditions other than daylight.
3. **Intersecting Roadway -** The intersecting roadway is lighted.
4. **Ambient Light -** Illumination in areas adjacent to the intersection adversely affects the drivers' vision.
5. **Channelization -** The intersection is channelized and the 85th percentile approach speed exceeds 40 miles per hour. A continuous median is not considered as channelization for the purpose of this warrant.
6. **School Crossing -** Scheduled events occurring at least once per week during the school year make it necessary for 100 or more pedestrians to cross at the school crossing during any single hour in conditions other than daylight, or a traffic engineering study indicates a need for lighting.
7. **Signalization -** The intersection is signalized.
8. **Flashing Beacons -** The intersection has a flashing beacon.

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

10-3.02 Programming

The Transportation District Engineer is responsible for requesting Planning and Programming to encumber funds for lighting installations.

10-3.03 Negotiations

In most instances, lighting installations involve negotiations and agreements with local authorities and power companies. The responsibility for negotiating with municipalities, counties, railroads, and power 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 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. A function 1 work authority is for preliminary design, function 2 is for detail design, and function 3 is for construction. Where the lighting design is part of the road plans, the engineer in charge of the road design 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 or the Lighting Unit in the Office of Traffic, Safety, and Technology (OTST) designs the lighting system and drafts the plans for lighting systems that will be installed under a state contract.

The lighting plans should include a title sheet showing the project location and description, the state and federal project number(s), the area and job number(s), appropriate signature lines, roadway design values, legends and symbols, a list of scales, and a plan index. Appropriate symbols are contained in the Mn/DOT road design "Technical Manual."

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.

Also included in the lighting plans should be a statement of estimated quantities. Normally, the lighting system pay items are itemized showing items for conduit, cable, light standards, etc. 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 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.

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

All luminaires and sign lights indicated in the plans should be labeled with a unique number. Numbers for roadway, tunnel, and underpass luminaires should consist of the feedpoint number above a number indicating the luminaire on that feedpoint. The luminaires should be numbered consecutively. Sign light numbers should consist of the feedpoint number above a letter indicating the sign light on that feedpoint and should be numbered from left to right separately for signs facing each direction of travel on the roadway.

The plans should include wiring diagrams to detail the wiring of the lighting circuits and to show wire sizes.

Information sheets should be included when appropriate.

The designer must contact the appropriate power company to establish source of power(s). The power company may require extra equipment and have an electrical service charge. All communications with the power company shall 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 given in the plans or in the Mn/DOT Standard Specifications for Construction, as well as information that is to be specially brought to the bidders' attention. This information may include an explanation of the electrical distribution system, materials specifications for materials that are not in the standard specifications book, construction requirements that are not included in the standard specifications book, 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 special provisions for lighting systems. The Lighting Unit may help if requested.

10-3.07 Preparation of Agreements

An agreement is a legal document detailing the cost responsibility of the various parties involved in installing, maintaining, and providing power to a lighting system. The district prepares agreements for lighting that is not a part of a road construction project.

Agreements for lighting that is a 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 and one or more power company, railroad, or municipality (city or county). An agreement with a railroad is described below, followed by a description of an agreement with a power company and then with a municipality. The terms of the agreements will be unique to each lighting project, and so only the general considerations are presented.

10-3.07.01 Agreement with a Railroad

Agreements and permits may be necessary for power cables over or under railroad tracks. Highway maintenance funds should be used for any costs incurred.

10-3.07.02 Agreement with a Power Company

Mn/DOT typically meters all roadway lighting and an agreement with the local power company is not needed. In rural locations, it may make sense to have an agreement with the local power company.

An agreement with a power company details the method of paying for power for the lights, certain maintenance of the lights, and possibly for providing power company owned lights. Rates for highway lighting may include maintenance such as luminaire and glassware maintenance and cleaning, lamp replacement, ballast maintenance, and photo-cell maintenance in addition to supplying electrical energy. The service cabinet, wiring system, and pole knockdowns are almost always maintained by the state and are not part of an agreement with the power company. Agreements with power companies should be open ended agreements such that additions or changes to the number and types of lights covered may be made by properly processing an exhibit showing the addition or change. A flat rate is then charged for each light fixture of each particular type.

The rates charged by power companies, except municipal utilities, are regulated by the Minnesota Public Service Commission. The power company must set forth these conditions in a letter to the Commission 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 Commission. Municipal utilities are regulated by the residents of the municipalities which own and operate them rather than by the Minnesota Public Service Commission.

When power company owned lights are to be provided, the district traffic office should prepare a preliminary exhibit containing the name of the power company, location, type, and number of lights, and send it to the Lighting Unit of the OTST for processing. If the state does not have an open ended agreement with the power company to provide power company owned lights, the district may request the Lighting Unit to write one. Agreements for power company owned lights should include maintenance by the power company.

Agreements with the power 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.

Exhibits are necessary for additions and changes to existing open ended agreements. An exhibit is a reduced copy of a lighting plan layout sheet and shows the exhibit number, the highway, the city if applicable, the power company, the feedpoint number, and the total number of lights of each type after the addition or change. Attached to the layout is a Signature sheet indicating the exhibit number, the number and date of the open ended agreement which is being altered by the exhibit, and a summary of the changes. The district notifies the power company of the date of effect of the change once the lights have been turned on.

Two copies of all exhibits are sent to the Electrical Services Section 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, and power cost 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 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 state lighting cost participation policy found at www.dot.state.mn.us/stateaid/forms/dsll 1.pdf. Such factors as the location of the lights, 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.

The recommended cost splits are as described below:

1. **Trunk Highways - Freeway (Limited Access Including Interstate)**
   a. The state will determine what portions of freeway type highways will be lighted and the lighting intensities to be provided in accordance with the requirements in the Traffic Engineering Manual - Chapter 10. The state will install, maintain and pay the power cost for those lighting units it deems to be needed. Roadways which will be considered and may be lighted are the main travelled roadways, ramps, and the intersections of ramps with cross streets.

      The lighting of frontage roads not concurrent with ramps should be the sole responsibility of the local road authority.

   b. The lighting of every interchange is not deemed to be necessary. The state will install lighting units and pay for them where engineering and economic studies indicate the existence of appropriate justification in accordance with the requirements in the Traffic Engineering Manual - Chapter 10. If a local road authority requests that unjustified lighting at an interchange be installed and the requester is willing to pay the plan preparation, construction, maintenance and power costs and the installation is approved by the District/Division Engineer, the system will be installed in accordance with Mn/DOT's standards as indicated in the Traffic Engineering Manual - Chapter 10. The state will maintain the system and be reimbursed by the requesting agency.

2. **Trunk Highways (Arterial and Expressway)**
   a. The state will determine what portions of trunk highways will be lighted and the lighting intensities to be provided in accordance with the requirements in the Traffic Engineering Manual - Chapter 10. The state will install, maintain and pay the power cost for those lighting units it deems to be needed.

   b. If a local authority desires to install a lighting system on a trunk highway within its jurisdiction, the local authority is normally responsible for all costs. The state may pay up to 50% of the construction cost for continuous or intersection lighting at Mn/DOT's standards as indicated in the Traffic Engineering Manual. The local road authority will pay the remaining construction cost and be solely responsible for all maintenance and power costs. Any lighting systems installed on the right-of-way by Mn/DOT, or a local road authority with less than 100% Mn/DOT participation, requires the local road authority to apply for a Utility Permit, Form 2525.

   c. If a local road authority is operating a lighting system on a street at its own expense, and the reconstruction of the street by the state requires relocation of all or part of the system, the local road authority will pay the cost of relocation.

   d. The lighting of every rural intersection is not deemed to be necessary. If a local road authority requests that lighting be installed and lighting is justified, the state may pay 50% of the construction cost at trunk highway/local road authority intersections or may pay 100% of the construction cost at trunk highway/trunk highway intersections and the local road authority will be solely responsible for all maintenance and power costs. If a local road authority is willing to pay the plan preparation, construction and maintenance costs, including power, of an unjustified roadway lighting system, the District Engineer may approve the installation.

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

For lighting systems that are being installed by a municipal contract, the district should request funding from the Office of Investment Management with money from the special agreements fund.

3. **Aesthetic Bridge Designs**

   Refer to Highways (including Bikeways) 6.1.G-1 Policy and Procedures for Cooperative Construction Projects with local Units of Government.

10-3.08 Project Letting

Upon the completion of the plans, special provisions, cost estimate, and agreement. the project will be advertised, bids accepted, and the project awarded to the lowest qualified bidder.

10-4.00 LIGHTING SYSTEM DESIGN

Once the decision is made to install lighting, the design stage can begin. This section describes typical Mn/DOT designs. The design must be appropriate for the site and must provide the level and uniformity of light suggested in the AASHTO 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 Guide. Both methods produce satisfactory results.

Several manufacturers of lighting fixtures and some consultants offer computer programs to analyze light levels for a user-defined roadway with user-defined lighting installed. These programs are excellent tools for determining luminaire mounting heights, wattages, and spacings necessary to provide the proper light levels and uniformity of light on a roadway.

10-4.01 Typical Lighting Systems

10-4.01.01 Continuous Freeway Lighting

In order to obtain the 0.6 - 1.1 footcandles light levels and the 3:1 to 4:1 average to minimum uniformity ratio as indicated for freeways in the AASHTO Guide, the lights may be median barrier mounted lighting units, roadside mounted lighting units, or both Median barrier mounted lighting units with double mast arms provide the same number of luminaires with fewer poles than roadside mounting requires. Back side spill light from the luminaires is utilized by the opposite roadway with median barrier mounted lighting units but is wasted with roadside mounted lighting units. Barrier mounted lighting units are less likely to be knocked down than are roadside mounted lighting units, however they can be very difficult to maintain.

Lighting units mounted on a median barrier typically use double 6-foot davit-type mast arms. Roadside mounted lighting units typically use either a single 12-foot davit-type mast arm and placed 19 - 26 feet behind the edge of the traveled roadway; or a tenon-type mounting assembly and placed 23 - 36 feet from the edge of the travelled roadway.

The lights for a roadway with two lanes in each direction are typically 40-foot poles with 250 watt high pressure sodium luminaires, and 240 feet between poles. For a roadway with four or more lanes in each direction, the lights are typically 49-foot poles with 250 watt high pressure sodium luminaires, and 280 feet or more between poles.

When adequate clearance and slopes are available, vertical mount lighting units may be utilized. The vertical mount lights are typically 45-foot poles with single or double tenon mounted with 250 watt high pressure sodium luminaires. They can also be mounted on a median barrier or bridge.

Roadways with three lanes in each direction may use either of the above configurations depending on the surrounding lighting. Roadways with more than 4 lanes in each direction may require both median barrier mounted lights and roadside mounted lights to achieve the desired light level and uniformity.

Median barrier mounted lights should not be used in high volume areas or in areas without a 10-foot inside shoulder.

10-4.01.02 Partial Interchange Lighting

Figure 10.1, "Typical Luminaire Locations, Partial Interchange Lighting" and Figure 10.2, “Typical Luminaire Locations, Partial Interchange Lighting, Vertical Mount Poles”, elsewhere in this chapter, shows typical luminaire locations for partial interchange lighting. This figure is a modification of a similar figure in the AASHTO Guide. The lights are typically the same as those described above for continuous freeway lighting with 2 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, on the through roadway through the interchange, and on the crossroad between the ramp terminals.

10-4.01.04 Tunnel Lighting

The AASHT0 Guide contains lighting levels and uniformity values for tunnel lighting. A typical tunnel lighting system uses ceiling mounted counter beam or high pressure sodium underpass lighting fixtures. The fixtures are typically mounted to junction boxes embedded in the tunnel as part of the tunnel construction plan.

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 Guide.

10-4.01.05 Underpass Lighting

Where the AASHTO Guide indicates that underpass lighting is desirable, the lights are typically high pressure sodium underpass fixtures for each direction of travel on the roadway, mounted on the abutment of the bridge or on a pier. If such mounting would place a fixture more than about 10 feet from the edge of the travelled roadway, the fixture is typically mounted on the bottom of the diaphragm.

10-4.01.06 Rest Area Lighting

The AASHTO Guide gives light levels and uniformity values for use in rest areas. The lights for the entrance and exit ramps of a rest area are typically the same as those described above for continuous freeway lighting with 2 lane roadways. Lights in the parking area of the rest area are typically 30 foot and 40 foot in the truck parking area, non-breakaway, single or double mast arm poles with metal halide luminaires. On walkways around rest area building, the lights are typically 12-foot poles utilizing a white light source. The spacing of poles for these areas varies with the geometrics. All poles except those on the entrance and exit ramps are typically painted steel decorative poles.

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 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.

Where lights are to be installed on a bridge, the desirable locations for the lighting units are at abutments and at pier locations, or at 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 utilize davit type mast arms so that there are no joints to be weakened by vibration.

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

The installation of navigation and air obstruction lights are an integral part of the bridge design. 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 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 limit the height allowable for the poles or may mandate the use of cutoff type fixtures or obstruction lights. The distance within which an airport needs to be considered varies with the type of installation. For example, a high mast tower lighting system would affect an airport at a greater distance than would continuous freeway lighting utilizing 40-foot 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 with continuous freeway lighting.

10-4.01.12 Intersection Lighting

Street lighting for at-grade intersections is shown in Figure 10.3, "Standard illumination Plan for Intersections." The poles and luminaires may be selected according to the guidelines given previously, or may be selected to match existing street lighting in the city where the intersection is located, or may be a part of a traffic signal system. The local agency may be required to maintain anything other than Mn/DOT standard fixtures.

Lighting should be provided at all signalized and flashing beacon intersections. A signal pole shaft extension with a luminaire mast arm should be utilized whenever possible to avoid adding more poles at the intersection. Street lights on traffic 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 foot candles, the light intensity at the intersection should be doubled as a rule.

10-4.01.13 Roundabout Intersection Lighting

roundabout intersections are lit to a level similar to that of an intersection. Warrants and guidelines are given in the AASHTO Guide and the Mn/DOT Design Manual.

10-4.02 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 Federal Highway Administration may have requirements differing from those found in this AASHTO standard, particularly with regard to breakaway devices, and the lighting system designer should check on such requirements before specifying types of poles for a lighting project.

The designer must determine the pole height, type and length of mast arm(s), material and finish, and method of mounting. 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, and 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 places several high wattage luminaires atop high towers to, illuminate a large area. It uses fewer poles, places poles farther from the travelled roadway, and provides a more uniform and pleasing lighting pattern than conventional lighting. High mast tower lighting may be objectionable near residential neighborhoods because the high luminaire mounting heights, sometimes exceeding 100 feet, can cause glare to those areas.

Conventional lighting units should have davit type mast arms or 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.

Non-breakaway poles should be galvanized steel. Breakaway poles should be unfinished aluminum or stainless steel. Decorative poles should usually be painted steel. 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 Mn/DOT 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, and 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 pole bases include the tapered high base, the anchor base, the shoe base, and the standard transformer base. Types of 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 base Light poles higher than 40 feet and up to 49 feet in height should mount on the Design H light base. These light bases and the anchorage for light standards mounted on a bridge or median barrier are detailed in the Mn/DOT Standard Plates Manual. Pole anchors in a median barrier require a specially widened section of the barrier, called an AL section, to be itemized in the road plans.

The designations for the various pole types are given in Figure 10.4, "Pole Type Designations."

Pole placement is an engineering decision which 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 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, existing guard rail, rock, narrow roadside clearances, ditches, standing water, power lines, nearby airports, traffic signals and nearby residential neighborhoods. Poles should be placed behind noise walls if the site permits Poles should be placed at least 2 feet behind any existing guard rail, or at a distance that will allow the guard rail to properly deflect upon impact. When street lights are installed in conjunction with traffic signals, the lights should be installed on the same poles as the traffic signals, if possible.

Long radius curves may be lighted as a straight roadway. Luminaires mounted on the inside of a short radius curve 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 trucks.

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 a lamp, reflector, refractor, ballast if required, photocell if required, and housing. Several factors have influenced the choice of the type of luminaire that the state currently uses. The efficiency of a lamp in converting electrical energy to light, the ability of the lamp to maintain its light output over the course of the lamp life, the length of the lamp life, the color of the light, and the distribution of the light are all factors which affect the cost and effectiveness of installing, operating, and maintaining the lights, and, hence, affect the choice of light source. The luminaires should be a standard type that is maintainable by and approved by OTST's Electrical Services Section.

Most luminaires used for roadway lighting utilize high intensity discharge (HID) lamps. These lamps produce light by the discharge of an electric arc through an appropriate gas. These lamps require a ballast to provide proper starting and operating voltages to the lamp. A regulating ballast compensates for variations in the incoming voltage and certain types produce a constant wattage power load on the power lines.

The optical unit of the luminaire, consisting of the lamp, the reflector, and the refractor, determines the pattern of light that the luminaire emits. The Illuminating Engineering Society publication ANSI/IES RP8, "American National Standard Practice for Roadway Lighting", latest revision, defines light output patterns for luminaires based on isocandela traces for the light output in relation to the mounting height. The typical luminaire used by the state utilizes a Type II medium cutoff distribution. When the roadway is very wide, a Type III medium cutoff distribution is acceptable, but not required. A cutoff distribution does not allow more than 2.5% of the lumen output at an angle of 90 degrees above nadir, therefore reducing light pollution.

In determining the light output for a luminaire, the lighting system designer must consider the luminaire light loss factor. 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 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. A factor of 0.9 (10 percent light loss) may be used for normal roadway lighting, while a factor as low as 0.4 (60 percent light loss) may be used in a tunnel where the fixtures become very dirty very quickly.

Different types of lamps and luminaires have different advantages and disadvantages which make them more suitable or less suitable for a particular use.

The high pressure sodium (HPS) luminaire is most commonly used by the state. The lamp emits light across the spectrum with a predominance in the orange-yellow region. The HPS lamp is very efficient and is the best for most roadway lighting. HPS is not good for use on signs because the light it produces does not render the proper colors on standard signs. The lamp requires a ballast and special device to produce a very high voltage surge for starting. The HPS lamp usually cycles on and off at the end of normal life.

The metal halide (MH) luminaire is being used more often in the State because of the elimination of the mercury vapor (MV) luminaire. Some MH luminaires are in operation as part of high mast tower lighting. The color value of the metal halide lamp is good and phosphor is not required. There are two versions of the lamp, one designed for basedown operation and the other for baseup operation. The lamp must operate in the proper position.

The fluorescent lamp is no longer installed on new systems, but is still in operation on some existing sign lighting systems. The fluorescent lamp has shown a poor maintenance history and is adversely affected by cold weather.

The low pressure sodium (LPS) lamp is a very efficient light source in that it provides the most light for the same amount of electricity of any of the light sources described. LPS lighting has proven to have maintenance problems requiring frequent lamp replacement. The LPS lamp provides very poor color rendition. The lamps are very long, altering the light distribution pattern from the luminaire. For these reasons the State does not use LPS light sources.

Luminaires for roadway lighting should normally be the "cobra head" style. However, in certain circumstances "shoebox" style and "vertical mount" style luminaires are being used more often. Shoebox style luminaires are often appropriate for the interior (parking lot and walkway) lights in rest areas. Where a municipality is maintaining the lights, other decorative luminaires may be desirable.

Luminaires should only have photo electric cell when the electrical service point (feedpoint) does not provide photoelectric control.

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 power company service conductors, provisions for grounding, and a meter and meter socket when necessary. The designer locates feedpoints for projects in the metropolitan area from the power company serving the area. The districts locate feedpoints in other areas of the state. The OTST Lighting Unit should then be contacted to assign a feed point number.

The local power company should be contacted early in the planning stage to determine the various locations where power is available for the project. The power 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 power company representative. The transformers necessary to provide the correct voltage and current are usually furnished and installed by the power company.

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 where they can be easily accessible for maintenance, will not obstruct the view of motorists, will not be prone to flooding, will not be prone to being hit, and 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 power 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 power 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 power 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 appropriate.

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 the meter reader 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.

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, a circuit breaker load center can replace the service cabinet, with the luminaires operating at 120 volts and each luminaire having its own separate photoelectric control.

The branch circuit breakers in the standard Type L1, Type L2, Type T1, Type T2, Type A or type B lighting service cabinets are 20 ampere, single 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 3 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, the branch circuit breakers must have a higher current rating

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. By wiring the luminaires as described and wiring adjacent luminaires on opposite phase wires, the system will operate with alternate lights still lit if one of the circuit breakers on the branch circuit opens.

Where lighting is installed along the side of a roadway in a grassy area, the lighting branch circuits should utilize direct buried armored cable. Direct buried cable has a lower installation cost than individual conductors in conduit. Where the direct buried cable passes under roadways, it should pass through a conduit for protection and to avoid the need to break up the pavement to trench the cable in. See Figure 10.5, "Typical Conduit Placement (Cloverleaf Interchange)" and Figure 10 5, Typical Conduit Placement (Diamond Interchange)." Conduit under roadways should be a minimum of 3 inches to allow space for future conductors to be run under the roadway and should have insulating bushings 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 non-metallic conduit, and conduit installed as part of a bridge or tunnel will usually be rigid steel conduit. When individual conductors are run through a non-metallic conduit system, a separate equipment grounding conductor must be indicated in the plans along with the phase and neutral wires in the conduit. Separate equipment grounding conductor should also be run with the phase and neutral conductors inside rigid steel conduit also if the conduit passes through handholes, since the insulated grounding bushings on the conduit ends inside the handholes can corrode quickly, leaving the system ungrounded.

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 bronze armor direct buried 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 armored 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 given in the Appendix to this chapter.

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. Splices in pull boxes are acceptable if there is no good way to make the splice in a light pole base. Underground 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 does not add extra splices since a splice is already required at each light pole base to connect the light to the system.

A 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

The providing of temporary lighting may be desirable In construction areas or near at-grade intersections on highways where the warrants listed previously are met. The Transportation District/Division Engineer may request the installation of temporary lights from a power company, or the temporary lights may be installed by the contractor or state.

Lighting installed by the power company is maintained by the power company, and, while it may be a power company's 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 power 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 power company do not have to keep track of which 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 which is not part of an agreement with the power 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, Mn/DOT no longer uses sign lighting. When required, plans and specifications for illuminating overhead signs are done by the OTST Signing Unit.

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, ditches, standing water, etc., may make it necessary or desirable to locate the pole differently than is indicated in the plans. 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 - 26 feet behind the edge of the travelled roadway for davit-type mast arms and 23 - 36 feet from the edge of the travelled roadway for tenon-type mount assemblies. If this distance can not be achieved, contact the District Traffic Office. If a guardrail or noise wall exists at the location and is not indicated in the plans, light poles should be placed behind it if possible. Clearance between the back of the guardrail and the front of the light pole should be at least 2 feet. Poles should not be closer than 20 feet in any direction from power lines. If 20 feet cannot be maintained, contact the power 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 power company of this date, in writing, for billing purposes, with a copy to the 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 with a copy being sent to the Lighting Unit.

The Mn/DOT 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 cleaning glassware, replacing lamps, replacing ballasts, replacing broken glassware, replacing knocked down poles, painting poles when applicable, and repairing the electrical distribution system. Operation and maintenance are often lumped together under the term maintenance, with the supplying of electrical power being considered a type of maintenance.

Responsibility for operating and maintaining lighting systems is detailed in the agreement and may fall upon the power 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.

Maintenance of an electrical lighting system includes maintaining everything within the system from the point of attachment to the power source or utility out to the last light on the feedpoint. The following are some definitions for lighting maintenance including power cost:

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

Luminaire Maintenance - This includes relamping lighting units, replacing all damaged luminaire glassware and repairing loose connections, replacing luminaires when damaged or when the ballast fails, replacing photoelectric controls on luminaires when applicable, replacing defective starter boards and cleaning glassware.

Pole or Knockdown Maintenance - This includes 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 repairing or replacing handholes when needed, locating underground wire, installing approved splices or replacing wires, and repairing or extending conduit.

Light Base Maintenance - This includes repairing damaged bases, repairing or replacing bolts, repairing concrete, and repairing conduits.

Cabinet and Pad Maintenance - This includes a complete lighting cabinet, maintenance including photoelectric cell, repairing anything located on the pad, and repairing the electrical distribution system.

10-6.02 Budgeting (Mn/DOT)

Payment for Energy - The district should budget for the energy bills for roadway lighting for which the state has responsibility, as per the exhibits in effect.

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 (Mn/DOT)

10-6.03.01 Maintenance Procedures

The District Traffic Engineer is responsible for the surveillance of all lighting owned by Mn/DOT within their district. The district and the Electrical Services Section are responsible for entering all lights that are either inoperable or knocked down into the Facilities Management System (FMS).

1. Utility Repair - If the utility is responsible for the repair, the district traffic office sends a copy of the FMS form to the utility. When the utility completes its work, it should complete the form, return the original to the district/division traffic office which should file it. The district traffic office then closes out the report on the FMS.
2. Electrical Services Repair- If the Electrical Services Section is responsible for the repair, the Electrical Services Section will keep the FMS form. When the Electrical Services Section completes its work, it should complete the form and close out the report on the FMS.

10-6.04 Obtaining Electrical Power from Mn/DOT Lighting or Signal Systems

Other Mn/DOT offices as well as non-Mn/DOT agencies, have tapped into Mn/DOT signal and lighting equipment maintained by the Metro or Central Office Electrical Services Section (ESS). On occasion this has occurred without prior authorization or notification.

After a request for power (feedpoint) has been made with the local power utility, and no other source of power is available or deemed to be too expensive, the requester may request power from a Mn/DOT signal or lighting system. A signal system refers to any cabinet containing traffic signal, traffic management, or traffic recording equipment. Sharing an electrical power source with Mn/DOT benefits other offices and agencies, and can be accomplished without adverse effects on the efficiency or safety of the electrical system. In many cases, this type of installation will result in a substantial savings in tax payer cost when compared to establishing a separate source of electrical power. All costs incurred by the new installation shall be paid by the requester.

In order to assure safe and efficient operation of all equipment, however, and to monitor electrical power sharing and billing, prior approval must be obtained 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

1. The requester seeking electrical power shall submit a scaled drawing, signed by a professional engineer or certified 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 ESS, and will work with the requester to develop an acceptable proposal.
3. The requester shall contact the local 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 Mn/DOT lighting unit is the power source, a 3 to 5 amp in-line fuse must be provided in the base of the lighting unit. This fuse must be a breakaway fuse and be labeled as to its use. If the Mn/DOT lighting unit is photoelectrically controlled, the circuit is only energized at night.
- If a Mn/DOT 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 be obtained ahead of any photoelectrically controlled circuit unless the new installation is to be photoelectrically controlled.
- If the lighting system providing power is metered, only the lighting cabinet may be used as a power source, not a lighting unit, 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 Mn/DOT.
- The installation must be inspected by ESS and the required electrical permits be obtained from the local electrical inspector to insure code compliance and safety to maintenance personnel and the public. ESS 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 previously stated.

1. The requester seeking electrical power shall submit a scaled drawing, signed by a professional engineer or certified 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 appropriate district will review the information with ESS, and will work with the requester to develop an acceptable proposal.
3. The requester shall contact the local utility company to notify them of the installation and set up a billing procedure. Documentation of this agreement shall be forwarded 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

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

General

- Mn/DOT may disconnect the system without prior notice if the installation interferes with the operation of the Mn/DOT system.
- If Mn/DOT relocates or moves the system providing power, it is the requesting office's responsibility to reconnect to Mn/DOT's system or to find an alternate source of power.
- The requester shall submit as-built plan sheets, signed by a professional engineer or certified electrician, to the district within 48 hours of connection into a Mn/DOT system.
- Only a certified electrician will be allowed access to the systems used as the power source. Prior notification must be given to ESS.
- The requesting office will be responsible for maintaining all equipment after the power source.
- The requesting office shall provide the appropriate district and Electrical Services Section 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 Mn/DOT power source to the location being served.

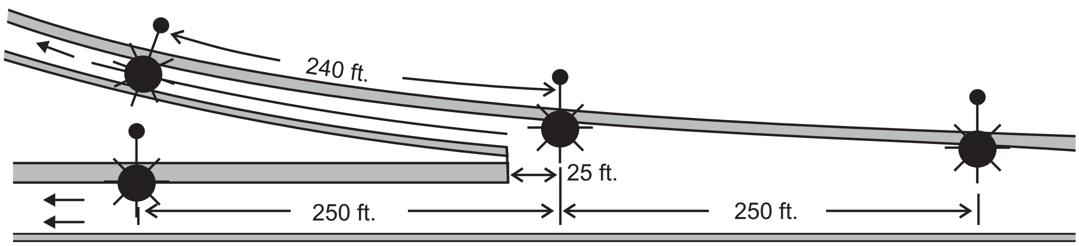
10-6.04.03 Special Additional Requirements for a non-Mn/DOT Agency

A Mn/DOT permit will be required for any installation request.

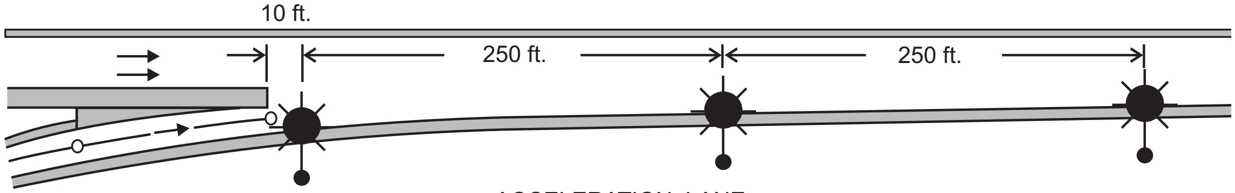
10-7.00 REFERENCES

The AASHTO Guide and the IES American National Standard Practice for Roadway Lighting 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, 2000. Illuminating Engineering Society, 120 Wall Street, New York, New York 10005.
2. American National Standard Practice for Tunnel Lighting, ANSI/IES RP 22, 1987. Illuminating Engineering Society, 345 East 47th Street, New York, New York 10017.
3. The Roadway Lighting Design Guide, October, 2005, American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, D.C. 20001.
4. Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD), current edition
5. A Policy on Geometric Design of Highways and Streets, 2004 American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, D.C. 20001.
6. Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 2001. AASHTO, 444 North Capitol St. N W., Suite 225, Washington, D.C. 20001.
7. Illuminating Engineering Society of North America Lighting Library.



DECELERATION LANE



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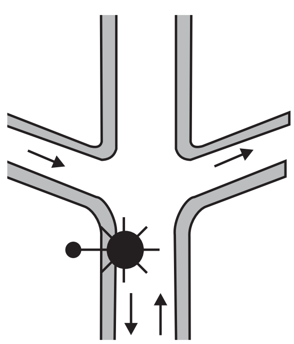
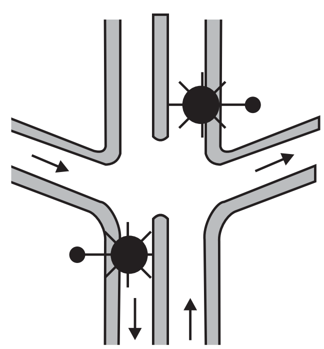


SIMPLE CROSSROAD-
RAMP TERMINALS



DIVIDED CROSSROAD-
RAMP TERMINALS

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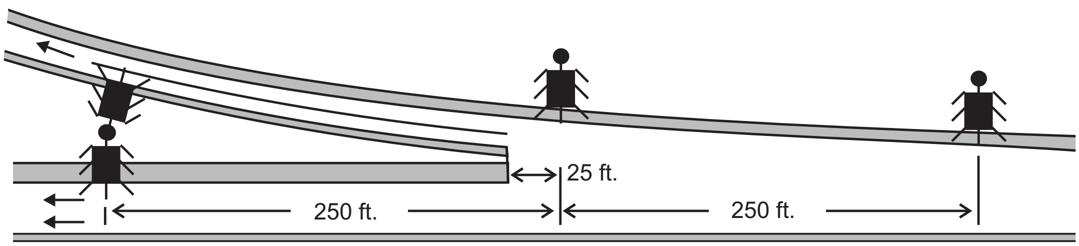
January 1,1996	**TYPICAL LUMINAIRE LOCATIONS PARTIAL INTERCHANGE LIGHTING DAVIT ARM POLES**	FIGURE 10.1



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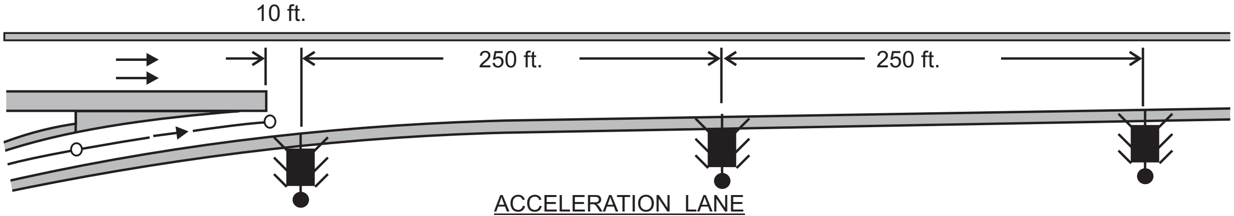
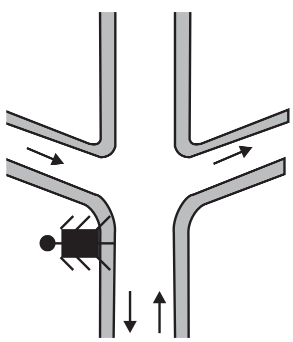
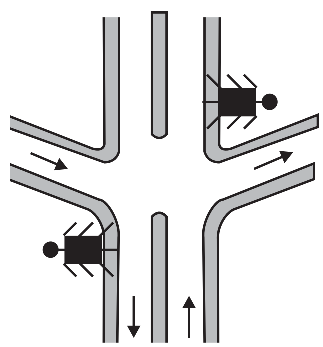


ACCELERATION LANE



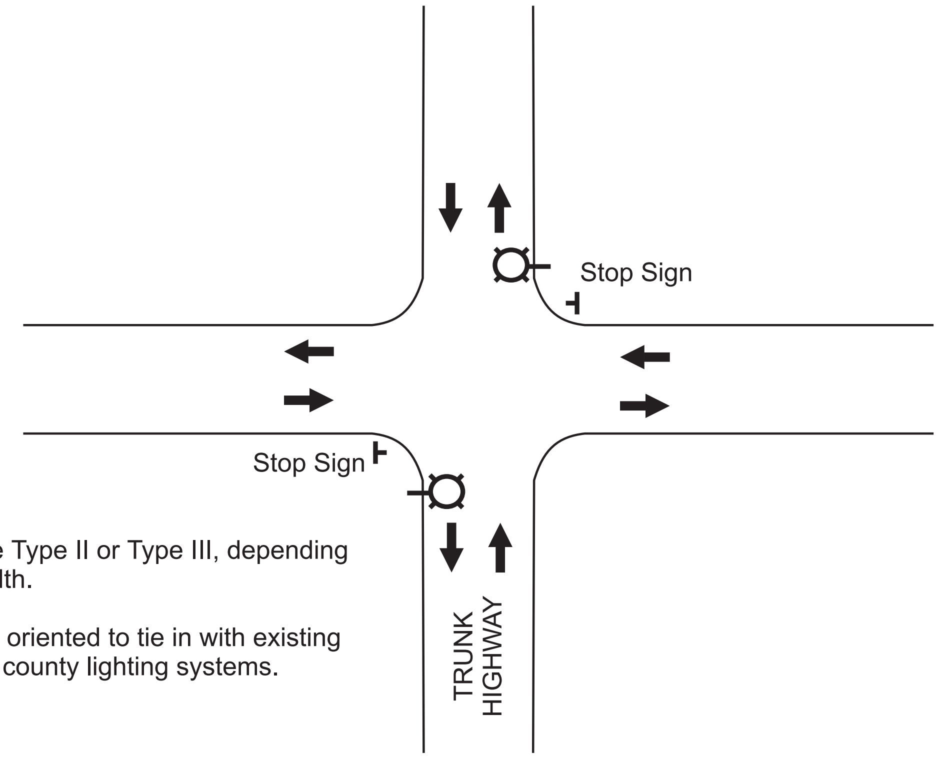
SIMPLE CROSSROAD-
RAMP TERMINALS



DIVIDED CROSSROAD-
RAMP TERMINALS

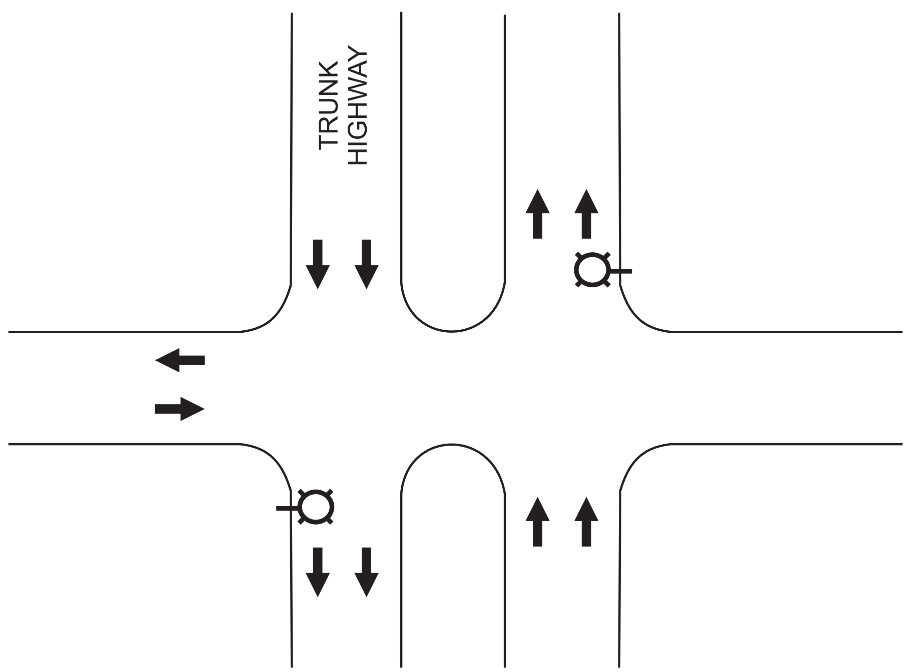
Text Ref.: 10-4.01.02

July 1, 2000	**TYPICAL LUMINAIRE LOCATIONS** **PARTIAL INTERCHANGE LIGHTING** **VERTICAL MOUNT POLES**	FIGURE 10.2



NOTE:
Luminaires shall be Type II or Type III, depending on the roadway width.

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 10.3

Generally, the pole type designation contains the mast arm length, the type of pole, and the nominal pole height.

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

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 characters after the dash give the nominal pole height.

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

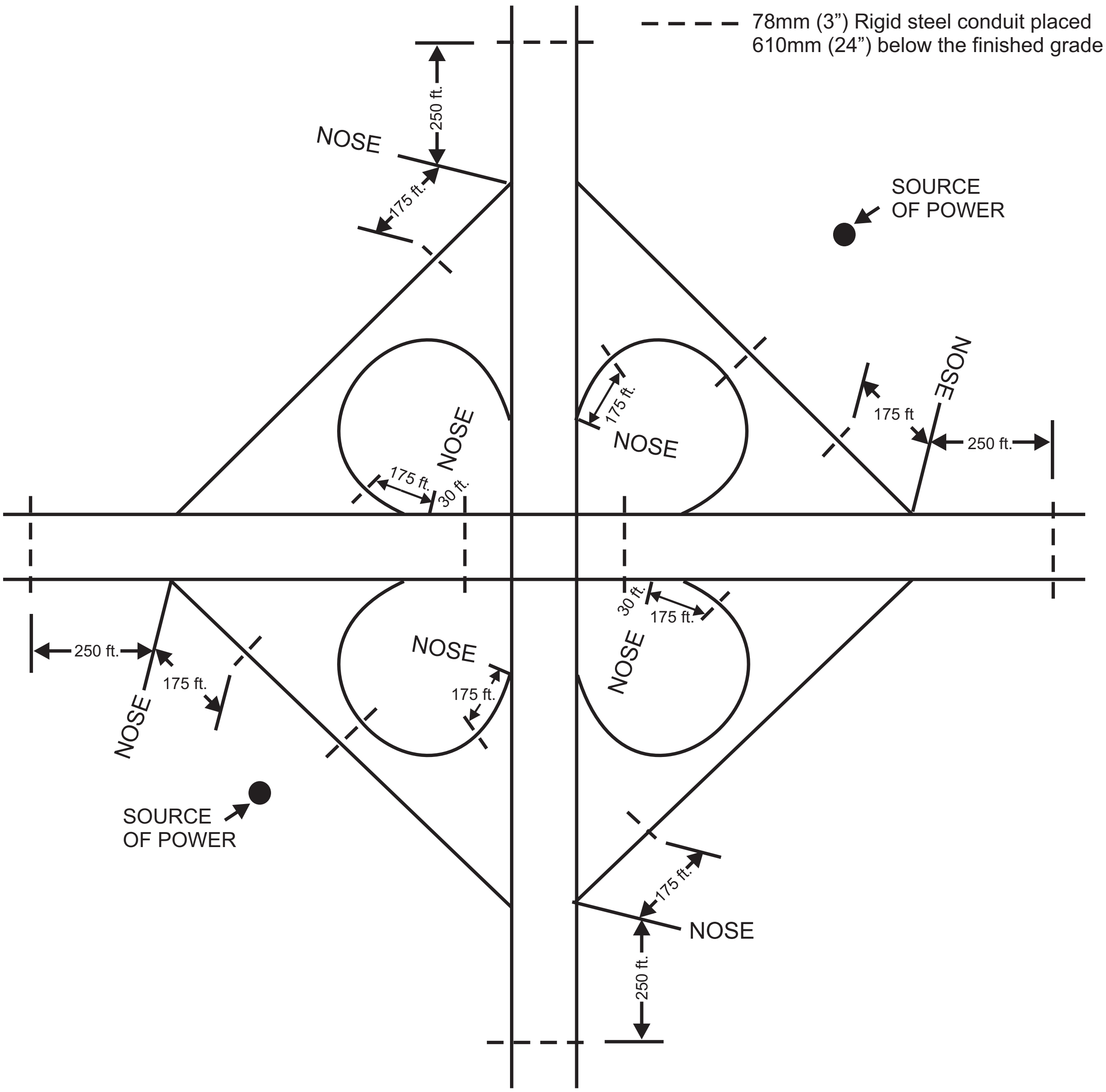
9-40: 9 foot mast arm with 40 foot mounting height, transformer base or high base, and aluminum or stainless steel, as indicated in the plans.

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.

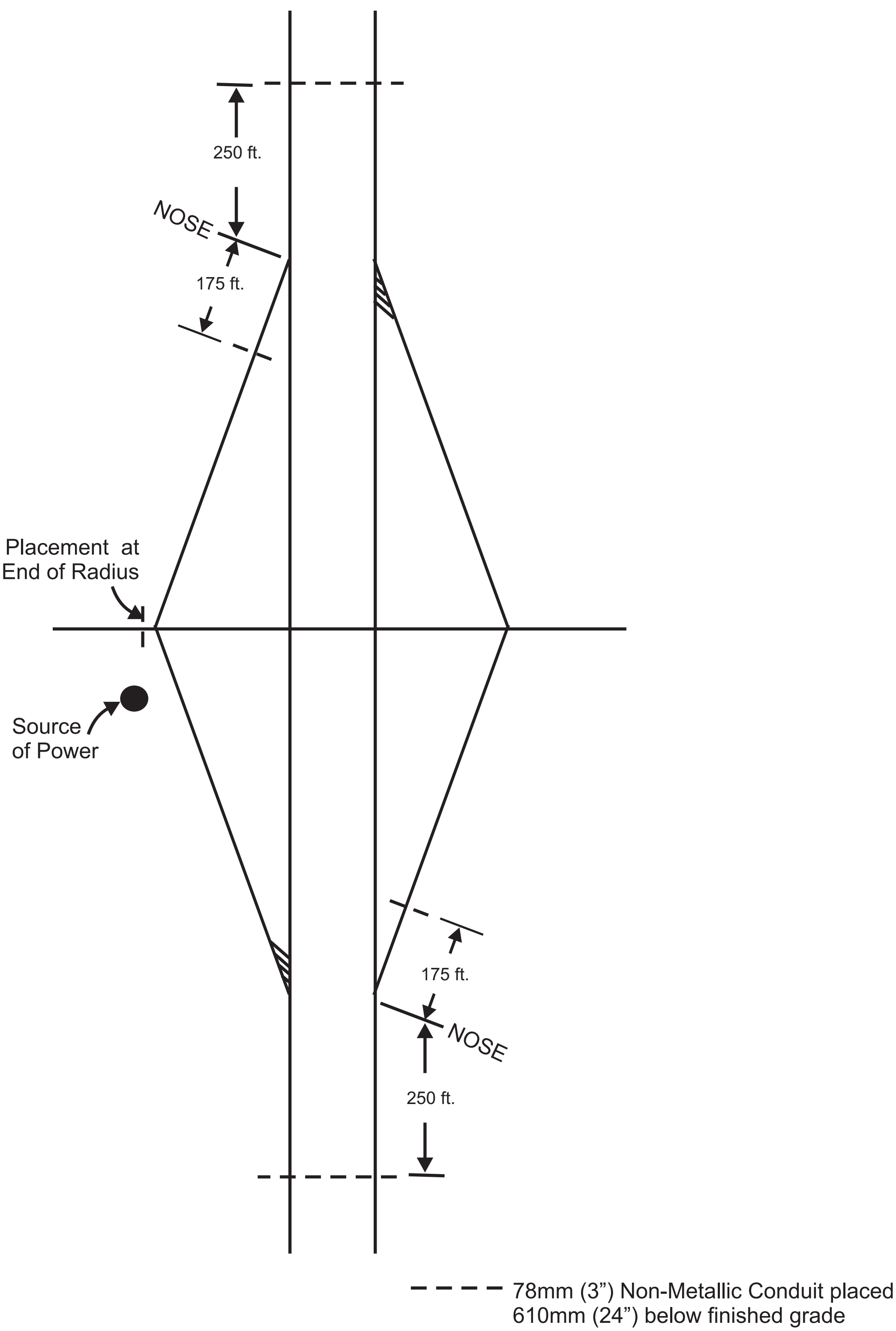
Text Ref.: 10-4.02.01

July 1,1998	**POLE TYPE DESIGNATIONS**	FIGURE 10.4



Text Ref.: 10-4.02.04

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



Text Ref.: 10-4.02.04

January 1,1996	**TYPICAL CONDUIT PLACEMENT (DIAMOND INTERCHANGE)**	FIGURE 10.6

Chapter 10
LIGHTING OF TRAFFIC FACILITIES

APPENDIX 10-10.01
VOLTAGE DROP CALCULATIONS

APPENDIX 10-10.01:

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

$$E = I \times R$$

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	0.05100	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				**3.0702**

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

Current in AMPS for Mercury Vapor Luminaires

Luminaire Voltage	Lamp Wattage		
	175	250	400
120	2.0	2.7	4.3
240	1.0	1.4	2.1

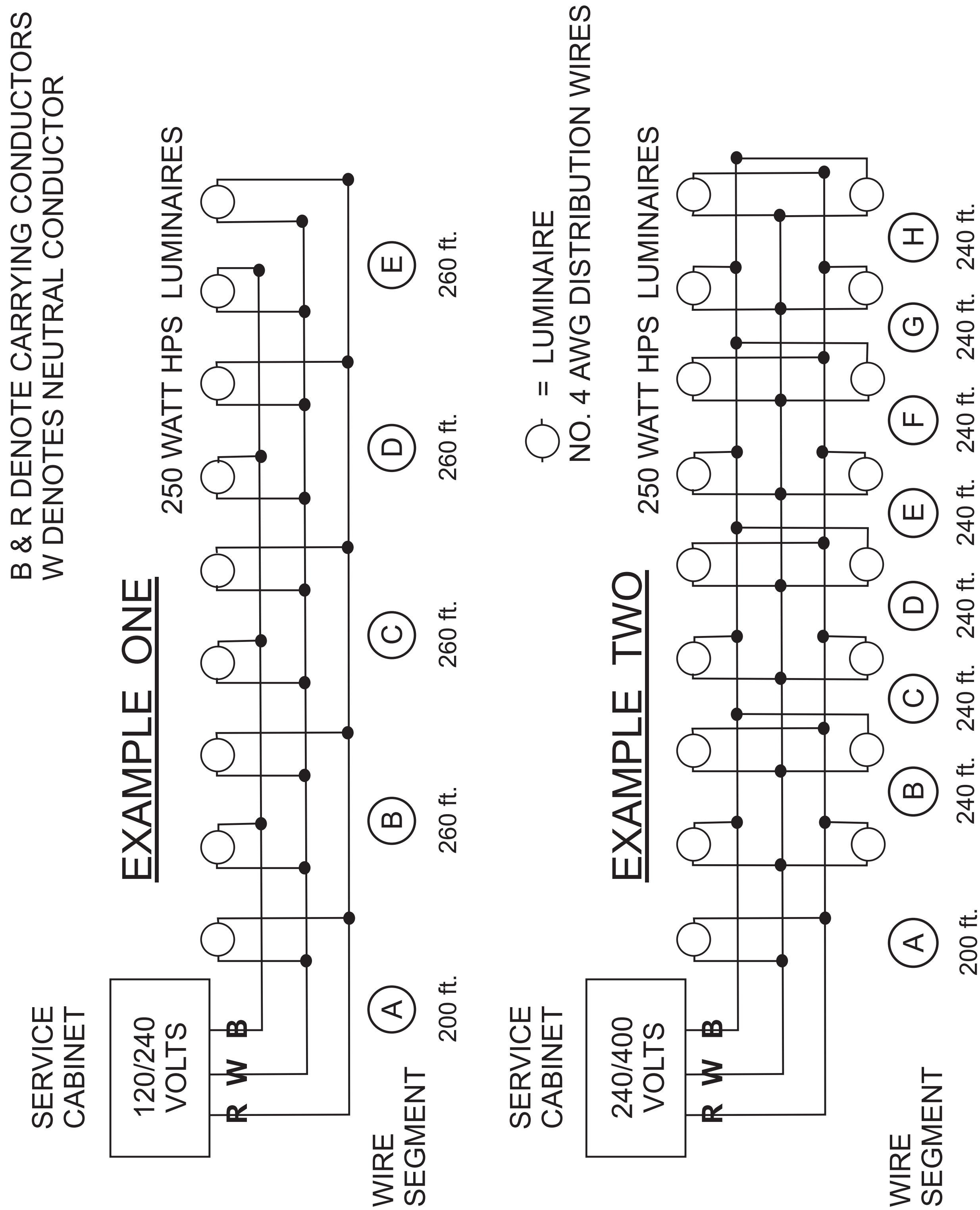
Resistance of Conductors in Ohms Per 1000 Feet

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

July 1,1991	VOLTAGE DROP CALCULATION VALUES	FIGURE 10.8



Text Ref.: Chapter 10 Appendix

January 1,1996	**VOLTAGE DROP CALCULATION EXAMPLES**	FIGURE 10.9