Highway Illumination Manual

Texas Department of Transportation

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Manual: *Highway Illumination Manual*

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Purpose

To establish and revise internal procedures and requirements necessary to implement Texas Department of Transportation (TxDOT) administrative rules on continuous and safety lighting systems as set forth in 43 TAC 25.11, and to provide information relevant to highway illumination.

Supersedes

The revised *Highway Illumination Manual* supersedes all prior versions of the *Highway Illumination Manual*.

Changes

This manual represents a nearly complete revision of the superseded manual to reflect new and updated state and federal policies and standards pertaining to highway illumination.

Descriptions of the changes in each chapter are as follows:

Chapter 1 - Introduction:

- Training, references, and responsibilities were updated.

Chapter 2 - Lighting Systems, Eligibility, and Warrants:

- Definitions for eligibility and warrants were updated.
- Warrants were modified to more closely follow the AASHTO *Roadway Lighting Design Guide*.

Chapter 3 - Master Lighting Plans:

- The overview was updated, and the AASHTO *Roadway Lighting Design Guide* was referenced for the most current information on master lighting plans.

Chapter 4 - Lighting Agreements:

- This chapter was updated using the most current information from the *Negotiated Contracts Policy Manual* and the *Negotiated Contracts Procedures Manual*.

Chapter 5 - Lighting Equipment:

- Details for each of the electrical and illumination items in the 600 series from the TxDOT Standard Specifications were added.
- Details for each of the electrical and illumination items covered in the 11000 series of the Departmental Material Specification were added.
- Information covering the Material Producers List for Roadway Illumination and Electrical Supplies was added.
- Information on the ED, RID, RIP, HMID, HMIP, and HMIF standard sheets was added.

Chapter 6 - Lighting Design and Layout:

- A section with illumination levels was added.
- Information concerning FAA obstruction lighting for high mast poles was added.
- Various sections were updated to reflect current practices.

Chapter 7 - Electrical Systems:

- A section covering TxDOT policy on utility lighting on TxDOT ROW, the National Electrical Safety Code (NESC), and the National Electrical Code (NEC) was added.
- Additional information on electrical services was added.
- Additional information concerning circuit design and voltage drop was added.

Chapter 8 - Temporary Lighting:

- Information covering method of payment for temporary lighting was updated.

Chapter 9 - Construction and Maintenance Guidelines:

- Information on relocation of light poles was updated.

Chapter 10 - Resources:

- This section was added to consolidate additional information.
- Links to Form 1409, Texas Administrative Code Rule 25.11, and Texas Health and Safety Code Chapter 425 were added.
- Memos covering TxDOT policy on the use of the NESC and NEC were added.
- The clear zone table from the *Roadway Design Manual* was added.
- The glossary was updated and added to this section.

Review History

General Counsel Division Review. The General Counsel Division reviewed the draft version of this manual and offered many comments and suggestions, which we considered and incorporated as appropriate.

Compliance Division Review. The Compliance Division reviewed the draft version of this manual and offered many comments and suggestions, which we considered and incorporated as appropriate.

District and Division Review. Potential users in several districts and concerned divisions reviewed the draft versions of this manual. We received numerous comments and suggestions, which we considered and incorporated as appropriate.

Contact

Address questions concerning information contained in this manual to Greg Jones of the Traffic Operations Division, 512-416-3121.

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Archives

Past manual notices for the *Highway Illumination Manual* are available in a pdf archive.

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Chapter 1 — Introduction

Contents:

Section 1 — Overview

Purpose of Manual

The purpose of this manual is to provide procedures, guidelines, and information concerning highway illumination.

Users of Manual

This manual is intended for use by:

- planners and designers of highway illumination systems
- construction and maintenance personnel involved with highway illumination.

Although this manual contains information on electrical circuits, it does not cover the full range of knowledge necessary to design, install, or maintain electrical circuitry.

Training

TxDOT Classroom Courses:

- TRF 450 TxDOT Roadway Illumination and Electrical Installations. This course covers the TxDOT electrical requirements for roadway illumination installations from the electrical service to the controller. TRF 450 is required for certification of contractor personnel to do electrical work on TxDOT highways per Item 7 of TxDOT's Standard Specifications.
- TRF 452 Qualified Person in Electric Arc Flash. This course provides training on NFPA 70E Article 130 to personnel who are required to examine, adjust, service, or maintain electrical equipment.
- TRF 453 Electrical Requirements for Installation of Traffic Signals. This course covers TxDOT electrical requirements for signal installations from the electrical service to the controller.

TxDOT eLearning:

- TRF 804 through TRF 827. These are short online courses covering various parts of TxDOT's electrical and illumination systems. A contractor's electrical certification can be renewed for three years by completing and passing three of these courses.

- Electrical training videos. 23 videos covering TxDOT electrical systems and lighting equipment are available on the TxDOT eLearning - Electrical Training Videos page of the TxDOT website. The videos cover inspection, installation, operation, troubleshooting, and design practices.

Other Training:

- Electrical Review Team. The electrical review team reviews projects under construction in the field for the purpose of educating and training contractors and TxDOT personnel in the practical application of TxDOT specifications and practices. Electrical Review Team visits can be scheduled by contacting the Traffic Operations Division (TRF).

Experience

Personnel with practical electrical experience can provide valuable expertise in the inspection of illumination projects and the maintenance of lighting. Those holding or having recently held an electrical license can help assure conformity with the National Electrical Code and good electrical practices.

References

The following table lists publications that may serve as additional references for issues related to highway illumination.

References Related to Highway Illumination

Publication	Source
◆ *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges* ◆ *Traffic Operations Standard Plan Sheets*; This publication includes: • Electrical Details (ED) • High Mast Illumination Details (HMID) • High Mast Illumination Poles (HMIP) • High Mast Illumination Pole Foundation (HMIF) • Roadway Illumination Details (RID) • Roadway Illumination Poles (RIP). ◆ *Texas Manual on Uniform Traffic Control Devices (TMUTCD)* ◆ other TxDOT manuals	Texas Department of Transportation (TxDOT) ◆ Internet:www.txdot.gov ◆ TxDOT Crossroads (internal only): http://crossroads/
National Electrical Code	National Fire Protection Association (NFPA) Internet: www.nfpa.org
◆ *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* ◆ *Roadway Lighting Design Guide*	American Association of State Highway and Transportation Officials (AASHTO) Internet: www.transportation.org
◆ *IESNA Lighting Handbook: Reference and Application* (HB-10) ◆ *IESNA Recommended Practices for Roadway Lighting* (RP-8-14) ◆ *IESNA Recommended Practices for Tunnel Lighting* (RP-22-11) ◆ other IESNA publications	Illuminating Engineering Society of North America Internet: https://www.ies.org/
FAA Advisory Circular AC 70/7460-1L, "Obstruction Marking and Lighting"	Federal Aviation Administration Internet: https://oeaaa.faa.gov/
Title 43, Texas Administrative Code, Section 25.11, "Continuous and Safety Lighting Systems"	Office of the Texas Secretary of State Internet: http://www.sos.state.tx.us

References Related to Highway Illumination

Publication	Source
Texas Health and Safety Code, Chapter 425, "Regulation of Certain Outdoor Lighting."	Texas Legislature Internet: http://www.statutes.legis.state.tx.us/
various electrical standards	Underwriter's Laboratories Internet: http://www.ul.com
various electrical standards	NEMA Internet: http://www.nema.org

Section 2 — Responsibilities

Introduction

This section outlines the responsibilities of TxDOT divisions and districts regarding highway illumination.

Traffic Operations Division

The Traffic Operations Division (TRF):

- prepares policies, procedures, and standards for electrical and illumination systems
- develops and maintains standard lighting agreement forms
- reviews and processes plans, specifications, and estimates (PS&E) for electrical and illumination projects
- assists districts with design, construction, and maintenance problems associated with electrical and illumination systems
- reviews and prequalifies Roadway Illumination and Electrical Supplies for the Material Producers List (MPL)
- conducts electrical and illumination design training
- reviews lighting and electrical field changes
- assists districts with luminaire pole shop drawings and submittal review of electrical and illumination projects
- writes specifications for warehouse stock and for purchase requisitions for lighting equipment.
- oversees and develops electrical and illumination training classes
- oversees Electrical Review Team (ERT) contract
- oversees sampling and testing of luminaires.

Bridge Division

The TxDOT Bridge Division (BRG) reviews and approves shop drawings for nonstandard luminaire poles.

Districts

TxDOT Districts:

- initiate, process, and retain lighting agreements with cities and counties when necessary
- review and approve shop drawings for standard illumination projects
- design lighting and electrical projects
- ensure local government compliance with lighting agreements
- construct electrical and illumination projects in accordance with plans
- maintain electrical and illumination systems
- operate electrical and illumination systems
- ensure that standard designs are compatible with and applicable to plans
- prepare and submit "Notice of Proposed Construction or Alteration" (FAA 7460-1) to the Federal Aviation Administration (FAA), as stated in the *PS&E Preparation Manual*. The TxDOT Design Division (DES) also forwards submission and clearance paperwork to the districts. These FAA requirements are found in Advisory Circular AC 70/7460-1L, "Obstruction Marking and Lighting."

Chapter 2 — Lighting Systems, Eligibility, and Warrants

Contents:

Section 1 — Overview

Introduction

This chapter describes the different lighting systems, which roadways are eligible for those systems, and the conditions that warrant each system.

Types of Lighting Systems

Title 43, Texas Administrative Code, Section 25.11, defines two basic types of roadway lighting systems — "continuous lighting" and "safety lighting." The rules also describe instances in which continuous lighting may be classified as safety lighting. Subsequent sections of this chapter describe each of these types.

Eligibility and Warrants

The rules specify the types of highways eligible for the spending of state funds on each type of illumination system. TxDOT can only install and maintain lighting systems on **eligible** roadways where the conditions **warrant** such installation.

Eligibility. Eligibility refers to the rules that determine when state funds may be spent to install roadway lighting on a state highway. Eligibility requirements for safety and continuous lighting are defined in Section 25.11 of the Texas Administrative Code and are described in this chapter.

Warrants. TxDOT uses warrants to justify the need for and expense of roadway lighting at eligible locations. TxDOT's warrants are based on those in the AASHTO Roadway Lighting Design Guide. To determine if an eligible location meets the relevant warrant, TxDOT assesses roadway conditions in terms of criteria called "cases." These cases are coded for ease of reference. The code consists of either "CL" (for continuous lighting) or "SL" (for safety lighting), followed by a dash and a number (for example: CL-2 or SL-4).

When roadway conditions meet or exceed one or more of the relevant cases, then the roadway in question warrants the lighting — in other words, the warrant is met. Meeting of warrants does not obligate TxDOT to provide lighting, but warrants may be used along with other criteria, like availability of funds and crash data, to determine if lighting should be installed on a project.

After the warrant is met, TxDOT may enter into a partnership agreement with the city or local government (if necessary) and program the financing.

Section 2 — Continuous Lighting

Description

A continuous lighting system provides relatively uniform lighting on main lanes, direct connections, `ramp terminals,` and complete interchange lighting of all interchanges. Frontage roads are not normally continuously lighted by TxDOT.

The lighting assemblies may be luminaires on conventional poles, high mast assemblies, or a combination.

NOTE: Continuous lighting requires the financial participation of the local government (see “Lighting Agreements,” Chapter 4).

Eligibility

The following roadways are eligible for continuous lighting systems:

- urban freeways that are multi-lane divided facilities for which full control of access is provided
- multi-lane arterial highways with partial control of access where the following conditions exist:
  - access is provided to abutting property
  - at-grade crossings are provided at minor streets and roads, and
  - grade separation structures are provided at major crossings of arterial highways, streets, and roads.

Warrants

Continuous freeway lighting may be warranted by at least one of the conditions described in the following table.

Warranting Conditions for Continuous Freeway Lighting

Case	Warranting Conditions
CL-1	Sections in and near cities where the current average daily traffic (ADT) is 30,000 or greater.
CL-2	Sections where three or more successive interchanges are located with an average spacing of 1.5 miles or less and adjacent areas outside the right-of-way are substantially urban in character.
CL-3	Sections of 2 miles or more passing through a substantially developed suburban or urban area in which one or more of the following conditions exist: ◆ Local traffic operates on a complete street grid having some form of street lighting, parts of which are visible from the freeway ◆ The freeway passes through a series of developments such as residential, commercial, industrial and civic areas, colleges, parks, terminals, etc. that include lighted roads, streets, parking areas, yards, etc. ◆ Separate cross streets, both with and without connecting ramps, occur with an average spacing of 0.5 miles or less, some of which are lighted as part of the local street system ◆ The freeway cross section elements, such as median and borders, are substantially reduced in width below desirable sections used in relatively open country.
CL-4	Sections where the ratio of night to day crash rates is at least 2 times the statewide 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. NOTE: Because the ratio of night to day crash rates for a given section of roadway cannot always be statistically verified, this measure must be considered as an aid to design rather than an absolute rule. Engineering judgment should be exercised when using this warrant.

For streets and highways other than freeways, AASHTO has not established continuous lighting warrants for the installation of roadway lighting that satisfy all conditions. In general, lighting may be considered for those locations where the relevant governmental agencies agree that lighting would contribute substantially to the safety, efficiency, and comfort of vehicular and pedestrian traffic.

Continuous lighting may be provided for all major arterials in urbanized areas and for locations or sections of streets and highways where a study indicates that lighting would significantly reduce the nighttime crash rate.

Specially Funded Projects

For specially funded projects, the project authorization must describe the ownership and maintenance responsibilities for the continuous lighting.

Section 3 — Safety Lighting

Description

Safety lighting may be installed at any interchange, highway intersection, or other decision-making point or points of nighttime hazard. Safety lighting may be used to the extent necessary to provide for safety enhancement and the orderly movement of traffic.

There are three kinds of safety lighting: **partial interchange/intersection**, **complete interchange/intersection**, and **spot**. Which is used depends on the warranting conditions.

Partial interchange/intersection lighting covers:

- acceleration and deceleration lanes
- ramp terminals
- crossroads at frontage road or ramp intersections
- other areas of nighttime hazard.

Complete interchange/intersection lighting covers the limits of the interchange, including:

- main lanes
- direct connections
- ramp terminals
- frontage road or crossroad intersections.

Spot lighting is another kind of safety lighting. Spot lighting usually consists of one to five units intended to illuminate a nighttime hazard, such as sections with complex geometry or raised channelization.

For contracting purposes, all types of safety lighting are handled in the same manner.

Eligibility

Any highway designated as part of the state highway system is eligible for safety lighting provided that TxDOT anticipates that:

- the safety of nighttime traffic movements will be enhanced, and
- the incidents of nighttime crashes might be minimized or eliminated.

Warrants

Conditions warranting safety lighting vary depending on the type of roadway (freeway, expressway, or other designated on-system highway) and whether the proposed lighting is partial interchange, complete interchange, or spot.

Freeways and Expressways. For freeways and expressways, safety lighting may be warranted under one of the conditions described in the following table.

Warranting Conditions for Freeway and Expressway Safety Lighting

Type of Lighting	Case	Warranting Conditions
Partial Interchange/ Intersection	SL-1	Current average daily traffic (ADT) ramp traffic entering and leaving the freeway within the interchange area exceeds 5,000 for urban conditions or 3,000 for suburban conditions or 1,000 for rural conditions.
	SL-2	Current ADT on the through traffic lanes exceeds 25,000 for urban conditions, 20,000 for suburban conditions, or 10,000 for rural conditions.
	SL-3	Ratio of night to day crash rates within the interchange area is at least 1.25 times the statewide average for all similar unlighted sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. NOTE: Because the ratio of night to day crash rates for a given section of roadway cannot always be statistically verified, this measure must be considered as an aid to design rather than an absolute rule. Engineering judgment should be exercised when using this warrant.
Complete Interchange/ Intersection	SL-4	Current ADT ramp traffic entering and leaving the freeway or expressway within the interchange areas exceeds 10,000 for urban conditions, 8,000 for suburban conditions, or 5,000 for rural conditions.
	SL-5	Current ADT on the crossroad exceeds 10,000 for urban conditions, 8,000 for suburban conditions, or 5,000 for rural conditions.
	SL-6	Existing substantial commercial or industrial development that is lighted during hours of darkness, is located in the immediate vicinity of the interchange, or where the crossroad approach legs are lighted for 0.5 miles or more on each side of the interchange.
	SL-7	The ratio of night to day crash rates within the interchange area is at least 1.5 times the statewide 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. NOTE: Because the ratio of night to day crash rates for a given section of roadway cannot always be statistically verified, this measure must be considered as an aid to design rather than an absolute rule. Engineering judgment should be exercised when using this warrant.

Other Designated On-System Highways. For streets and highways other than freeways, AASHTO has not established safety lighting warrants for the installation of roadway lighting that satisfy all conditions. In general, lighting may be considered for those locations where the relevant governmental agencies agree that lighting would contribute substantially to the safety, efficiency, and comfort of vehicular and pedestrian traffic.

Spot Safety Lighting. Spot safety lighting may be used at intersections or other areas where lighting will provide safer movement of traffic.

Continuous Lighting Classified as Safety Lighting

A continuous lighting system may qualify as a safety lighting system, provided all of the following conditions are met:

- the system is installed on a freeway with full control of access
- the freeway passes through unincorporated areas or through incorporated areas with municipal populations of less than 50,000 people according to the latest federal census
- the freeway has an ADT volume in excess of 70,000 vehicles, and
- a TxDOT study of the traffic volume or nighttime crash rate of the freeway indicates that continuous lighting will substantially improve traffic safety and the efficiency of nighttime traffic.

Section 4 — Bikeway and Pedestrian Way Lighting

Eligibility

TxDOT may expend funds for continuous and safety lighting systems on bikeways and pedestrian ways on any segment of the state highway system and on any highway maintained by the Department.

Adjacent Roadway Lighting

When bikeway or pedestrian way lighting is installed, TxDOT may expend funds for lighting systems on the adjacent roadway to the same extent that lighting is provided for the bikeway or pedestrian way. Illumination levels should meet the requirements set forth in the AASHTO *Roadway Lighting Design Guide*.

Section 5 — Systems Financed, Installed, and Operated by Other Agencies

TxDOT Policy

Local governments may finance, install, and operate illumination systems on a highway not lighted by TxDOT.

Guidelines

TxDOT will cooperate with local governments in the consideration of such illumination systems. TxDOT personnel may assist and advise in the planning and design of such systems when requested by a local government.

Roadway lighting systems installed by local governments on a segment of the state highway system must meet all safety-related requirements under federal and state law and TxDOT functional manuals.

Local governments must obtain the approval of the state for all proposals to install illumination on a state highway. These proposals should be reviewed by TxDOT for compliance with pole placement guidelines and the National Electric Code. Such installations must be in accordance with municipal maintenance agreements, if applicable, and in some cases, the local government must obtain a utility permit from the district.

Chapter 3 — Master Lighting Plans

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Section 1 — Overview

Introduction

The commitment to lighting roadway facilities is a large responsibility. A master lighting plan can help fulfill this responsibility by defining the direction and ultimate goal desired. This chapter provides general guidelines for implementing a master lighting plan when local authorities determine that such a plan is desirable for their community.

Definition

A master lighting plan is a formal arrangement between local governments and other entities within a regional area to coordinate and standardize the design, operation, and maintenance of public lighting. Master lighting plans can include lighting curfews and modern electronic monitoring and control systems.

Benefits

The basic benefits of lighting include safety, beautification, and security for people and property. Additional benefits derived from a master lighting plan include:

- improved safety through maximization of resources
- a consistent image, reflecting local culture and tastes
- links to various sections of the city
- an identification of the nature of the site (residential versus “restaurant row” for example)
- better management of energy use
- tighter control of sky glow and light trespass
- aid in implementing lighting curfews
- increased public security (other concerns may warrant immediate turning on or off)
- coordinated maintenance
- coordinated maintenance specifications, such as poles, breakaway devices, and luminaires.

Plan Development

For more information on developing a master lighting plan, see Chapter 2, Master Lighting Plans, in the AASHTO Roadway Lighting Design Guide. The TxDOT Traffic Operations Division (TRF) can assist with the development of a master lighting plan.

Chapter 4 — Lighting Agreements

Contents:

Section 1 — Overview

Introduction

All lighting projects within the corporate limits of a city or town involving state financing require an executed agreement between the local government and TxDOT. The agreement defines the responsibilities of each party in regard to construction, maintenance, and operation of the lighting system. The agreement should be executed before the project is let to contract.

Authority

TxDOT has the authority to construct, maintain, and operate lighting systems on highways on the state highway system. The rules are in Title 43 of the Texas Administrative Code, Section 25.11.

When an Agreement is Required

The most common instances requiring an agreement are when:

- TxDOT installs a traffic signal, safety lighting, or a continuous lighting installation within the corporate limits of a city.
- a proposed installation involves a city or other entity providing materials, labor, or engineering for which TxDOT will reimburse the city or entity, or
- a county requests continuous or safety lighting on-system and agrees to pay for operation and maintenance.

When an Agreement is Not Required

A written agreement is not necessary when:

- the traffic signal, safety lighting or continuous lighting system is installed by TxDOT in an unincorporated area completely within TxDOT right of way, or
- a minute order covers the responsibilities of both TxDOT and the city, and the city has passed an ordinance or resolution accepting the minute order of the Texas Transportation Commission. A

minute order may be used in lieu of an agreement depending on the level of detail addressing the responsibilities of each entity.

Ordinance or Resolution

Agreements with cities must be accompanied by an ordinance or resolution authorizing the elected head of the city or a designated representative to sign the agreement.

Agreements with counties must be accompanied by an order of the commissioner's court authorizing the county judge to sign the agreement.

The city or county secretary's certificate must also accompany all agreements to verify that the ordinance or resolution was passed by the city or county. If the secretary has signed and sealed the resolution or ordinance, then a separate secretary's certificate is not required.

Lighting Agreements

A lighting agreement is usually required whenever TxDOT installs continuous or safety lighting in incorporated cities or under special circumstances when requested by counties.

A continuous lighting system provides relatively uniform lighting on all main lanes and direct connections and complete interchange lighting of all interchanges. Continuous lighting requires the financial cooperation of the city, because the benefits derived extend beyond enhanced safety for motorists.

Safety lighting is used at urban or rural interchanges, highway intersections, and points of night time hazards to enhance safety of the facility. If the safety lighting is within a municipality, TxDOT must enter into an agreement with the city. The type of agreement depends on whether TxDOT will maintain the system directly or contract with the city for maintenance. TxDOT mainly installs lighting on roadways on the state highway system. TxDOT occasionally installs lighting on off-system roadways as part of larger projects when no state funds are being expended.

Initiation of Agreement

The design engineer should contact the city prior to designing the lighting system to determine the extent of lighting desired and to work out city participation. A lighting agreement, if necessary, should be initiated at that time.

Traffic Engineering Agreement (TEA) Templates

The following tables give a quick overview of the different types of lighting agreement templates. These lists are intended to act as an aid in quickly determining the correct agreement.

Safety Lighting Templates

Template No.	Short Title	Template Description
TEA 19	Safety Lighting (Blanket) (SM, CP)	Used for the construction, maintenance, and operation of safety lighting systems within municipalities where TxDOT provides maintenance and contracts with the city for electrical costs.
TEA 20	Safety Lighting (Blanket) (City M&P)	Used for the construction, maintenance, and operation of safety lighting systems within municipalities where the city provides maintenance on a force account (reimbursement) basis and receives reimbursement for electrical costs from TxDOT.

Continuous Lighting Templates

Template No.	Short Title	Template Description
TEA 21	Continuous Lighting SC(100) - (CMO)100 (B)	Used for the construction, maintenance, and operation of continuous highway lighting systems within a municipality where TxDOT constructs and retains ownership, while the city provides funding for all maintenance and operation costs.
TEA 22	Continuous Lighting SC(100) - CMO(100) (SL)	Used for the construction, maintenance, and operation of continuous highway lighting systems within a municipality where the lighting system has clearly defined limits. TxDOT constructs and retains ownership, with the city being responsible for maintenance and operation.
TEA 23	Continuous Lighting SC(100) - CMO(100) (SL)	Used for the construction, maintenance, and operation of continuous highway lighting systems within a municipality where construction, maintenance and operation costs, and ownership are split 50-50 between the city and TxDOT.

Modifying Standard Templates

Contract Services should be contacted if either party wishes to modify the terms and conditions of the standard contract templates.

More Information

For more information on the statutory authority and policies that guide TxDOT concerning negotiated contracts, see the Negotiated Contracts Policy Manual.

Section 2 — Lighting Agreements

Background

A lighting agreement is usually required whenever TxDOT installs continuous or safety lighting in incorporated cities or under special circumstances when requested by counties.

Continuous lighting requires the financial cooperation of the city because the benefits derived extend beyond enhanced safety for motorists. Some of these benefits are improved aesthetics, lower crime rates, and greater visibility.

Written Agreement Not Required

A lighting agreement is not necessary when a city is authorized through a Municipal Maintenance Agreement to install, operate, and maintain a safety lighting or continuous lighting system within its corporate limits at city expense.

Default

If a local government defaults on any lighting agreement with TxDOT, TxDOT will discontinue any further funding of continuous lighting systems in that local government's jurisdiction, unless the executive director determines that such action would be inconsistent with the safety of the traveling public.

Lighting Systems Financed, Installed, and Operated by Other Agencies

Local governments may finance, install, and operate illumination systems on marked state highways not lighted by TxDOT.

TxDOT cooperates with local governments in the consideration of such illumination systems. TxDOT personnel may assist and advise in the planning and design of such systems when requested by a local government.

Roadway lighting systems installed by local governments on a segment of the state highway system must meet all safety-related requirements under federal and state law and TxDOT functional manuals. These lighting systems should also conform to the National Electrical Code (NEC).

Local governments must obtain written approval from the TxDOT district office for all proposals to install, maintain, and operate on-system lighting. TRF is available to review and offer recommendations when requested by the district. Such installations must be in accordance with the municipal maintenance agreement, if applicable, and in some cases, the local government must obtain a utility permit from the district. A separate agreement is not necessary.

Quotation on Plan Title Sheet

For blanket agreements (except for specific limits), the following quotation from the agreement should appear on the title sheet of the plans with the city authorized signature.

> Attachment No. XX-XX to special AGREEMENT FOR CONSTRUCTION, MAINTENANCE AND OPERATION OF CONTINUOUS HIGHWAY ILLUMINATION SYSTEM WITHIN MUNICIPALITIES, dated _____________. The City-State construction, maintenance and operation responsibilities shall be as heretofore agreed to, accepted, and specified in the Agreement to which these plans are made a part.

The attachment sequence number (XX-XX) should be inserted into the quotation. Most districts use a yearly format for the sequence number, such as "Attachment No. 02-95."

Safety Lighting Agreements

Safety lighting is used at specific spot locations to enhance safety of the facility. TxDOT bears the cost of installation, operation, and maintenance of safety lighting at interchanges, highway intersections, and points of night time hazard in both urban and rural areas, as traffic needs dictate.

If the safety lighting is within a municipality, TxDOT must enter into an agreement with the city. The type of agreement depends on whether TxDOT will maintain the system directly or contract with the city for maintenance.

Safety Lighting Incidental to Other Agreements

When safety lighting (on traffic signal poles, separate poles, or underpass structures) is installed by TxDOT in an incorporated city as part of a traffic signal installation, and a separate power source is not required, the safety lighting is considered incidental to the traffic signal installation and is usually covered by a municipal maintenance agreement or a traffic signal agreement.

For more information see the Traffic Signals Manual, Chapter 5.

Safety Lighting Incorporated Into a Continuous Lighting System

If a TxDOT installed or funded safety lighting system is later incorporated into the limits of a continuous lighting system in which TxDOT participated in the cost of installation, then the cost of operation and maintenance of the safety lighting system is shared by TxDOT and the local government on the same basis as they share the cost of operation and maintenance of the continuous lighting system.

If a TxDOT installed or funded safety lighting system is later incorporated into the limits of a continuous lighting system in which TxDOT does not participate in the cost of installation, then TxDOT continues to pay the entire operation and maintenance cost of the safety lighting system; however, TxDOT will not participate in the cost of operation and maintenance of the continuously lighted sections into which the safety lighting system is incorporated.

Agreement No. 19: Safety Lighting (Blanket) (SM, CP)

Full Title: Agreement for Construction, Maintenance and Operation of Safety Lighting Systems Within Municipalities (State maintains and contracts for power) (Blanket Agreement).

Use: For the construction, maintenance, and operation of safety lighting systems within municipalities when TxDOT maintains the safety lighting and is responsible for contracting for the electrical power.

If the city selects this agreement, TxDOT will:

- contract for power, and

- perform all maintenance work.

The Safety Lighting (Blanket) (SM, CP) agreement automatically renews every two years.

A reduced copy of each signed title sheet referencing this agreement should be kept with the original agreement for record purposes.

Agreement No. 20: Safety Lighting (Blanket) (City M&P)

Full Title: Agreement for Construction, Maintenance and Operation of Safety Lighting Systems Within Municipalities (State contracts through city for maintenance and power) (Blanket Agreement).

Use: For the construction, maintenance, and operation of safety lighting systems within municipalities where the city provides the maintenance and power to safety lighting systems.

The city will:

- receive reimbursement from TxDOT for maintenance and power costs
- charge TxDOT an established rate for electricity costs, and
- provide maintenance on a force account basis or by its authorized agent.

A reduced copy of each signed title sheet referencing this agreement should be kept with the original agreement for record purposes.

Agreements for Continuous Lighting Systems

Continuous lighting provides lighting along a stretch of freeway or expressway to enhance the overall nighttime visibility and safety of traffic.

There are two kinds of standard agreements for continuous lighting systems - the "100 Percent Agreement" and the "50-50 Agreement." Which agreement is used depends on whether TxDOT bears the entire cost of the system or shares the expense with a local government.

The 100 percent agreement provides that TxDOT assumes the total cost of design and installation of the continuous lighting system, and that the local government assumes all cost of the subsequent operation and maintenance.

The 50-50 agreement provides that TxDOT and the local government share equally the cost of the installation, operation, and maintenance of the continuous lighting system.

Agreement No. 21: Continuous Lighting SC (100)-CMO (100)(B)

Full Title: Agreement for Construction, Maintenance and Operation of Continuous Highway Lighting Systems Within a Municipality (Freeways or Expressways) (Blanket Agreement).

Use: For the construction, maintenance, and operation of continuous highway lighting systems within a municipality where TxDOT constructs the system and retains ownership, while the city provides funding for all maintenance and operation costs.

Features of this agreement include:

- construction and ownership remain 100 percent the responsibility of TxDOT
- the city has 100 percent of the responsibility for maintenance and operation of continuous lighting systems covered by this agreement, and
- the percentage responsibilities of the city and TxDOT are set by rule in the Texas Administrative Code, and cannot be altered.

This agreement applies primarily to continuous highway lighting systems on freeways or expressways.

The agreement automatically renews every two years.

A reduced copy of each signed title sheet referencing this agreement should be kept with the original agreement for record purposes.

Agreement No. 22: Continuous Lighting SC (100)-CMO (100) (SL)

Full Title: Agreement for the Construction, Maintenance and Operation of Continuous Highway Lighting Systems Within a Municipality (Freeways or Expressways) (Specific Limits).

Use: For the construction, maintenance, and operation of continuous highway lighting systems within a municipality where the city does not wish to execute a blanket type agreement, but wishes instead to execute a separate agreement for each lighting system with defined limits. TxDOT retains 100 percent ownership with the city assuming 100 percent responsibility for maintenance and operation.

Features of this agreement include:

- the beginning and ending limits of the lighting systems are clearly defined
- construction and ownership remain 100 percent responsibility of TxDOT
- the city has 100 percent of the responsibility for maintenance and operation of continuous lighting systems covered by this agreement, and
- the percentage responsibilities of the city and TxDOT are set by rule in the Texas Administrative Code and cannot be altered.

This agreement applies primarily to continuous highway lighting systems on freeways and expressways. Districts should use this agreement if the city refuses to sign a blanket agreement.

Agreement No. 23: Continuous Lighting SC (50)-CMO (50) (SL)

Full Title: Agreement for Construction, Maintenance and Operation of Continuous Highway Lighting System(s) Within a Municipality (Freeways and Expressways) (Specific Limits).

Use: For construction, maintenance, and operation of continuous highway lighting systems within a municipality where construction, maintenance, and operation costs, as well as ownership, are split 50-50 between the city and TxDOT.

Features of this agreement include:

- establishment of a separate advance funding agreement for the city's portion of the total funds
- defined beginning and ending limits of the lighting systems
- work contracted out by TxDOT, and
- city operation and maintenance.

The agreement applies primarily to continuous highway lighting systems on freeways or expressways.

More Information

For more information on lighting and other traffic engineering agreements, see the Negotiated Contracts Policy Manual, Chapter 11.

Section 3 — Lighting Agreement Processing and Execution

Background

To assure that agreements are enforceable and consistently applied, TxDOT has established guidelines to help cities, other local governments, or private entities develop their agreements. Guidelines for executing and processing most agreements are covered in this section.

The TxDOT Traffic Operations Division (TRF) is the Office of Primary Responsibility for Traffic Engineering agreements. Questions about the agreements or the procedures should be directed to TRF Engineering Operations Section at 512-416-3118.

Standard Templates

Templates of all standard traffic agreements are maintained by Contract Services. These templates are available from the Contract Services Crossroads website under Standard Contracts, then Traffic.

Standard ordinance and resolution forms are also available on Contract Services Crossroads website (TEA 31 through TEA 37).

Excess Cost

Sometimes participating cities or other local governments want amenities, qualities, or features that exceed the standard design equipment, systems, or practices of TxDOT incorporated into lighting systems and traffic signal systems. TxDOT will incorporate these desired items into the systems to the extent practicable. In this case, an advance funding agreement is required and the local government must furnish all additional estimated funds.

Private Agreements

A private agreement is required when a TxDOT traffic signal or lighting installation encroaches upon private property.

The district coordinates surveys and negotiates with affected parties when developing the agreements. The proposed agreement is forwarded to TRF for additional review.

The TxDOT Right of Way Division (ROW) performs a final check and may execute the agreement on behalf of TxDOT.

No work should be started on private property until the property owner has been furnished a fully executed copy of the agreement.

Preparing an Agreement

After a determination is made that an agreement is needed, the district should access Contract Services' Crossroads website to obtain the most current version of the needed template. The template should be completed by the district.

Contract Services Review

The district should contact Contract Services before contract execution if the local government wishes to modify terms and conditions of the standard agreements. The draft agreement with revised terms should be submitted via email to: CS_Contract_Review@txdot.gov. Contract Services will perform a review of the agreement and respond by e-mail to the district with the results of its review.

Executing an Agreement

The district prepares and mails to the city or other entity for execution:

- two original hard-copy unexecuted agreements
- one blank sample ordinance or resolution, and
- one blank sample city secretary’s certificate for execution by the city.

Alternatively, the district can email PDF copies of the above documents.

After receipt of the signed agreements from the city or other entity, the individual with TxDOT signature authority executes both original agreements. Please refer to Contract Services' Crossroads website under "Delegation of Authority" to determine the appropriate official with TxDOT signature authority.

All agreements should be fully executed before plans, specifications, and estimates (PS&E) submission to the Design Division (DES) on all projects scheduled for local or statewide letting.

Digital Signature

Contract Services strongly recommends the use of digital signatures to fully execute agreements in place of a wet signature. TxDOT currently uses DocuSign, digital signature-as-a-service software that can be used to create and obtain secure digital signatures. If you have questions about the uses of DocuSign, please contact Contract Services at 512-416-4620. For all other DocuSign inquiries and technical support, please contact Information Management Division at 512-302-4357.

Agreement Requirements for Cities

Agreements with cities must be accompanied by an ordinance or resolution authorizing the elected head of the city, or a designated representative, to sign the agreement.

A completed city secretary's certificate must also accompany all agreements to verify that the ordinance or resolution was passed by the city. If the city secretary has signed and sealed the resolution or ordinance, then a separate city secretary's certificate is not required.

Agreement Requirements for Counties

When the agreement is with a county, it must be accompanied by an order of the commissioner's court authorizing the county judge to sign the agreement.

A county secretary's certificate must also accompany all agreements, unless the county secretary signs and seals the order.

Document Retention

When a contract is closed out, the file of record should be securely stored and protected until the legal document retention requirements have been met.

More Information

For more information on processing and executing traffic engineering agreements, see the Negotiated Contracts Policy Manual, Chapter 11.

Chapter 5 — Lighting Equipment

Contents:

Section 1 — Overview

Overview

This chapter covers the specifications, materials, and construction practices related to the equipment used in highway illumination.

TxDOT Standard Specifications Book

TxDOT's Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges specifies standard equipment and procedures to be used in the construction and maintenance of TxDOT highway projects.

Roadway illumination projects typically use specifications from the Chapter 600 Items - Lighting, Signing, Markings and Signals. Typical specifications used in a roadway lighting project include:

- Item 416, "Drilled Shaft Foundations"
- Item 610, "Roadway Illumination Assemblies"
- Item 613, "High Mast Illumination Poles"
- Item 614, "High Mast Illumination Assemblies"
- Item 616, "Performance Testing of Lighting Systems"
- Item 618, "Conduit"
- Item 620, "Conductors"
- Item 621, "Tray Cable"
- Item 622, "Duct Cable"
- Item 624, "Ground Boxes"
- Item 628, "Electrical Services".

Departmental Material Specifications

Departmental Material Specifications (DMS) are reference specifications for various materials published by the TxDOT Construction Division. For roadway illumination projects, the material specifications are in the 11000 series.

- DMS-11010 through DMS-11012 specifies roadway luminaires
- DMS-11020 through DMS-11021 specifies high mast equipment
- DMS-11030 specifies conduit
- DMS-11040 specifies conductors
- DMS-11050 specifies tray cable
- DMS-11060 specifies duct cable
- DMS-11070 specifies ground boxes
- DMS-11080 through 11085 specifies electrical service equipment.

These specifications are referenced by the Standard Specifications and by the electrical and lighting standard sheets, and are available on the TxDOT website.

Material Producer List

The Material Producer List contains TxDOT-approved products and materials from various manufacturers and producers. The MPL for roadway illumination equipment is called Roadway Illumination and Electrical Supplies. The MPL is posted on the TxDOT website and is updated regularly.

The Traffic Engineering section of the TxDOT Traffic Operations Division (TRF) reviews electrical and lighting equipment submittals for inclusion on the MPL. Materials that meet specifications are placed on the MPL and require no further submittals when used on construction or maintenance projects.

The prequalified equipment on the MPL for Roadway Illumination and Electrical Supplies includes:

- Item 610: LED roadway luminaires, HPS roadway luminaires, induction underpass luminaires, HPS lamps, photoelectric controls, breakaway fuse holders, and breakaway transformer bases
- Item 614: HPS high mast luminaires, HPS lamps, high mast assembly kits, and high mast rings
- Item 618: Rigid metallic conduit, PVC conduit, and High Density Polyethylene Conduit (HDPE)
- Item 620: XHHW conductors and breakaway fuse holders
- Item 621: Tray cable

- Item 622: Duct cable
- Item 624: Ground boxes and covers
- Item 628: Electrical service equipment and photoelectric controls.

Other MPL lists may also apply to roadway lighting projects, including:

- Roadway Illumination Pole and Luminaire Arm Fabrication Plants: Item 610 requires fabricators of roadway illumination poles and arms to be approved in accordance with DMS-7380, "Steel Non-Bridge Member Fabrication Plant Qualification." This MPL contains a list of approved fabrication plants.
- High Mast Illumination Pole Fabrication Plants: Item 613 requires fabricators of high mast poles to be approved in accordance with DMS-7380, "Steel Non-Bridge Member Fabrication Plant Qualification." This MPL contains a list of approved fabrication plants.
- High Mast Ring and Support Assembly Fabrication Plants: Item 614 requires fabricators of high mast rings and support assemblies to be approved in accordance with DMS-7380, "Steel Non-Bridge Member Fabrication Plant Qualification." This MPL contains a list of approved fabrication plants.

Standard Sheets

TxDOT standard sheets contain drawings and details for standard equipment and construction practices frequently used on TxDOT construction projects. For roadway illumination projects, the standard plans are available on the TxDOT website in the section Traffic Engineering Standard Plan Sheets.

- ED -The Electrical Details sheets specify construction practices for installing conduit, conductors, ground boxes, and electrical service equipment.
- RID -The Roadway Illumination Details sheets specify construction practices for installing pole lighting, light pole foundations, and underpass lighting.
- RIP - The Roadway Illumination Pole Details sheets specify construction and fabrication practices for light poles, luminaire arms, anchor bolts, and breakaway transformer bases.

- HMID - The High Mast Illumination Details sheets specify construction and fabrication details for high mast rings, lowering devices, electrical systems, and luminaires.
- HMIP - The High Mast Illumination Poles sheets specify construction and fabrication details for high mast poles.
- HMIF - The High Mast Illumination Pole Foundations sheets specify construction and fabrication details for high mast pole foundations.

Special Specifications and Special Provisions

If non-standard equipment is called for on a project, it may be specified by special specification or by special provision. A special specification is a supplemental specification not covered by the standard specifications. A special provision is an addition or revision to a standard specification or a special specification.

Special specifications and special provisions must be submitted via email to CST_RDWY_SPECS@txdot.gov for approval before using them on a project. Previously used special specifications and provisions are available on the TxDOT website and may be resubmitted for new projects.

Section 2 — Roadway Illumination Assemblies

Item 610 - Roadway Illumination Assemblies

TxDOT standard pole lighting and underpass lighting is specified by Item 610, "Roadway Illumination Assemblies." Item 610 includes luminaires, poles, luminaire arms, anchor bolt assemblies, and conductors internal to the assembly. The poles must be fabricated at a plant on the MPL for Roadway Illumination Pole and Luminaire Arm Fabrication Plants.

Configurations

Lighting assemblies specified by Item 610 use three typical configurations based on the purpose of the lighting:

- Continuous lighting typically uses 50' light poles with either 400 watt HPS or the equivalent size LED. This configuration can light a roadway to minimal freeway levels up to 60' across the roadway from the luminaire.
- Safety lighting typically uses 40' light poles with either 250 watt HPS or the equivalent size LED. This configuration can light a roadway to minimal levels up to 50' across the roadway from the luminaire.
- Underpass lighting is typically mounted to the bridge structure at 16' mounting height, with either 150 watt HPS or the equivalent size LED.

TxDOT roadway illumination assemblies are designated by the RIP standards with the codes shown in Figure 5-1.

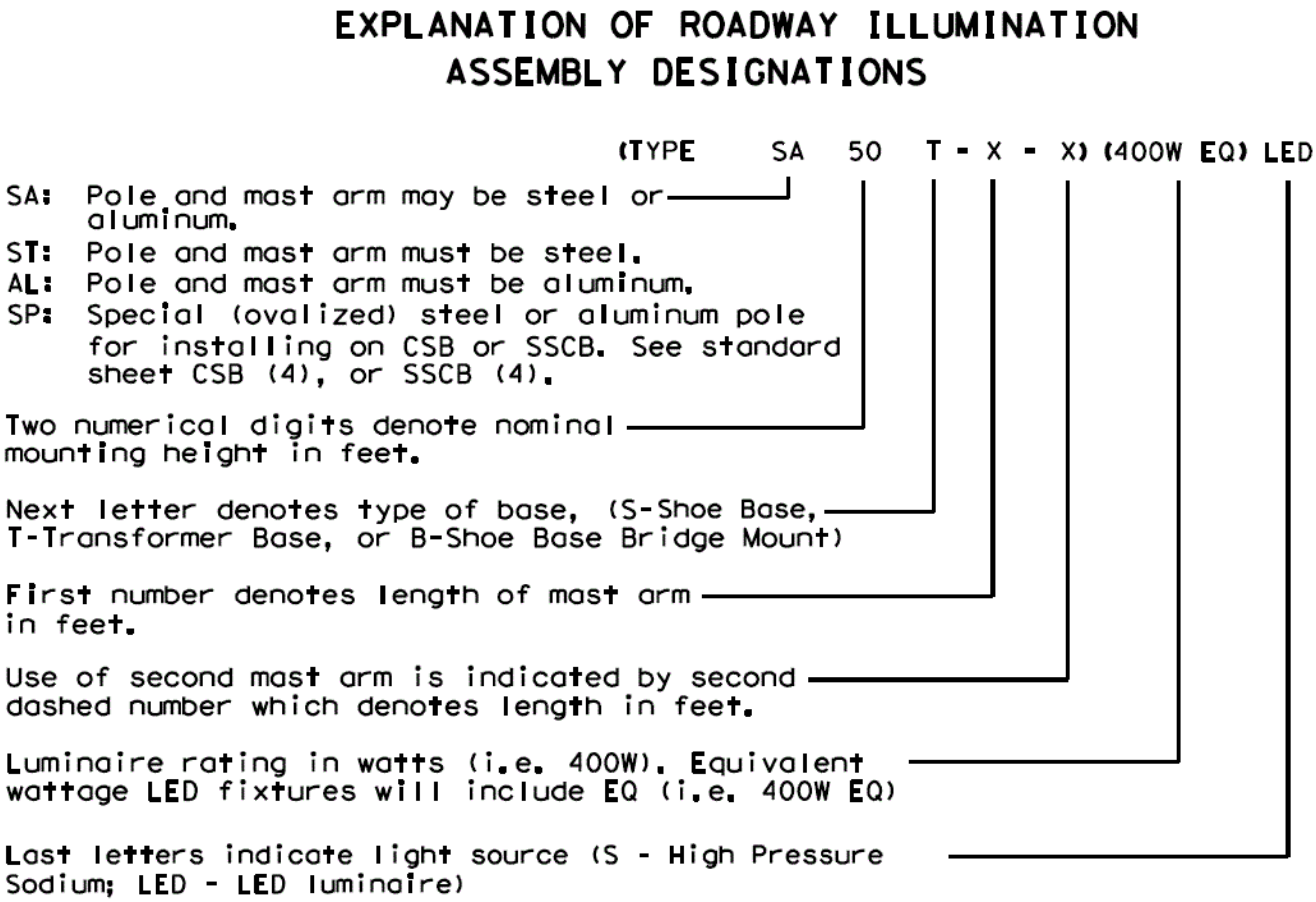

Figure 5-1. Explanation of roadway illumination assembly codes.

DMS 11010

Item 610 of the Standard Specifications references DMS-11010, "Roadway Illumination Light Fixtures," as the main fixture specification. DMS-11010 in turn references DMS-11011 for LED luminaires, and DMS-11012 for HPS luminaires.

RID Standards

The Roadway Illumination Details (RID) standards are used in most plan sets that contain illumination. RID(1) contains general notes needed for most installations. RID(2) shows details for illumination foundations. RID(3) has details for underpass illumination.

LED Luminaires

TxDOT began using LEDs for roadway lighting in 2010. Before that, the dominant technology was high pressure sodium, which has been used since the 1970s. Since most of TxDOT's existing lighting infrastructure is based on HPS, the performance of TxDOT's LED luminaires is based on the equivalent HPS luminaires.

LED has several advantages over HPS for roadway lighting:

- HPS lamps have to be replaced every 3-5 years. LED luminaires do not have replaceable lamps, but are expected to last for 15-20 years. The long life reduces the need for maintenance, which saves time and money. Reduced maintenance also increases safety, since it requires less time for maintenance crews to work on the roadway.
- LED luminaires use less energy than their equivalent HPS luminaires. For example, at the time of writing, one of TxDOT's approved LED fixtures draws 185W compared to its 400W equivalent HPS fixture.
- LED luminaires emit white light, compared to the yellowish light of HPS. Colors are rendered better with white light and this can improve visibility for the driver.

TxDOT LED roadway luminaires are specified by DMS-11011. Features of the specification include:

- Three standard sizes of LED luminaire: 150W EQ, 250W EQ, and 400W EQ. The sizes correspond to the equivalent 150W, 250W, and 400W HPS standard luminaires used by TxDOT. The LED fixtures may be used as direct replacements for their equivalent size HPS luminaire.
- Unique Light Loss Factor (LLF) computed for each fixture at 70,000 hours (approximately 16 years). The design LLF is posted with each prequalified luminaire on the MPL.
- Verification testing of luminaires by the manufacturer. The luminaire manufacturer tests a sample of each batch of fixtures built, and sends the results to TRF for evaluation. If the sample meets specifications, TRF passes the batch and the fixtures are released for construction. Fixtures do not need to be sampled and tested from the project unless the engineer sees a need for it.

- Surge protection. Surge protection to 10kA and 10kV is included on the luminaire to help ensure long life.
- Warranty. The luminaires are warranted for 10 years when non-operable due to defects in the material or workmanship. A date code is included on an internal label to verify the warranty period.

HPS Luminaires

TxDOT's HPS roadway luminaire specification is DMS-11012. The standard luminaire sizes are 150W, 250W, and 400W.

In most cases LED is a better choice for roadway lighting than HPS because of LED's maintenance and energy benefits. However HPS is a valid light source and may be used as long as it is available.

Prequalification

TRF reviews LED luminaire submittals for conformance to DMS-11011, and reviews HPS for conformance to DMS-11012. When all testing and documentation has been received and accepted, the luminaires are added to the MPL for Roadway Illumination and Electrical Supplies. The six standard configurations are: 150W EQ, 250W EQ, and 400W EQ; with input voltages of either 240V or 480V.

Light Loss Factor (LLF)

The LLF is a depreciation factor based on how the light output of a fixture decreases with time. All photometric calculations for illumination design should use the LLF that corresponds to the luminaire used.

For LED the LLF is based on how well the luminaire dissipates heat. An LED luminaire that dissipates heat well will depreciate slower, and will have a higher LLF than a luminaire that does not dissipate heat well. For TxDOT LEDs the LLF is between 0.70 and 0.90, and is posted with each luminaire on the MPL. The method for determining a LED luminaire's LLF is in DMS-11011.

For HPS, the LLF is based on the depreciation characteristics of a HPS lamp. TxDOT's design LLF for HPS is 0.65.

Light Distribution Patterns

The Illumination Engineering Society (IES) writes many of the industry standard specifications for fixtures. The IES has designated several standard types based on their light distribution patterns. Figure 5-2 shows plan views of light distribution patterns for the basic types of conventional luminaires. TxDOT standard roadway luminaires are typically IES Type II or Type III.

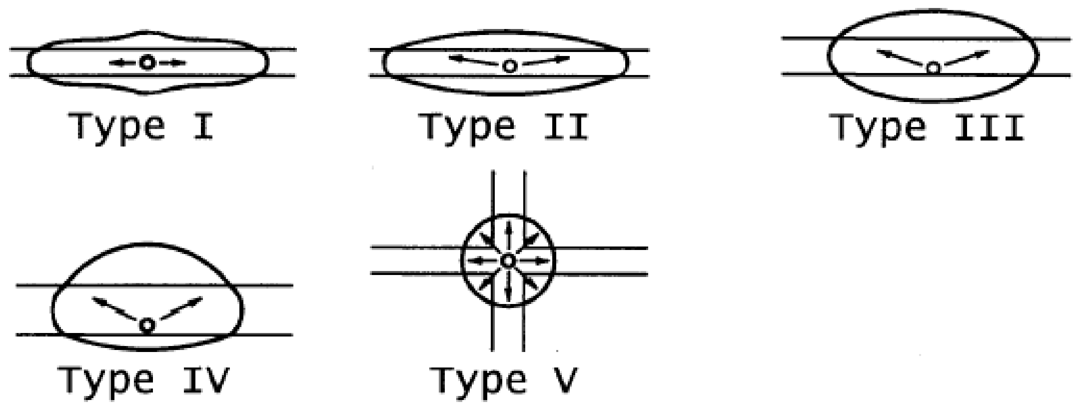

Figure 5-2. Plan views of light distribution patterns for basic types of conventional luminaires.

Luminaire Poles

Luminaire poles specified by Item 610 are made of galvanized steel or aluminum. The poles and arms must be fabricated at an approved plant in accordance with DMS-7380. The MPL for Roadway Illumination Pole and Luminaire Arm Fabrication plants contains a list of the plants that meet the specifications.

Poles fabricated according to the RIP standards at an approved plant do not require shop drawing submittals. Aluminum poles and alternate designs to the RIP standards require electronic shop drawing submittals.

RIP Standards

The Roadway Illumination Pole (RIP) standard sheets contain the specifications and details for TxDOT's standard illumination poles. It includes details for shoe base poles, transformer base poles, barrier-mounted poles, luminaire arms, anchor bolts, and pole bases. The RIP sheets should be included in the plans whenever standard luminaire poles are used on a project.

Shoe Base Poles

Shoe base poles have a square baseplate and are bolted directly to a foundation, bridge bracket, or retaining wall bracket. These poles will not break away when struck by a vehicle and should only be used in locations where they are not likely to be hit. Typical locations for shoe base poles are behind guard rails, outside the clear zone, or mounted on a bridge or retaining wall bracket.

Shoe base poles have a hand hole near the bottom of the pole for access to electrical connections. Even though the pole is not breakaway, the RID standards require a two-pole fused breakaway connector for the internal conductors that is accessible through the hand hole. This can be used to disconnect the luminaires from the circuit as needed during maintenance.

Transformer Base Poles

Transformer base (T-base) poles are similar to shoe base poles, but the base plate is sized to fit on top of a transformer base, which is bolted to a foundation. T-base poles are designed to break away when hit, and should be used in locations inside the clear zone where they might be struck by a vehicle.

The transformer base originated in the days when the ballast (or transformer) for the luminaire was placed in the base of the pole, and the fixture housing and lamp were at the top of the pole. When luminaires began using internal ballasts, the T-base was kept for its breakaway characteristics even though it was no longer needed to house the ballast.

A transformer base is a breakaway support made of aluminum. TxDOT T-bases are designed to have the strength to support a 50 foot pole with two 12 foot arms, and also to be easily broken on impact (frangible). Transformer bases must meet AASHTO requirements and also must be impact tested and approved by the FHWA. TxDOT's approved T-bases are listed under Item 610 on the MPL for Roadway Illumination and Electrical Supplies.

Transformer base poles do not typically have a hand hole in the pole, but the electrical connections are made up in the T-base. TxDOT T-bases have a non-metallic door to discourage metal theft. The RID standards require a two-pole fused breakaway connector for the internal conductors to be placed in the T-base. If the pole is hit and breaks away, the breakaway connector will safely separate the pole from the electrical circuit.

Light Pole Foundations

A roadway illumination foundation is necessary for all ground-mounted light poles. They are typically specified by 0416 6029 DRILL SHAFT (RDWY ILL POLE) (30 IN). The foundation's concrete and steel is included in Item 416, and the anchor bolts are included in Item 610. If a riprap pad is used around the foundation, it is typically specified by 0432 6001 RIPRAP (CONC)(4 IN).

Details for TxDOT's standard roadway illumination foundations are on the RID(2) standard sheet. The standard diameter is 30 inches, and the depth is 6 to 10 feet, depending on soil conditions. Roadway illumination foundations are measured by the linear foot of drill shaft depth.

In previous standards, grounding for the foundation consisted of a ground rod in the foundation plus a bonding conductor between the anchor bolts and the steel in the foundation. The bonded steel and anchor bolts create a concrete-encased grounding electrode (see NEC 250.52(A)(3)). A concrete encased grounding electrode typically has lower resistance and creates a better connection to ground than a ground rod. Since the concrete-encased electrode creates a good ground, the ground rod in the foundation was removed from the latest version of the standard.

Poles on Traffic Barriers

Luminaire poles are frequently mounted on traffic barriers when barriers are available. Poles on barriers have good protection from being hit and are able to efficiently light traffic lanes in both directions.

Barrier-mounted poles have a special 8 in. x 18 in. rectangular base plate that will fit on the top of a traffic barrier. The round pole is "squashed" at the base by the fabricator so it will fit on the narrow base plate.

Barrier-mounted poles have hand holes for access to wiring, and all hand holes should be oriented on the same side of the barrier for easier maintenance. Even though the pole is not breakaway, the RID standards require a two-pole fused breakaway connector for the internal conductors that is accessible through the hand hole. This can be used to disconnect the luminaires from the circuit as needed during maintenance.

Traffic barriers require extra reinforcement to support light poles. Details for mounting light poles on F-shape barriers are in the standard sheet CSB(4). Details for light poles on single-slope barriers are on standard sheet SSCB(4).

Poles on Bridges

Light poles on bridges are typically mounted on concrete brackets along the outside edges of the bridge behind the traffic rail. The BL standard sheet contains electrical and structural details for installing lighting on bridges. Light pole locations on bridges should be shown on the bridge plan sheets as well as on the lighting sheets to help ensure the brackets are constructed along with the bridge slab.

The BL standard recommends structural locations for poles placed on bridges. To reduce pole vibration, the pole should be placed within an eighth of a bridge span distance from the bent. The pole should also be placed at least 4 feet from the center of any bent and at least 3 feet from any deck drain. These factors should be considered along with illumination levels when laying out pole locations.

Poles on Retaining Walls

Light poles may be mounted on retaining walls with a concrete bracket behind the traffic rail. The structural and electrical details are on standard sheet RW(LB). The pole should not be placed on the bracket until after the coping and pavement have been constructed.

Breakaway Connectors

Breakaway connectors are fused or unfused connectors in the bases of light poles. Fuses are required in the "line" conductor (hot wire) of all light poles for circuit protection. This is accomplished by using special pull-apart fuse holders (breakaway connectors). If the light circuit uses a neutral conductor, the neutral part of the breakaway connector should be unfused.

TxDOT uses double-pole breakaway connectors that are designed to separate both power conductors at once. In addition to being a breakaway device, they also work well as a way to disconnect the luminaire from the rest of the circuit. For this reason, double-pole breakaway connectors are required in both breakaway and non-breakaway poles, to serve as a breakaway device and as a way to disconnect the luminaire.

When installing a breakaway connector, attach the female connector to the energized end of the wire. Leave the male connector with the wires traveling up the pole. This reduces the possibility of someone coming into contact with the energized circuit if the pole is knocked down.

Underpass Lighting

Underpass lighting is mounted to the bridge structure and is detailed on RID(3). Luminaires are typically 150W EQ but may be larger for heights above 16'. Each lighting circuit on a bridge requires a lockable fused disconnect mounted at least 10 feet above grade on the bridge column or bent cap.

Type 1 underpass assemblies are mounted with 2 in. diameter arms on the bent cap of the bridge. This is the simplest mounting and may be used when the bent is close enough to the roadway for the underpass lighting to be effective.

Type 2 underpass assemblies are mounted on the bridge beams, and are used when lighting mounted on the bent would be too far from the edge of the roadway to be effective. Type 2 arms are attached near the top of the beam to avoid the beam's internal reinforcing steel strands. If the height of the beam is less than 54 in. then the luminaire is mounted on a 2 in. diameter arm. If the height of the beam is greater than 54 in. then the clamped part of the arm is

2 ½ in. diameter, and reduces down to 2 in. where the luminaire is attached.

Each underpass luminaire is protected with internal 10 amp time delay fuses to remove the luminaire from the circuit in case of failure. Underpass circuits that use a neutral require one fuse per fixture, and circuits with two hot conductors require two fuses per fixture.

Standard sheet RID(3) has details for Type 1 underpass, Type 2 underpass, and general notes applicable to most underpass installations.

Item 616 - Performance Testing of Lighting Systems

Performance testing under Item 616 is included in the specifications for roadway illumination under Item 610 and high mast illumination under Item 614. Item 616 calls for a 14 day operational test, with 48 hours of constant operation followed by 12 days of operation controlled by photocell. Once the system passes the 14-day test and the contract is accepted, TxDOT will relieve the contractor of maintenance responsibilities.

Section 3 — High Mast Lighting Assemblies

Introduction

High mast lighting assemblies require three standard specification items for a complete assembly. Item 613 specifies the pole. Item 614 specifies the mechanical parts, electrical parts, and luminaires. Item 416 specifies the foundation.

Configurations

High mast lighting assemblies are specified by pole height and by photometric type. The standard pole heights are 100', 125', 150', and 175'. The photometric types are Types A, B, and S:

- Type A high masts are specified as 150' poles with 12 HPS or 6 LED luminaires, spaced 920' apart, and able to light an 8-lane highway to minimal AASHTO freeway levels.
- Type B high masts are specified as 150' poles with 12 HPS or 6 LED luminaires, spaced 800' apart, and able to light a 14-lane highway to minimal AASHTO freeway levels.
- Type S high masts are specified as 150' poles with 12 HPS or 6 LED luminaires, and able to light a 450' square area to a minimum of 0.20 foot candles.

Type A and B high mast luminaires have asymmetric optics. This means that instead of creating a round light pattern, they create a long narrow light pattern that works well for lighting a roadway. All Type A or B high mast fixtures on a ring are required to be mounted level and oriented the same direction, typically toward the road. Since they are radially spaced in a ring, the optics must be rotatable to allow aiming.

Type S high mast luminaires have symmetric optics which create a round pattern around the pole. The luminaires must be mounted level, but since they have a round pattern they do not require rotation of the luminaire.

Item 613 - High Mast Illumination Poles

High mast poles are specified by Item 613 and include the pole and anchor bolts. The poles must be fabricated at a plant listed on the MPL for High Mast Illumination Pole Fabrication Plants.

HMIP Standards

The High Mast Illumination Pole (HMIP) standard contains details and dimensions for TxDOT's standard high mast pole. The standard pole heights are 100', 125', 150', and 175'. The design wind speeds are 80 mph and 100 mph. The wind speed for a location is determined by the standard sheet Wind Velocity and Ice Zones (WV & IZ).

Poles fabricated at an approved fabrication plant and according to the HMIP standards do not require shop drawing submittal.

Item 614 - High Mast Illumination Assemblies

Item 614 specifies the electrical and mechanical working parts of a high mast lighting assembly. This includes the luminaires, wire rope, rings and supports, obstruction lighting, hoisting assemblies, power drive assemblies, and all other electrical equipment.

The ring and support assemblies must be fabricated at a plant listed on the MPL for High Mast Ring and Support Assembly Fabrication Plants. Luminaires are specified by DMS-11020 or Special Specification 6156. Rings, mechanical, and other electrical parts are specified by DMS-11021 and the HMID standard sheets.

DMS-11020 High Mast Light Fixtures

HPS high mast luminaires are specified by DMS-11020. TxDOT typically uses 12 400W HPS luminaires on a ring. HPS luminaires are prequalified on the MPL for Roadway Illumination and Electrical Supplies.

HPS high mast luminaires are not pretested, so they require sampling and testing from the field. Two luminaires must be sampled from each high mast type in the field, unless there are less than 15 luminaires of a certain type. These are sent to a luminaire test lab for testing. TRF oversees the testing contract, receives the test reports, and evaluates whether the luminaires pass or fail to meet specifications.

In most cases LED is now a better choice for high mast lighting than HPS because of LED's maintenance and energy benefits. However HPS is a valid light source and may be used as long as it is available.

SS 6156 LED High Mast Light Fixtures

LED high mast light fixtures are specified by Special Specification 6156. SS 6156 includes all the other mechanical and electrical parts listed in Item 614, so for a LED high mast assembly, SS 6156 would be used in place of Item 614.

TxDOT LED high mast luminaires are able to use 6 fixtures to light the same area that is lit with 12 TxDOT HPS fixtures. They are designed to be a direct replacement for a 12 fixture HPS ring, and have the same distribution types A, B, and S.

LED high mast luminaires are not currently on an MPL and require submittals for each project. However TRF has reviewed several brands and may be contacted for assistance in evaluating whether a submitted luminaire meets specifications.

LED high mast luminaires do not currently have sampling and testing requirements.

DMS-11021 High Mast Illumination Assembly Kits

All high mast mechanical and electrical materials required for a complete high mast lighting assembly that are not specified elsewhere are specified by DMS-11021. This includes rings, ring supports, obstruction lights, hoisting assemblies, power drive assemblies, electrical equipment, power cord, enclosures, and other materials detailed in the HMID standards.

High mast illumination assembly kits are prequalified under Item 614 on the MPL for Roadway Illumination and Electrical Supplies.

HMID Standards

The High Mast Illumination Details (HMID) standard sheets contain the specifications and details for the structural, mechanical, and electrical parts of TxDOT's standard high mast lighting assemblies. It includes details for the ring, ring supports, lowering system, and other mechanical and electrical systems needed to construct a complete assembly. The HMID sheets should be included in the plans whenever high mast lighting assemblies are used on a project.

High Mast Illumination Pole Foundations

A high mast illumination pole foundation is necessary for all high mast poles. They are typically specified by 0416 XXXX DRILL SHAFT (HIGH MAST POLE) (XX IN), where the diameter XX can range from 54 in. to 66 in. The foundation's concrete and steel is included in Item 416, and the anchor bolts are included in Item 613. The riprap pad around the foundation is typically specified by 0432 6001 RIPRAP (CONC)(4 IN).

High mast illumination pole foundations are measured by the linear foot of drill shaft depth.

HMIF Standards

The High Mast Illumination Foundation Details (HMIF) standard sheets contain the specifications and details for TxDOT's standard high mast foundations. They include details for the foundation, and design information for the drill shaft depth, diameter, and anchor bolts. The HMIF sheets should be included in the plans whenever high mast lighting assemblies are used on a project.

Section 4 — Conduit, Conductors and Ground Boxes

Item 618 - Conduit

Item 618 contains specifications for furnishing and installing conduit. This includes conduit, fittings, junction boxes, supports, trenching, and backfill. Conduit is measured by the linear foot.

The material specifications are in DMS-11030, "Conduit." Standard sheet ED(1) contains general material and construction details that apply to all conduit installations and should be included in all plan sets that use conduit. Standard sheet ED(2) contains details for conduit supports and should be used when conduit is to be mounted on structures.

DMS-11030

DMS-11030 specifies the materials for Rigid Metal Conduit (RMC), Polyvinyl Chloride Conduit (PVC), and High Density Polyethylene Conduit (HDPE). Conduits that meet the material specification are listed by their types under Item 618 in the MPL for Roadway Illumination and Electrical Supplies.

DMS-11030 also contains specifications for conduit fittings and junction boxes. These materials are not listed on the MPL, but compliance with the specifications should be verified in the field.

Item 620 - Electrical Conductors

Item 620 contains specifications for furnishing and installing conductors. This includes conductors, splices, ground rods, and breakaway connectors. Conductors are measured by the linear foot.

The material specifications are in DMS-11040, "Conductors." Standard sheet ED(3) contains general material and construction details that apply to all conductor installations and should be included in all plan sets that use conductors.

DMS-11040

DMS-11040 specifies the materials for type XHHW conductors. Conductors that meet the material specification are listed by their types under Item 620 in the MPL for Roadway Illumination and Electrical Supplies. This section of the MPL also contains approved breakaway fuse holders that meet the specification.

DMS-11040 also contains specifications for splicing materials and ground rods. These materials are not listed on the MPL, but compliance with the specifications should be verified in the field.

Item 621 - Tray Cable

Item 621 contains specifications for furnishing and installing tray cable. Tray cable is a multi-conductor cable assembly and follows the requirements in the NEC for "Power and Control Cable Type TC." The material specifications are in DMS-11050, "Tray Cable." Tray cable is measured by the linear foot.

DMS 11050

DMS-11050 specifies the materials for 3-conductor and 4-conductor tray cable with type XHHW insulation. Cables that meet the material specification are listed with their sizes under Item 621 in the MPL for Roadway Illumination and Electrical Supplies.

Item 622 - Duct Cable

Item 622 contains specifications for furnishing and installing duct cable. Duct cable is a factory assembly of conductors in a non-metallic raceway, and follows the requirements in the NEC for "Nonmetallic Underground Conduit with Conductors." Duct cable is measured by the linear foot.

The material specifications are in DMS-11060, "Duct Cable." Standard sheet ED(11) contains general material and construction details that apply to all duct cable installations and should be included in all plan sets that use duct cable.

DMS 11060

DMS-11060 specifies the materials for HDPE duct cable with XHHW conductors. Cables that meet the material specification are listed with their sizes under Item 622 in the MPL for Roadway Illumination and Electrical Supplies.

Item 624 - Ground Boxes

Item 624 contains specifications for furnishing and installing ground boxes. Ground boxes may be either factory-made or cast in place. Item 624 includes ground boxes, covers, and concrete aprons.

The material specifications are in DMS-11070, "Ground Boxes." Standard sheet ED(4) contains general material and construction details that apply to all ground box installations and should be included in all plan sets that use ground boxes.

DMS 11070

DMS-11070 specifies the materials and requirements for precast polymer concrete ground boxes and covers. Five sizes of the Types A, B, C, D, and E are specified. Ground boxes that meet the material specification are listed by their types under Item 624 in the MPL for Roadway Illumination and Electrical Supplies.

Section 5 — Electrical Services

Item 628-Electrical Services

Item 628 contains specifications for furnishing and installing electrical services. This includes all components, including poles, service supports, foundations, anchor bolts, riprap, enclosures, breakers, service conduit (up to and including the elbow if below ground), and other associated materials that make up the electrical service equipment.

Electrical services that meet the material specifications are listed by type under Item 628 in the MPL for Roadway Illumination and Electrical Supplies.

Configurations

Electrical services are designated in the ED standards with the codes shown in Figure 5-3.

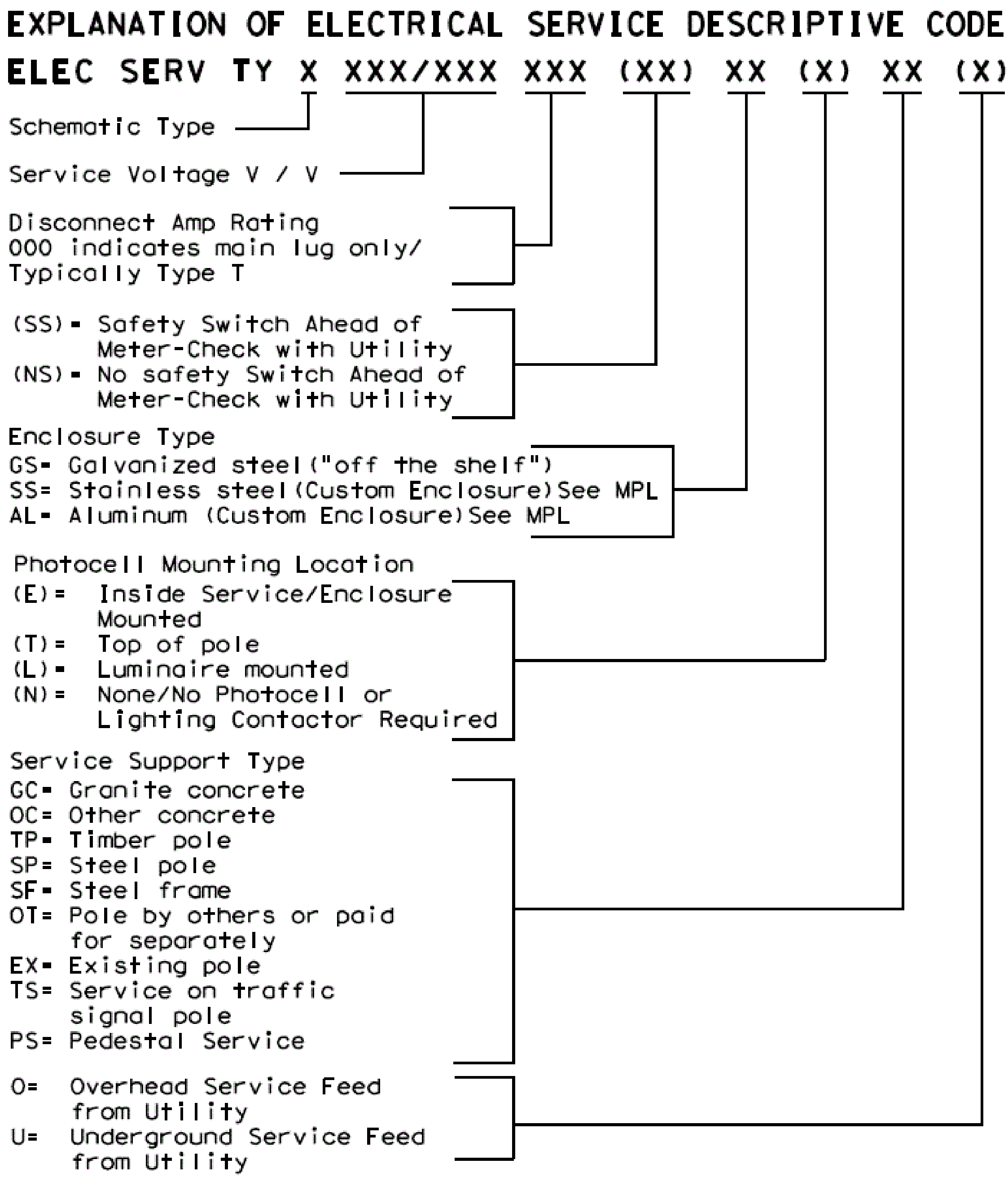

Figure 5-3. Explanation of electrical service descriptive code.

- Schematic type refers to the wiring diagrams for electrical service Types A, C, D, or T from ED(6).
- Service voltage is typically either 120/240V or 240/480V single phase.

- Disconnect rating is the amp rating of the main breaker. Type T services have no main breaker and are designated with 000.
- SS is used if a safety switch ahead of the meter is required by the local electric provider. NS is used if a safety switch is not required.
- The service enclosure may be made of galvanized steel (GS), stainless steel (SS), or aluminum (AL). GS enclosures are only allowed as called for in DMS-11082 through DMS-11084. GS is not allowed for Type A services or for custom-built C or D enclosures. All Type T services are galvanized steel (GS).
- Enclosure mounted photocells (E) are mounted inside the service enclosure, positioned to receive light through a window. As an alternative, the photocell may be placed at the top of the service pole (T), or on each individual luminaire (L). Electrical services with no photocell are designated by (N).
- The service support types GC, OC, TP, SP, and SF are specified by DMS-11080 and the ED standards. Types OT, EX, and TS are existing or are specified elsewhere in the plans. Pedestal services PS are specified by DMS-11080, DMS-11085, and ED(9).
- Overhead services (OH) are fed from the electric utility to a weatherhead at the top of the pole. Underground services (UG) are fed from the electric utility through underground conduit into the bottom of the service equipment.

Standard Sheets

The ED standard sheets detail the different types of electrical services and their supports:

- ED(5) contains general material and construction details that apply to all electrical service installations and should be included in all plan sets that have electrical services. It also contains the legend for electrical service descriptive codes.
- ED(6) contains schematics for electrical service Types A, C, D, and T and should be included in all plan sets that have electrical services.
- ED(7) contains details for electrical services mounted on steel poles and steel frames.
- ED(8) contains details for electrical services mounted on traffic signal poles.

- ED(9) contains details for pedestal electrical services
- ED(10) contains details for electrical services mounted on granite concrete, other concrete, and timber poles.

DMS 11080

DMS-11080, "Electrical Services," contains the material specifications common to all electrical services specified by Item 628. This includes the circuit breakers, enclosures, labeling, control circuits, photocells, contactors, and service supports.

- DMS-11081, "Electrical Services - Type A"
- DMS-11082, "Electrical Services - Type C"
- DMS-11083, "Electrical Services - Type D"
- DMS-11084, "Electrical Services - Type T"
- DMS-11085, "Electrical Services - Pedestal (PS)"

Type A Electrical Services

Type A electrical services are used to power lighting circuits only. All circuits are controlled by a lighting contactor and photo control. All circuits are automatically switched on during the night and off during the day. Line voltage for Type A services may be 120/240V or 240/480V.

Type A services use individual feed-through branch circuit breakers mounted to a back plate in the cabinet. Typically the maximum number of circuits in a Type A service is 4 or 5.

Type C Electrical Services

Type C electrical services are similar to Type A services in that they are used to power lighting circuits only. All circuits are controlled by a lighting contactor and photo control. All circuits are automatically switched on during the night and off during the day. Line voltage for Type C services may be 120/240V or 240/480V.

Type C services use a panelboard and plug-in breakers and can power more circuits than a Type A service. If more than 5 lighting circuits are needed at service, then a Type C should be used.

Type D Electrical Services

Type D electrical services are used to power both constant power circuits and lighting circuits. A Type D service contains a panelboard with a main breaker and several slots for plug-in type breakers. It contains a 2-pole lighting contactor and photocell that will switch one circuit on and off for lighting. Type D services are 120/240V only.

Type D services are typically used for traffic signals, where the controller requires constant power and the lights are only powered at night.

Type T Electrical Services

Type T electrical services are used for constant-power circuits only. It contains a load center with a maximum of 6 plug-in breaker spaces and has no main breaker and no lighting controls. Type T services are stock items from the manufacturer with galvanized steel enclosures only, and are not custom built like Types A, C, and D. Type T services are 120/240V only.

Type T services are used for signals and Intelligent Transportation Systems (ITS) locations with no lighting and a small number of circuits.

Pedestal Services

Pedestal services contain the electrical equipment in a pedestal enclosure rather than mounted on a pole. The pedestal is approximately 4 feet tall and may be made of aluminum or stainless steel. All conduits enter the pedestal from underground. A pedestal service may contain Type A, C, or D service equipment. Pedestal services are typically used in landscaped or pedestrian areas where a neat appearance is required.

The pedestal service contains the TxDOT service equipment in the front part of the pedestal, with the utility meter and connections in the back. The pedestal service is designed to use a standard utility kWh meter.

Electric utilities typically use a standard meter for 120/240V services, and some use a standard meter for 240/480V services. However, some utilities use a transocket to meter 480V services. A transocket has to be mounted in a separate cabinet and will not fit in the TxDOT pedestal.

If a 480V pedestal service is planned for a project, the designer should verify whether the electric utility requires a standard meter or a transocket. If a transocket will be used, it will need to be installed separately from the pedestal, or else a pole-mounted service could be used instead of a pedestal.

Chapter 6 — Lighting Design and Layout

Contents:

Section 1 — Overview

Project Design Procedures

Highway illumination project designers generally follow the steps shown in the table below.

Highway Illumination Project Design Process

Step	Action
1	Determine whether the lighting will be safety lighting or continuous lighting; then check to see to what extent lighting is warranted. (See Chapter 2.)
2	If the project is inside a city's limits, contact the city to see if they are willing to help finance continuous lighting for the project. (See Chapter 4.) Obtain the proper lighting agreement.
3	Determine what type of lighting to use (pole height, median or house side mounting or high mast). (See guidelines and standards throughout this chapter.)
4	Place lighting poles for the entire project. (See "Spacing of Light Poles" and "Pole Placement Guidelines" in this chapter.)
5	Contact utility company to determine the type of service available and possible electrical service locations. (See Chapter 7 "Electrical Service.")
6	Lay out circuits, keeping road crossings to a minimum, as jacking or boring escalates costs. (See Chapter 7, "Circuit Design.")
7	Determine and label poles, length and size of wire, conduit, and duct cable. NOTE 1: Show pole station number and offset from base line or edge line if applicable. NOTE 2: For poles with similar offsets, offset can be shown by plan note. NOTE 3: Electrical service numbers and light pole numbers are recommended.
8	Prepare sheet summaries and project summaries. (The project summary shows the items and quantities needed for the entire project. It is compiled from the sheet summaries and usually includes the electrical service data.)
9	If the project is inside a city limit, submit plans and title sheet with the proper quotation for city approval and signature. (For example, see Chapter 4, "Quotation on Plan Title Sheet.")

Project Lead Time

For projects involving mainly illumination, an appropriate lead time must be allowed for the contractor to obtain the necessary materials. Typical lead time is 90 days for conventional lighting and 120 days for high mast lighting. This gives the pole manufacturers ample time to fabricate poles.

Joint Usage

Joint usage of poles is encouraged to reduce roadside clutter and the number of fixed objects along the roadside. When lighting is provided at signalized intersections and when conditions permit, the luminaires should be mounted on the traffic signal pole.

Luminaires on Traffic Signal Poles

Luminaires on traffic signal poles should be powered from the same electrical service that powers the traffic signal.

Luminaire arms should be perpendicular to the roadway to be lighted. TxDOT roadway luminaires are designed to project light to the left and right of the luminaire to efficiently light the roadway.

Railroad Crossings

For work involving railroad overpasses, consult the *Rail-Highway Operations Manual* for required agreements with or notification of railroad companies.

Underpasses

Underpass lighting may improve safety in situations where:

- the roadway beneath the underpass has continuous lighting on both sides of the underpass
- pedestrian activity is expected along the roadway near or beneath the underpass
- the geometry of the roadway changes beneath the underpass, for example a narrow shoulder
- other hazards exist.

If none of these situations exist, adding underpass lighting will not usually significantly improve the safety of the roadway.

Tunnels

For lighting purposes, a tunnel is defined as a structure over a roadway which restricts the normal daytime illumination of a roadway section such that the driver's visibility is substantially diminished. Tunnels cover roadways and produce a shadow that limits the ability of the driver to see objects or obstructions within the tunnel.

Tunnel lighting can require both daytime and nighttime lighting. Tunnel lighting design is outside the scope of this manual. For more information, see the AASHTO Roadway Lighting Design Guide and ANSI/IES RP-22-11 Tunnel Lighting.

Sidewalks and Bikeways

When installing lighting using state funds on sidewalks and bikeways (henceforth termed pedestrian lighting) along streets and highways, it is essential that the street be lit to the same level as the sidewalk or bikeway. This road lighting may be existing or may be added with the pedestrian lighting; it may be a part of the same lighting system or a separate lighting system.

This requirement is not intended to oblige cities or other entities to light the entire roadway if they desire some type of lighting along the roadway in accordance with Chapter 2, "Systems Financed, Installed, and Operated by Other Agencies." However, the following points are generally accepted and should be considered.

- The reduction of veiling glare is beneficial.
- Veiling glare observed by a motorist is mitigated by increasing the illuminance of the roadway.

The street and sidewalk or bikeway may be considered together as one element in determining minimum light level and uniformity. The contribution of both the pedestrian lighting system and the road lighting system may be considered for calculating light levels and uniformity of the sidewalk or bikeway and the roadway.

Aesthetic Lighting

TxDOT uses aesthetic lighting to highlight roadway structures, walls, and landscaping. Further information and guidelines for aesthetic lighting are detailed in the Landscape and Aesthetics Design Manual, Chapter 4, Section 9.

Other Types of Lighting

Other types of lighting systems (such as for rest areas, parking lots, central business districts, or temporary lighting in work zones) may be designed to meet the applicable requirements of AASHTO, IESNA, CIE, or other standards as deemed appropriate by the district engineer.

Section 2 — Illumination Levels

Introduction

This section describes TxDOT's standards for illumination levels for various roadway lighting situations.

Illuminance and Luminance

Lighting levels for typical roadways may be designed by calculating either the illuminance levels, luminance levels, or both.

Illuminance in roadway lighting is a measurement of the amount of light that hits the pavement surface. Illuminance is measured in foot-candles (US customary units) or lux (SI units). TxDOT projects are typically calculated in foot-candles. Illuminance layouts may be designed with lighting design software or with illuminance templates. The illuminance at any point will be the sum of illuminance from one or several contributing sources.

Luminance in roadway lighting is a measurement of the reflected light from the pavement surface that is visible to the motorist's eye. Luminance is measured in candela per square meter (cd/m2).The reflectance characteristics of the pavement must be known to calculate luminance, and lighting design software is required for roadway luminance calculations.

The level and uniformity of illuminance or luminance along a highway depends on several factors, including the lumen output of the light source, luminaire distribution, mounting height, luminaire position, pavement reflectance, and pole spacing and arrangement. The same average level can be obtained by different installation arrangements, such as a few high-output light sources or a greater number of low-output sources.

The proper light loss factor (LLF) should be used in all lighting calculations. LLF is a depreciation factor applied to the calculated initial average illuminance or luminance. Each TxDOT LED luminaire has a unique LLF that is shown with that fixture on the Material Producer’s List (MPL) for Roadway Illumination and Electrical Supplies. TxDOT HPS luminaires use a LLF of 0.65 for all models.

Continuous Lighting

Continuous roadway lighting includes uniform lighting of all main lanes, direct connectors, and complete interchange lighting of all interchanges. TxDOT does not normally light frontage roads or ramps with continuous lighting, but lights the intersection of ramp and frontage road with safety lighting.

Illuminance and Luminance Design Values for Continuous Lighting

The recommended lighting levels for continuous lighting are in the table below. These values are based on Table 3-5a from the AASHTO Roadway Lighting Design Guide.

The table below contains the recommended illuminance and luminance values for continuous lighting of roadways based on roadway type and general land use. Either the illuminance method, the luminance method, or both methods may be used to specify the light levels for the roadway.

Illuminance and Luminance Design Values

Roadway and Walkway Classification (4)	Area Classifications	Illuminance Method			Luminance Method			Additional Values (both methods)
		Average Maintained Illuminance (Eavg)	Minimum Illuminance Emin	Illuminance Uniformity Ratio Eavg/Emin	Average Maintained Luminance			Veiling Luminance Ratio
		R2			Lavg	Uniformity		
	General Land Use	(foot-candles) (min)	(foot-candles)	avg/min (max)(3)	cd/m2 (min)	Lavg/ Lmin (max)	Lmax/ Lmin (max)	Lv(max)/Lavg(max)(2)
Interstate and other freeways	Commercial	0.6 to 1.1	0.2	3:1 or 4:1	0.4 to 1.0	3.5:1	6:1	0.3:1
	Intermediate	0.6 to 0.9	0.2	3:1 or 4:1	0.4 to 0.8	3.5:1	6:1	0.3:1
	Residential	0.6 to 0.8	0.2	3:1 or 4:1	0.4 to 0.6	3.5:1	6:1	0.3:1
Other Principal Arterials (partial or no control of access)	Commercial	1.6	As uniformity ratio allows	3:1	1.2	3:1	5:1	0.3:1
	Intermediate	1.2		3:1	0.9	3:1	5:1	0.3:1
	Residential	0.8		3:1	0.6	3.5:1	6:1	0.3:1
Minor Arterials	Commercial	1.4		4:1	1.2	3:1	5:1	0.3:1
	Intermediate	1.0		4:1	0.9	3:1	5:1	0.3:1
	Residential	0.7		4:1	0.6	3.5:1	6:1	0.3:1
Collectors	Commercial	1.1		4:1	0.8	3:1	5:1	0.4:1
	Intermediate	0.8		4:1	0.6	3.5:1	6:1	0.4:1
	Residential	0.6		4:1	0.4	4:1	8:1	0.4:1
Local	Commercial	0.8		6:1	0.6	6:1	10:1	0.4:1
	Intermediate	0.7		6:1	0.5	6:1	10:1	0.4:1
	Residential	0.4		6:1	0.3	6:1	10:1	0.4:1
Alleys	Commercial	0.6		6:1	0.4	6:1	10:1	0.4:1
	Intermediate	0.4		6:1	0.3	6:1	10:1	0.4:1
	Residential	0.3		6:1	0.2	6:1	10:1	0.4:1
Sidewalks	Commercial	1.3		3:1	Use illuminance requirements			
	Intermediate	0.8		4:1				
	Residential	0.4		6:1				
Pedestrian Ways and Bicycle Ways(1)	All	2.0		3:1				

Illuminance and Luminance Design Values

Roadway and Walkway Classification (4)	Area Classifications	Illuminance Method			Luminance Method			Additional Values (both methods)
		Average Maintained Illuminance (Eavg)	Minimum Illuminance Emin	Illuminance Uniformity Ratio Eavg/Emin	Average Maintained Luminance			Veiling Luminance Ratio
		R2			Lavg	Uniformity		
	General Land Use	(foot-candles) (min)	(foot-candles)	avg/min (max)(3)	cd/m2 (min)	Lavg/ Lmin (max)	Lmax/ Lmin (max)	Lv(max)/Lavg(max)(2)

Notes:

- Meet either the Illuminance design method requirements or the Luminance design method requirements and meet veiling luminance requirements for both the Illuminance and Luminance design methods.
- There may be situations when a higher level of illuminance or luminance is justified. The higher values for freeways may be justified when deemed advantageous by the agency to mitigate off-road sources.
- Physical roadway conditions may require adjustment of spacing determined from base levels of illuminance or luminance indicated above.

1. Assumes a separate facility. For Pedestrian Ways and Bicycle Ways adjacent to roadway, use roadway design values. Use R3 requirements for walkway/bikeway surface materials other than pavement types shown. Other design guidelines such as IESNA or CIE may be used for pedestrian ways and bikeways when deemed appropriate.
2. Lv(max) refers to the maximum point along the pavement, not the maximum in lamp life. The Maintenance Factor applies to both the Lv term and the Lavg term.
3. Higher uniformity ratios are acceptable for elevated ramps near high-mast poles.
4. See AASHTO publication entitled “A Policy on Geometric Design of Highways and Streets” for roadway and walkway classifications.

Definitions for Illuminance and Luminance Design Values Table

Commercial. That portion of a municipality in a business development where ordinarily there are large numbers of pedestrians and a heavy demand for parking space during periods of peak traffic or a sustained high pedestrian volume and a continuously heavy demand for off-street parking space during business hours. This definition applies to densely developed business areas outside of, as well as those that are within, the central part of a municipality.

Intermediate. That portion of a municipality which is outside of a downtown area but generally within the zone of influence of a business or industrial development, often characterized by moderately heavy nighttime pedestrian traffic and a somewhat lower parking turnover than is found in a commercial area. This definition includes densely developed apartment areas, hospitals, public libraries, and neighborhood recreational centers.

Residential. A residential development, or a mixture of residential and commercial establishments, characterized by few pedestrians and a low parking demand or turnover at night. This definition includes areas with single family homes, townhouses, and/or small apartments. Regional parks, cemeteries, and vacant lands are also included.

Principal Arterial. A roadway with high mobility and limited access. Principal arterials include freeways with full control of access and divided highways with partial control of access.

Minor Arterial. A roadway with moderate mobility and limited access. Minor arterials interconnect principal arterials and primarily serve through traffic.

Collector. A roadway with moderate mobility and moderate access. Collectors connect local roads to arterials.

Local. A roadway with high access and limited mobility. Local streets permit access to abutting land.

Illumination for Intersections

The recommended lighting levels for intersections of continuously lit roadways are in the table below. They are based on the functional classifications of the intersecting roadways and level of pedestrian use. The values are taken from Table 8 in ANSI/IES RP-8-14, Roadway Lighting.

The functional classifications of roadways are based on the Institute of Transportation Engineers (ITE) Guidelines for Residential Subdivision Street Design:

- Major - over 3,500 average daily traffic (ADT)
- Collector - 1,500 to 3,500 ADT
- Local - 100 to 1,500 ADT

Illumination for Intersections

Functional Classification	Average Maintained Illumination at Pavement by Pedestrian Area Classification in fc			Uniformity E_{avg}/E_{min}
	High	Medium	Low	
Major/Major	3.4	2.6	1.8	3.0
Major/Collector	2.9	2.2	1.5	3.0
Major/Local	2.6	2.0	1.3	3.0
Collector/Collector	2.4	1.8	1.5	4.0
Collector/Local	2.1	1.6	1.0	4.0
Local/Local	1.8	1.4	0.8	6.0

Safety Lighting

Safety lighting includes lighting rural and urban interchanges, highway intersections, railroad crossings, pedestrian conflict areas, and other points of nighttime hazard.

Lighting of Isolated Intersections and Interchanges

The recommended lighting levels for isolated intersections, interchanges, and railroad crossings are shown in the table below. These values are based on Table 9 from ANSI/IES RP-8-14, Roadway Lighting. For roadway intersections and interchanges, the road classification with the highest light level should be used. Roadway classifications in this table are defined the same as in the Illuminance and Luminance Design Values table displayed earlier in this section.

Illumination of Isolated Intersections

Road Classification	Average Illuminance fc	Uniformity Ratio Eavg/Emin
Arterial	0.9	3.0
Collector	0.6	4.0
Local	0.4	6.0

Pedestrian Areas

Lighting for pedestrian areas should be designed using both horizontal and vertical illuminance. Horizontal illuminance levels help the pedestrian to see the walkway. Vertical illuminance levels help the pedestrian to see and recognize other pedestrians in the walkway. The table below contains the recommended values for pedestrian areas. The table is based on Tables 4, 5, 6, and 7 from ANSI/IES RP-8-14, Roadway Lighting. The area classifications for the table below are defined as follows:

- **High Pedestrian Conflict Area -** Commercial areas in urban environments with high night-time pedestrian activity.
- **Medium Pedestrian Conflict Area -** Areas with moderate night pedestrian activities near community facilities such as libraries and recreation centers.
- **Low Pedestrian Conflict Area -** Residential areas.
- **Pedestrian Portion of Pedestrian/Vehicular Underpass -** Pedestrian areas such as sidewalks alongside a vehicle underpass, or underpasses designed for pedestrians only.

Illumination for Pedestrian Areas

Maintained Illuminance Values for Walkways				
Area Classification	**Description**	**E_{avg} (fc)**	**EV_{min} (fc)**	**E_{avg}/E_{min}***
High Pedestrian Conflict Areas	Mixed Vehicle and Pedestrian	2.0	1.0	4.0
	Pedestrian Only	1.0	0.5	4.0
Medium Pedestrian Conflict Areas	Pedestrian Areas	0.5	0.2	4.0
Low Pedestrian Conflict Areas	Rural/Semi-Rural Areas	0.2	0.06	10.0
	Low Density Residential (2 or fewer dwelling units per acre)	0.3	0.08	6.0
	Medium Density Residential (2.1 to 6.0 dwelling units per acre)	0.4	0.1	4.0
Pedestrian Portion of Pedestrian/ Vehicular Underpasses	Day	10.0	5.0	4.0
	Night	4.0	2.0	3.0

Section 3 — Plan Standards

Introduction

This section explains some of the standard practices used in TxDOT highway illumination plan layouts.

Scale of Plans

Generally, a scale of 1:100 provides plenty of detail for lighting layouts. Underpass lighting sometimes requires 1:50. Other special lighting systems, such as tunnel lighting, may require more detailed layouts.

Boring Logs

High mast lighting layouts should include soil boring logs. See the *Geotechnical Manual* (Bridge Collection) for details.

Standard Plan Symbols

TxDOT has developed standard illumination symbols to aid in plan preparation. Figure 6-1 explains these symbols.

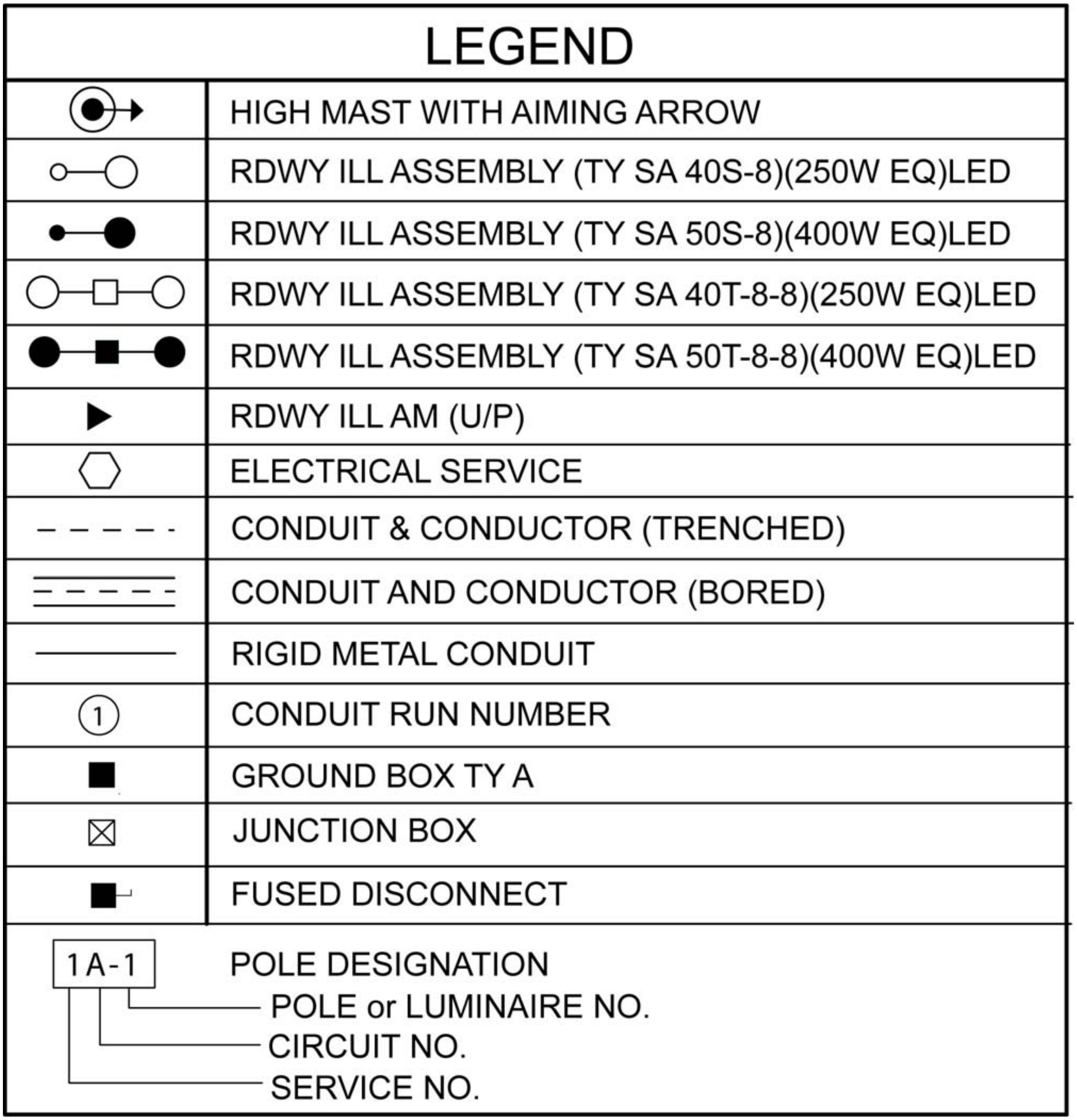

Figure 6-1. Standard symbols for light poles used by TxDOT in plan preparation. Note that breakaway transformer base poles are represented by a square, and non-breakaway (or shoe base) poles are represented by a small circle.

Section 4 — Conventional vs. High Mast Lighting

Introduction

Conventional lighting systems are lighting systems using mounting heights of 50 feet or less. High mast lighting uses mounting heights of 100 feet or more.

This section compares the advantages and disadvantages of conventional and high mast lighting and provides guidelines for deciding when to use high mast lighting.

Installation Costs

Installation cost comparisons between high mast and conventional lighting systems vary widely, depending on the application. High mast lighting for interchanges is frequently less expensive to install than conventional lighting, due to reduced complexity of conduit and conductor and the smaller number of fixtures and poles required. Outside the interchange, conventional lighting usually requires a smaller initial cost.

Maintenance Costs

Maintenance costs for the two types of systems differ greatly.

Conventional lighting requires the use of a bucket truck and frequently requires extensive traffic control, such as signs, cones, and lane closures. When poles are mounted on concrete traffic barriers, the inside lane usually has to be closed, resulting in significant traffic disruptions and safety hazards.

One or two persons with a pickup truck can usually perform maintenance on a high mast lighting system. High mast lighting may also eliminate the risks involved with having personnel working near high-speed traffic.

Some Deciding Considerations

Some important questions to consider when deciding whether to use conventional or high mast lighting are:

- Will lane closures be necessary for maintenance? What will be the effect on traffic?
- What is the initial cost difference?
- What is the maintenance cost difference? (When designing a lighting system, consider all maintenance costs, including costs incurred by other governmental bodies.)

- Would future upgrading of the roadway require relocating a conventional lighting system? Can a high mast system be installed that will not require relocation and that can provide construction lighting for future roadway projects?
- What is the proximity of airports and residential areas?

High Mast Systems Recommended

High mast lighting should be considered for most urban interchanges that qualify for complete interchange lighting and for tangent sections of freeways with initial average daily traffic (ADT) of 70,000 or greater where lane closure would be necessary for the maintenance of a conventional lighting system and where a study shows that substantial traffic flow disruptions would occur during such lane closures.

FAA Obstruction Evaluation

If high mast poles are to be placed within approximately 4 miles of an airport, the Federal Aviation Administration (FAA) may require an Obstruction Evaluation / Airport Airspace Analysis (OE/AAA) to ensure air safety.

Notice must be filed with the FAA if requested by the FAA or when anyone proposes any of the following types of construction or alteration:

- any construction or alteration exceeding 200 feet above ground level
- any construction or alteration that exceeds an imaginary surface extending outward and upward at any of the following slopes:
  - 100 to 1 for a horizontal distance of 20,000 ft. from the nearest point of the nearest runway of each airport described in 14 CFR 77.9(d) with its longest runway more than 3,200 ft. in actual length, excluding heliports.
  - 50 to 1 for a horizontal distance of 10,000 ft. from the nearest point of the nearest runway of each airport described in 14 CFR 77.9(d) with its longest runway no more than 3,200 ft. in actual length, excluding heliports.
  - 25 to 1 for a horizontal distance of 5,000 feet from the nearest landing and takeoff area of each heliport described in 14 CFR 77.9(d).
- any highway, railroad or other traverse way for mobile objects, of a height which, if adjusted upward, as defined in 14 CFR 77.9(c), would exceed a standard of 14 CFR 77.9 (a) or (b).
- any construction or alteration located on an airport described in 14 CFR 77.9(d).

The notice may be filed electronically online with the FAA on the FAA website.

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The FAA may request additional information such as a survey signed
and sealed by a Registered Professional Licensed Surveyor (RPLS)
before making a final determination.
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High Mast Systems and Light Trespass

High mast lighting should not be installed in areas where light trespass is an issue. This is generally areas where residential development is located directly along the highway right-of-way and pole placement is limited to the outside of the roadway. Special high mast designs should be considered to avoid light trespass, if high mast lighting must be employed. See "Glare and Sky Glow Issues" in the next section of this chapter for more information on light trespass.

High Mast Design and Layout

Layouts for high mast lighting are much more complicated than those for conventional lighting, since there are many different lighting fixtures and schemes available. The TxDOT Traffic Operations Division (TRF) provides high mast illumination design assistance upon request. High mast lighting design procedure is beyond the scope of this manual.

High mast lighting layouts should include soil boring logs. See the *Geotechnical Manual* (Bridge Collection) for details.

Section 5 — Glare and Sky Glow Issues

Introduction

Roadway lighting systems are coming under greater scrutiny from various sectors of the public. Issues such as glare, sky glow, and aesthetic lighting have achieved widespread attention and are open to criticism. Lighting designers should become familiar with these issues and be prepared to design lighting systems that meet required illumination levels while also considering the environmental and aesthetic effects.

Communities are adopting lighting ordinances meant to reduce sky glow (popularly termed "light pollution"). Lighting designers should be on notice that this is a very important issue. Light emitted above the horizontal does not benefit roadway lighting, but it can contribute to glare and may be considered visual clutter. Many people consider sky glow undesirable and even offensive. This is an important issue with the astronomical community, and is particularly annoying when equally effective lighting systems can be designed that reduce or eliminate up-lighting.

Cutoff and BUG Rating

Prior to 2007, the Illumination Engineering Society (IES) used the cutoff classification system to rate the amount of uplight produced by a luminaire. In 2007, cutoff classifications were replaced with BUG (Backlight, Uplight, Glare) ratings. BUG ratings are specified in IES document TM-15-11.

The center letter U of the BUG rating may range from U0 with no uplight, to U5 with over 1000 lumens of uplight. TxDOT's standard LED luminaires are specified to have an uplight rating of U0. If the luminaires are mounted level they will not emit any uplight.

Choice of Luminaires

Unless it is essential to have light aimed above the horizontal (as for building facades, landscapes, and central business districts, for example), luminaires with minimal uplight should be used for lighting projects.

When emitting light above the horizontal is absolutely necessary and in accordance with Texas Health and Safety Code, Chapter 425 (see appendix), the designer should strive to keep the above-horizontal light as low as practical to accomplish the intended effect. This can be achieved by using lower wattage luminaires, by shielding, or by luminaire design.

Luminaire Modification

Glare shields may sometimes be added to existing luminaires to reduce unwanted light straying onto private property. However, glare shields change the light distribution of the luminaire, so proposed luminaire modifications should be carefully analyzed to be sure the roadway lighting will remain acceptable.

Section 6 — Spacing of Light Poles

Standard Spacing for Freeways and Complete Interchange Lighting

For freeway lighting, TxDOT has standard spacings for conventional light poles to provide the minimum AASHTO-recommended illuminance levels. If higher light levels are needed, the spacing should be calculated with lighting design software.

50 ft. poles with 400W EQ LED luminaires may be spaced 270 ft. apart to provide the minimum recommended freeway illuminance levels. This will extend up to 60 ft. across the roadway from the luminaire. If wider roadways need to be lit, the spacing should be calculated with lighting design software.

40 ft. poles with 250W EQ LED luminaires may be spaced 220 ft. apart to provide the minimum recommended freeway illuminance levels. This will extend up to 50 ft. across the roadway from the luminaire. If wider roadways need to be lit, the spacing should be calculated with lighting design software.

Standard Spacing for Roadways Other than Freeways

To determine the required illumination levels for roadways other than freeways, use the tables in Section 2 of this chapter, the *AASHTO Roadway Lighting Design Guide*, or *ANSI/IES RP-8-14, Roadway Lighting*. An illumination program capable of calculating luminance or illuminance levels is required to determine if adequate illumination levels have been achieved.

Merge and Diverge Lanes

For partial interchange lighting, the first light pole for merge and diverge lanes should begin at the end of the weave area and continue to within 50 feet of the painted gore, as shown in Figure 6-2.

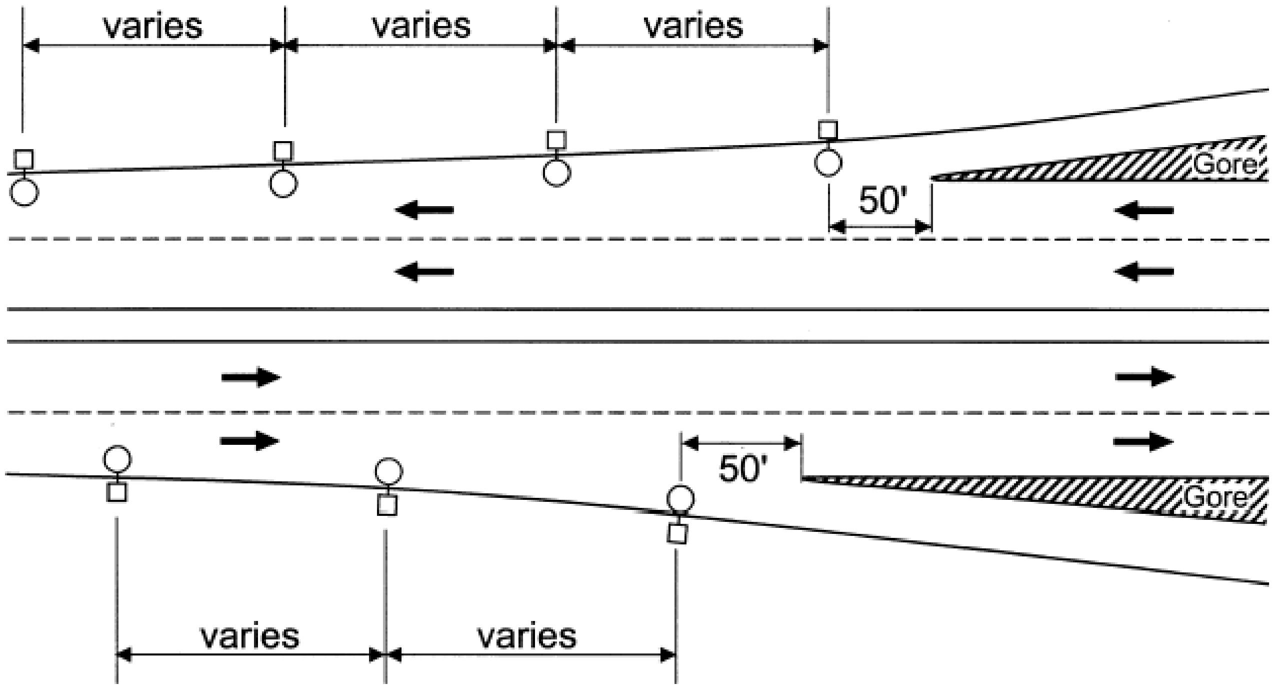

Figure 6-2. Typical placement for partial interchange lighting, 40 foot luminaire poles at merge and diverge lanes.

Lighting Near Overpasses

Poles supporting lighting for roadways beneath overpasses should be placed at least 20 feet from the overpass to reduce glare on the overpass.

Determining Mounting Height

Mounting height depends on the number of lanes to be lighted. The designer must use the mounting height that allows for adequate illumination levels. If proper lighting cannot be achieved with one pole, the designer should consider using additional poles to provide proper coverage.

Section 7 — Pole Placement Guidelines

Introduction

This section contains guidelines for the placement of conventional lighting poles in relation to other roadway elements. These guidelines apply to all designated routes, whether the poles are installed by construction contract, state forces, municipalities, or others.

Clear Zone

The clear zone, or clear recovery area, is provided along highways to allow vehicles veering off the travel lane opportunity for safe recovery or stopping. The clear zone width (always measured from the edge of the travel lane) depends on several factors, including:

- whether the surrounding area is rural or urban
- the functional classification of the highway
- the design speed
- average daily traffic (ADT).

The *Roadway Design Manual* contains a full discussion of the clear zone and provides the minimum and desirable widths for various roadways.

Light poles should be offset at least 2.5 feet from the curb face. All pole offset dimensions shown in this section are measured to the pole centerline. The clear zone table from the Roadway Design Manual is duplicated in Chapter 10 of this manual.

House Side vs. Median Mounting

"House side mounting" refers to the placement of luminaires between the curb and right-of-way line.

"Median mounting" refers to placement on open medians or medians with concrete traffic barrier.

Two Types of Poles

There are two types of poles used for conventional lighting: non-breakaway and breakaway. Non-breakaway poles are rigidly mounted, usually remaining upright when hit by a vehicle. Breakaway poles are designed so that the base will shear easily on impact. The table below briefly explains the advantages and disadvantages of both types when struck by an errant vehicle.

Breakaway and Non-Breakaway Poles — Pros and Cons

Type of Pole	Advantage	Disadvantage
Non-Breakaway	Normally does not fall down and cause further damage to surrounding people and property.	Likelihood of greater injury to occupants and damage to vehicle.
Breakaway	Less likelihood of damage to impacting vehicle and injury to occupants.	Falling pole may be hazard to surrounding pedestrians, traffic, or property.

Breakaway Poles Preferred

Because of their respective advantages and disadvantages, both types of poles have appropriate uses. However, unless special circumstances exist, breakaway poles are preferred over the non-breakaway type.

When Not To Use Breakaway Poles

Breakaway poles should not be used in situations where they are more hazardous than non-breakaway poles and situations in which the breakaway feature would be useless. Breakaway poles are not normally used if:

- substantial pedestrian traffic is expected in the area
- a falling pole could cause more damage than that caused by an automobile striking a rigid pole
- overhead electric lines are too close
- the pole is mounted atop a concrete traffic barrier
- the pole is mounted behind a metal beam guard fence (see following discussions on “Protection of Non-Breakaway Poles” and “Placement of Non-Breakaway Poles”).

Other considerations frequently come into play. The preceding list is provided only as an overview.

Protection of Non-Breakaway Poles

When a non-breakaway pole is used inside the clear zone, it must be protected from traffic. Acceptable methods of protection include mounting the pole:

- on a concrete traffic barrier
- behind a metal beam guard fence or other non-yielding structure.

Curbs are not considered adequate protection for non-breakaway poles.

Placement of Non-Breakaway Poles

Generally, non-breakaway roadway lighting poles may be used on the house side of roadways when placed outside of the clear zone or inside the clear zone when protected from impact.

Non-breakaway poles should be placed as close to the right-of-way line as lighting design and practicality permit. Wherever possible, non-breakaway poles should be placed among other nonyielding structures to minimize the hazard.

If non-breakaway poles are used and are not protected, the poles must be outside the clear zone and as close to the right-of-way line as possible subject to good lighting design practice.

Non-breakaway poles mounted behind metal beam guard fence should be placed at least 2.5 feet behind the guard fence to allow for deflection of the guard fence if hit.

Joint usage of poles is encouraged to reduce roadside clutter and the number of fixed objects along the roadside. When lighting is provided at signalized intersections and when conditions permit, the luminaires should be mounted on the traffic signal pole. Note that luminaires mounted on traffic signal poles should be powered from the signal electrical service.

Luminaires mounted on traffic signal poles should be oriented perpendicular to the centerline of the roadway being lighted.

Falling Area for Breakaway Poles

To understand the use and placement of breakaway poles, it is important to understand the concept of “falling area.” Research shows that most errant vehicles striking light poles are traveling at an angle less than 20 degrees from their original path and that light poles fall within one mounting height from the foundation along the direction of vehicle travel. A breakaway pole falls within 2/5 (40 percent) of its mounting height in a direction perpendicular to and away from the lane in which the errant vehicle was traveling (see Figure 6-3, “Falling area — final position of 50 feet luminaire support.”) Therefore, to prevent knocked down poles from encroaching onto other traffic lanes, breakaway poles should be placed so that they have a falling area of at least 2/5 of the mounting height behind the poles and one mounting height on the side of the pole.

EXAMPLE: In Figure 6-3, the falling area is calculated as follows:

$2/5 \times 50$ ft. mounting height = 20 ft. falling area

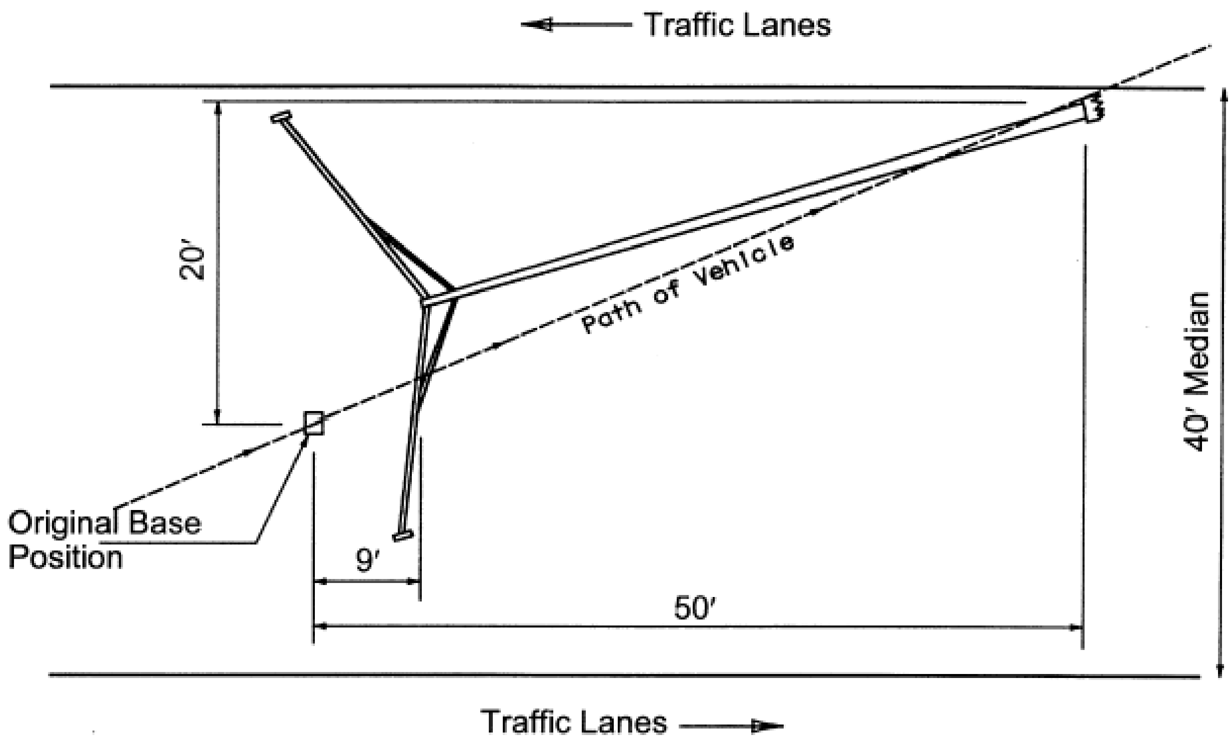

Figure 6-3. Falling area - final position of 50 foot luminaire support.

Use and Placement of Breakaway Poles

Unprotected roadway lighting poles located inside the clear zone should be breakaway, unless conditions dictate otherwise.

Breakaway poles placed on the house side of freeways should be 15 feet from lane edge and should provide a clearance behind the pole of 2/5 of the mounting height. For highways other than interstates, breakaway poles placed on the house side of travel lanes should be 15 feet from lane edge where practical. If sufficient right-of-way does not exist for this clearance, the poles may be placed just inside the right-of-way line, but not closer than 2.5 feet from lane edge.

House Side Lighting

For house side lighting, the poles should be located as far from the shoulder edge as practicable. Generally, the minimum should be 15 feet from the lane edge.

Figure 6-4 shows typical house side lighting of a controlled access roadway with a median less than 30 feet wide. If the median width were 30 feet or greater, then median lighting could be used.

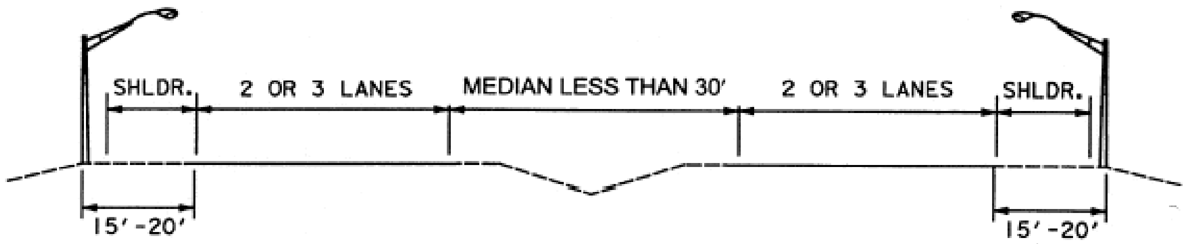

Figure 6-4. Typical house-side lighting for controlled access highway. In this example: Luminaires are 250W EQ LED - Mounting Height is 40 feet. - Spacing varies (see Section 6 of this chapter, Spacing of Light Poles).

Median Lighting

Breakaway poles placed in medians should not be closer than 2/5 of the mounting height from either main lane edge. Breakaway poles should not be placed in medians less than 30 feet wide, except as noted in the following paragraph.

Median lighting in narrow medians should be avoided. If no other alternative is possible, an exception may be made for divided city streets with curbed medians, speed limit of 45 MPH or less, and where pedestrian traffic allows the use of breakaway poles. In this situation, breakaway poles may be used if placed at least 2.5 feet from any curb face, the pole height should not exceed 30 feet and pole mast arm lengths should not exceed 4 feet. Light poles should not be installed in urban median areas less than 30 feet wide if any other design is practical.

The turning lane of a divided city street may be included as part of the median width when determining the falling area. Remember, though, 2.5 feet offset from curb face should be maintained.

Breakaway poles placed in city street medians should also be placed at least one mounting height back from the end of the median at intersections.

Non-breakaway poles should not be placed in medians unless properly protected.

Median Lighting Design Examples

The following illustrations show typical median lighting designs for various controlled access roadway sections.

Example 1 — Unprotected Median: Figure 6-5 shows a typical median lighting design for a controlled access roadway having an unprotected median 30 feet or greater in width. Here breakaway poles should be used.

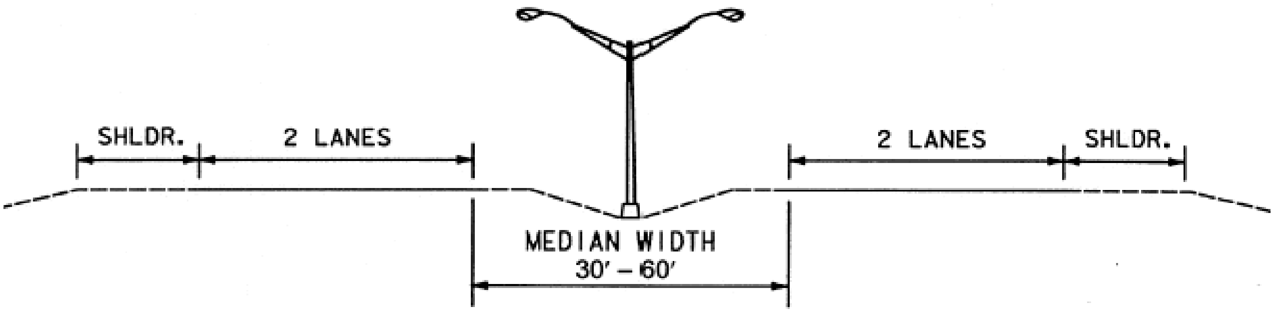

Figure 6-5. Median lighting with breakaway poles.

NOTE: Where median width exceeds 60 feet, it may be necessary to treat each main lane as a separate roadway, using two rows of poles in the median or house side (see Figure 6-4 for illustration of house side lighting).

Example 2 — Concrete Median Barrier: Figure 6-6 shows a typical median lighting design for a controlled access roadway having a concrete median barrier. Median width in this situation is typically 20 feet.

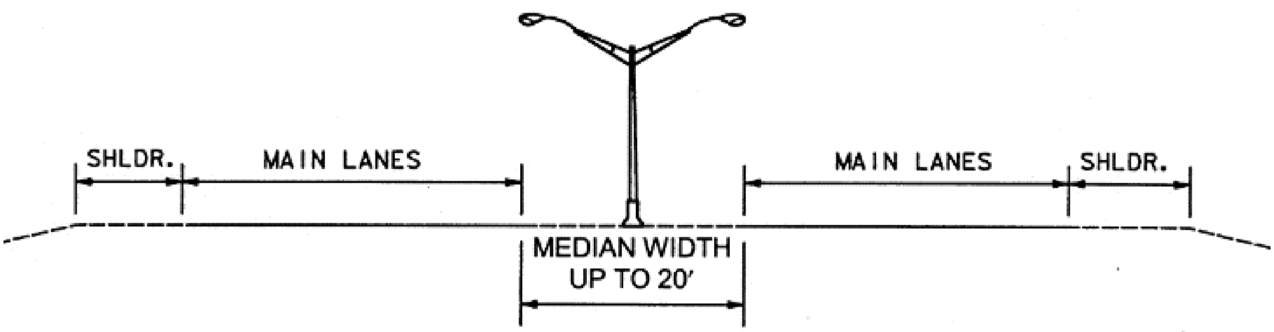

Figure 6-6. Median lighting with concrete median barrier.

The following table shows the recommended lighting for concrete median barriers.

Recommended Lighting for Concrete Median Barriers

Number of Lanes	Luminaires	Mounting Height	Spacing
2 or 3 each direction	250W EQ LED	40 feet	varies
4 or 5 each direction	400W EQ LED	50 feet	varies

Avoid Channelizing Islands

Avoid placing lighting poles in channelizing (dividing) islands, as the falling area of the pole is difficult to obtain except in cases where the island is very large.

Breakaway Pole Placement Examples

Figure 6-7 and Figure 6-8 show examples of breakaway pole placement and respective minimum applicable distances recommended for each of the cases listed in the following tables.

Breakaway Pole Placement Cases

Case No.	Case	Shown in
1.	Median-mounted poles or poles inside the clear zone of two separate roadways.	Figure 6-7
2.	Outside clear zone of frontage road, but inside the clear zone of main lanes.	Figure 6-7
3.	Outside clear zone of main lane, but inside clear zone of frontage road.	Figure 6-7
4.	Minimum distance from ramp.	Figure 6-7
5.	House side of frontage road.	Figure 6-7
6.	Minimum distance from overhead electric lines (OHE).	Figure 6-7
7.	City street intersection.	Figure 6-8

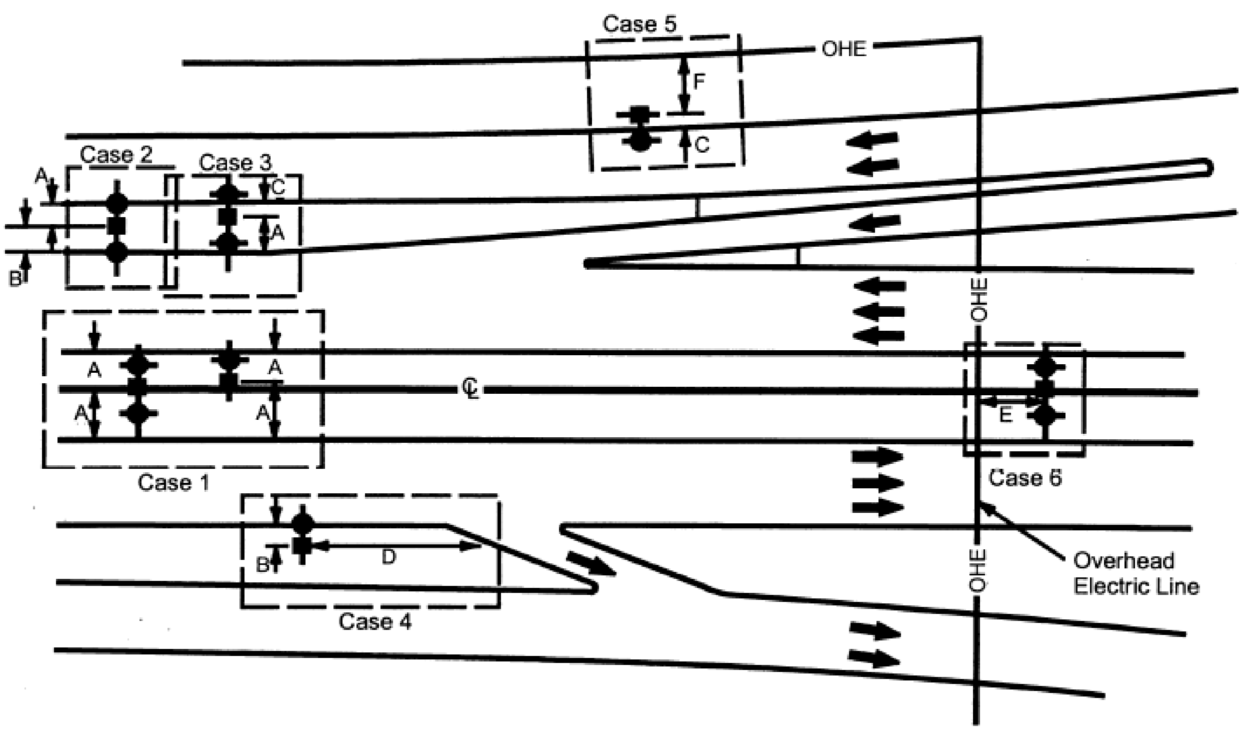

Figure 6-7. Controlled access facility illustrating example Cases 1 through 6. Minimum distances (designated here by the letters A through G) are shown in the table below.

Minimum Distances

(Indicated by Letter in this table and in Figure 6-8)				
A.	2/5 (40%) of one mounting height from edge of travel lane.			
B.	15 feet from edge of travel lane (20 feet desirable).			
C.	Depends on whether or not the roadway is curbed or uncurbed and on the design speed (see following table).			
	Pole Offset from Roadway			
			Distance from Curb Face or Lane Edge	
	Lane Edge	Design Speed	Desirable	Minimum
	Barrier Curb*	45 mph or lower	10 ft.	2.5 ft.**
	Barrier Curb*	50 mph or higher	20 ft.	15 ft.**
	Uncurbed	40 mph or lower	15 ft.	10 ft.**
	Uncurbed	45 mph or higher	20 ft.	15 ft.**
	* Curbed roadway denotes a roadway with a 6-inch minimum barrier-type curb. All mountable-type curb is considered as uncurbed. ** or as near ROW line as practicable.			
D.	One mounting height.			
E.	20 feet, or as required by utility company.			
F.	8 feet, or as required by utility company.			
G.	Clear zone.			

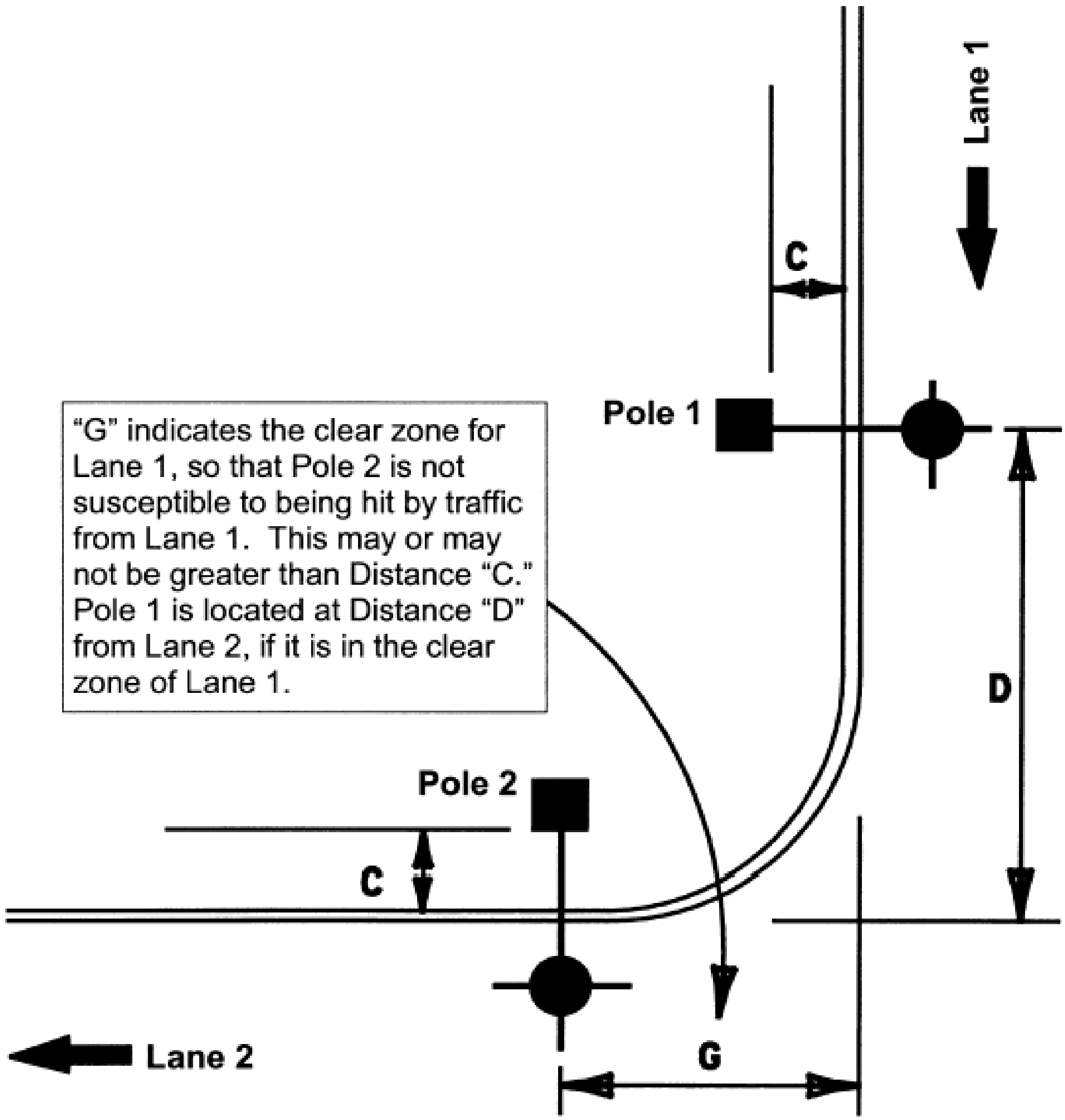

Figure 6-8. Example Case 7. Minimum distances (designated by letters) are shown in the preceding table.

Minimum Values

The distances shown and described in these guidelines as well as the clear zone definitions are minimum values. Even though breakaway poles may be placed in the clear zones, both breakaway and non-breakaway lighting poles should be placed as far away from the roadway as practical while maintaining the required light levels.

Poles in Sidewalks

The Americans with Disabilities Act (ADA) accessibility guidelines (36 CFR, Part 1191) stipulate that public sidewalks, where provided, must contain a continuous passage at least 36 inches wide. For this reason, the placement of poles in sidewalks should be avoided. Where such placement cannot be avoided, the sidewalk may need to be widened around the pole to maintain the required passage.

Foundation Height

Foundations for luminaire supports should be set flush with the ground line. Foundations placed on slopes should have the edge closest to the travel lanes flush with the ground.

Striking Height

Tests have shown that breakaway luminaire supports may not operate properly when the vehicle strikes the pole too high above the ground. Breakaway poles should, therefore, not be placed in areas where they are likely to be struck more than 28 inches above the top of the foundation. Limiting the negative side slopes to 1:6 between roadway and luminaire supports should ensure acceptable striking height.

Breakaway Pole Frangibility

Chapter 9, Section 2, “Breakaway Light Poles,” provides a discussion of the frangibility requirements for breakaway poles.

Chapter 7 — Electrical Systems

Contents:

Section 1 — Overview

Introduction

Electrical system design involves many considerations. This chapter covers the areas of special concern to roadway illumination.

National Electrical Code

The National Electrical Code (NEC) contains nationally recognized rules for the installation and use of electrical power. The NEC is written by the National Fire Protection Association (NFPA). Each section is written by committees of experts. The purpose of the NEC is the practical safeguarding of persons and property from hazards arising from the use of electricity.

Most local authorities adopt the NEC into law. Although the NEC is not law on state property, TxDOT has adopted it as the standard for electrical installations on State right of way (ROW) to ensure safe operation of electrical systems.

National Electrical Safety Code

The National Electrical Safety Code (NESC) contains nationally recognized rules for the safe installation, operation, and maintenance of utility electrical power and communication systems. The purpose of the NESC is the practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and associated equipment. Electric utility providers in Texas are required by state law to follow the NESC.

NEC, NESC, and Roadway Lighting on TxDOT ROW

TxDOT policy requires that lighting installed on TxDOT ROW be designed and wired according to the NEC (See 2005 memo in Chapter 10). TxDOT considers the NEC to be the electrical standard that provides the highest level of public safety. Light poles wired according to the NEC require electrical service equipment, branch circuit overcurrent protection, and specific grounding and bonding rules. Light poles installed by electric utility providers according to the NESC typically do not have these safety features.

Electric utility providers need permission from TxDOT to install any equipment on TxDOT ROW, and that equipment must be installed according to TxDOT policy. If an electric utility is to be involved in the installation of roadway lighting, it is important to make sure they are aware of the requirement to follow the NEC. Some electric utilities decline to install lighting if the NEC is required.

Engineering consultants and cities are not always aware of TxDOT's NEC policy, and will sometimes submit lighting and electrical plans that have been designed according to the NESC. If any of the following features are present in the plans, the designer should be contacted to ensure the plans submitted conform to the guidelines of the NEC:

- No electrical services present
- Lighting fed directly from electric utility poles
- Conduit installation only, with conductors and light poles to be provided later, or
- Plan sheets with electric utility company names in the title block.

For off-system lighting and electrical projects not on TxDOT ROW, but under TxDOT oversight, the work in the project must meet the NEC. However, after the project is finished, the city may install lighting according to the code they choose. In typical projects like this, the conduit will be installed according to the NEC as part of the project. After the TxDOT part of the project is finished, the city may arrange for installation of the conductors and lighting. (See 2008 memo in Chapter 10).

Electrical Details

Current TxDOT electrical specifications are contained in the Electrical Details (ED) Standard Sheets of TxDOT’s Traffic Operations Standard Plans. Information can be found at the following locations:

- ED(1): Conduits & Notes
- ED(2): Conduit Supports
- ED(3): Conductors
- ED(4): Ground Boxes

- ED(5): Service Notes & Data
- ED(6): Service Enclosure & Notes
- ED(7): Service Support Types SF & SP
- ED(8): Typical Traffic Signal System Details
- ED(9): Electrical Service Support Pedestal Service Type PS
- ED(10): Electrical Service Support Types GC, OC, & TP
- ED(11): Duct Cable/Conduit
- ED(12): Battery Box Ground Boxes.

Section 2 — Electrical Service

Introduction

Before designing the electrical circuit, the designer must first determine the service type. This section explains the types of service available and other concerns related to electrical service.

Electrical Service Data

Each electrical service in a plan set should be defined in an electrical service data chart. The data in the chart, combined with Item 628, DMS-11080, and the ED standards gives the contractor enough information to build the exact service equipment required for the project.

ELECTRICAL SERVICE DATA													
Electrical Service ID	Plan Sheet Number	Electrical Service Description	Service Conduit Size	Service Conductors No./Size	Safety Switch Amps	Main Ckt. Bkr. Pole/Amps	Two-Pole Contractor Amps	Panelbd/ Loadcenter Amp Rating	Branch Circuit ID	Branch Ckt. Bkr. Pole/Amps	Branch Circuit Amps	KVA Load
SB 183	289	ELC SRV TY A 240/480 100(SS)AL(E)SF(U)	2"	3/#2	100	2P/100	100	N/A	Lighting NB	2P/40	26	28.1
									Lighting SB	2P/40	25	
									Underpass	1P/20	15	
NB Access	30	ELC SRV TY D 120/240 060(NS)SS(E)TS(O)	1 1/4"	3/#6	N/A	2P/60		100	Sig. Controller	1P/30	23	5.3
							30		Luminaires	2P/20	9	
									CCTV	1P/20	3	
2nd & Main	58	ELC SRV TY T 120/240 000(NS)GS(N)SP(O)	1 1/4"	3/#6	N/A	N/A	N/A	70	Flashing Beacon 1	1P/20	4	1.0
									Flashing Beacon 2	1P/20	4	

Figure 7-1. Electrical Service Data. The main sections of the chart are defined below.

Electrical Service ID

Each service in the plans should have a unique identifying ID. To aid in identification, the ID should describe the location rather than just using a number or letter.

Electrical Service Description

The electrical service description describes the attributes of the service and should match that of the bid code. For information on service description codes see Chapter 5 Section 5 - Electrical Services and standard sheet ED(5).

Service Conduit Size

Service conduit size refers to the size of either the overhead or underground service conduit that feeds the service from the utility pole. For underground service conduit, the size is typically 2 inch PVC conduit. For overhead service conduit, the size is determined by the size of the conductors and by the requirements of the utility. Typical sizes for overhead service conduit are 1¼", 1½", and 2" RMC.

Service Conductors

Service conductor sizes are based on the size of the load as computed according to the NEC. The smallest service conductor size is #6 AWG. Since TxDOT standard services are always 3 wire single phase, the number of service conductors is always three, with two ungrounded (hot) conductors and one grounded (neutral).

Safety Switch

A safety switch is only needed if required by the local electric utility. Some utilities require a safety switch to be placed before the meter to allow their employees to turn off power to the meter for servicing. Most utilities that require a safety switch only require it for 480V services. The safety switch is always unfused. The safety switch amp rating is the same size or larger than the main breaker. Standard sizes are 60, 100, and 200 amps.

Main Circuit Breaker

A main circuit breaker is used on Type A, C, and D services. Type T services do not have a main breaker. The main breaker size is based on the size of the load as computed according to the NEC. Since TxDOT standard services are 3 wire single phase, the main breaker always has 2 poles.

It is recommended to use the smallest size main breaker allowed by the load and the NEC, with a minimum of 60 amps. For the types of breakers specified by DMS-11080, the smaller sizes can reduce the intensity of arc flash in a service cabinet in case of accidental ground faults or short circuits.

Two-Pole Contactor

Two-pole contactors are used on services that require lighting controls. On Type A and C services, the contactor switches all circuits on and off, and is the same size or larger than the main breaker. On Type D services, the contactor switches only the lighting circuit and is the same size or larger than the lighting breaker, typically 30 amps. Standard contactor sizes are 30, 60, 100, and 200 amps.

Panelboard/Load Center

A panelboard or load center contains an electrical bus with spaces for plug-in breakers. They are used in Type C, D, and T services only. The standard sizes are 70 (Type T only), 100, 125, and 225 amps. Type C and D services use panelboards with a minimum size of 100 amps.

Branch Circuit ID

Each breaker in the service should have a unique identifying ID. To aid in identification, the ID should describe the purpose of the circuit rather than just using a number or letter.

Branch Circuit Breakers

Double pole breakers use the line to line voltage on a single phase 3-wire service, and single pole breakers use the line to neutral voltage. Standard sizes for branch circuits are 15, 20, 30, 40, and 50 amps. Larger breakers may be used for feeder circuits to multiple high mast poles.

Branch Circuit Amps

The branch circuit amps column contains the actual expected load in amps for each branch circuit. For non-lighting circuits, the breaker size is typically the smallest standard size larger than the computed load. For lighting circuits, the breaker size is typically the smallest standard size larger than 125% of the computed load.

KVA Load

The KVA load is the sum of the computed loads for each branch circuit on the service. The formula for the load of each branch circuit in KVA is:

Circuit voltage (Volts) * Circuit load (Amps) / 1000

Separate Electrical Service for Signs

Separately metered electrical services should be installed for sign lighting and roadway lighting. This is necessary because different entities usually maintain the two systems. TxDOT usually maintains the electrical service supplying sign lighting, while cities or others may maintain illumination. This separation of service also eliminates conflicts between maintenance organizations of the two entities. (For further information, see “Maintenance Responsibilities of Cities” in Chapter 9, Section 5.)

Electrical Service Calculator

An electrical service spreadsheet calculator is available from the TxDOT Traffic Operations Division (TRF). The calculator takes the load and design information as inputs, and creates the service descriptive code and electrical service data chart.

Where Service Does Not Exist

If there are no distribution lines near a necessary electrical service location, the utility company can provide cost estimates for extending service to these points. This cost should be charged to the project under a force account function code.

The contractor must consult with the appropriate utility company to determine cost and requirements, and must coordinate the utility work as approved by the engineer. The contractor will be reimbursed only the amount billed by the utility; no additional amount for supervision of the utility’s work will be paid.

Coordination with Electric Utilities

Electric utilities may have requirements for service that conflict with TxDOT standard sheets or specifications. TxDOT typically has to follow utility requirements in order to get electrical service connected. If the designer is aware of any conflicts between standards and electric utility requirements, a detail or note should be added to the plans to help the Contractor correctly install the service equipment and avoid connection delays.

Section 3 — Circuit Design

Introduction

Once the service type is determined, the circuits can be designed. This section covers the major considerations in the design of roadway lighting circuits. Designers should refer to the *National Electrical Code (NEC) Handbook* for additional information.

Voltage Drop

The primary limitation on the length of circuits is the voltage drop. “Calculating Voltage Drop,” Section 4 of this chapter, explains how to calculate voltage drop.

Circuit Length Limits

At 480 volts, a 4,000 foot circuit of twin-arm poles can be served without unduly large conductors. At 240 volts, the circuit is limited to about 2,000 feet. (Conductor size and voltage drop are discussed in "Circuit Design" and "Calculating Voltage Drop" of this chapter.).

Conductors and Conduit Size

Another consideration is the number of conductors that can be installed in the various sizes of conduits. Annex C of the *National Electrical Code* shows the maximum number of conductors allowed in each conduit based on the capability of the wire to dissipate heat. However, with conduit runs of any substantial length, it is usually not practical to install the maximum number of conductors allowed in the conduit. A good rule of thumb is to limit the number of conductors to approximately one-half of the number shown in Annex C.

For underground lighting conduit, TxDOT's standard practice is to use 2 inch PVC. Although this is usually larger than required by the NEC for typical TxDOT lighting circuits, the larger size conduit is easier to clean and to pull conductors through. Since the largest cost of trenched conduit is the trench, 2-inch trenched conduit has a similar cost to smaller sizes of trenched conduit.

For underground lighting conductors, TxDOT's standard practice has previously been to use a minimum size of 8 AWG copper. However, it is now recommended to use the smallest size conductor that the NEC and voltage drop will allow, with a minimum size of 12 AWG. Using the minimum size conductor gives three advantages:

- Lower cost of installation
- Reduced consequences of copper theft. Smaller conductors reduce the scrap value of the copper and can help to reduce the incentive to steal it. If the conductors are stolen, the smaller conductors are less expensive to replace.
- Increased safety due to the possibility of reduced arc flash. Smaller conductors have higher resistance, which can reduce arcing if they are accidentally shorted or grounded during maintenance.

Conduit Run Length

As conduit run length and number of bends increases, the effort required to pull conductors also increases. Generally continuous conduit runs in excess of 700 feet are not recommended. Continuous conduit runs in excess 500 feet are not recommended when bends total 180 degrees. The NEC limits total conduit bends between pulling points to 360 degrees (no matter what the length of the run).

Overcurrent Protection

The ampacity of conductors is shown in Table 310.15(B)(16) and accompanying notes of the *National Electrical Code*. This ampacity should be observed in sizing overload protection for the circuit.

Lighting is considered a continuous load. NEC 210.20 requires that for continuous loads, the rating of the overcurrent device shall be at least 125% of the actual lighting load. For example, if the actual lighting load is 18 amps, then the minimum breaker size would need to be at least 1.25 x 18 amps = 22.5 amps. Since that is not a standard size, the next higher breaker size of 30 amps would be used.

When sizing overcurrent protection, the device closest to the load should be the smallest size. Devices should increase in size toward the service disconnect. For example, a 10 amp fuse might be used in the pole base where the branch circuit breaker is 20 amps, and the main breaker is a 60 amp circuit breaker.

Grounding Conductor Size

An equipment grounding conductor (EGC) should be installed in every conduit. The EGC may be sized according to NEC table 250.122, or it may be the same size as the largest current-carrying conductor in the conduit. For traffic signal installations, the minimum size of the EGC in every conduit is 8 AWG.

Copper Theft

Theft of copper conductors from roadway electrical installations is an ongoing problem for TxDOT and many other public entities. Replacing stolen conductors can have a high cost in materials and manpower. Copper theft also leaves the installation inoperable, which decreases safety for drivers.

Although there is no universal solution to prevent all copper theft, three strategies can be used to help deter it. Law enforcement can reduce theft by taking thieves off the street and punishing those involved. Engineering methods can be used to make it more difficult for thieves to access the wiring. Reducing the value of conductors by using smaller sizes or alternate materials can help reduce the incentive for theft. Details on the three strategies follow.

Law Enforcement:

- Texas Penal Code, Section 31.03, makes it a state jail felony to steal aluminum, bronze, copper, and brass up to a value of $20,000. This includes aluminum and copper conductors.
- Texas Occupations Code, Chapter 1956, requires scrap and recycling yards to collect information on sellers of scrap wire, including driver's license or official ID, contractor license, thumbprints, vehicle information, and photos or videos of the person selling the scrap.

Engineering Methods:

- Locking ground box covers, handhole covers, and T-base covers are available from several manufacturers.
- Eliminate junction boxes during design to reduce the number of access points to conductors.

- Ground boxes can be hidden a few inches underground. If this is done, then a method to locate them for maintenance is needed.
- Tack weld bolts to metal junction box covers. The tack weld needs to be removed for maintenance inside the box.

Reduce Value of Conductors:

- Use the smallest size conductor that will work according to the design and the NEC. The smaller wire is less expensive to replace and has less scrap value.
- Aluminum conductors have lower scrap value than copper, but the NEC has restrictions on the use of aluminum conductors that makes it mostly unsuitable for underground wiring. NEC 250.120(B) does not allow bare aluminum equipment grounding conductors to come in contact with the earth or to be used in corrosive conditions. Also NEC 250.120(B) does not allow aluminum equipment grounding conductors to be terminated within 18 inches of the earth. For these reasons, aluminum conductors are usually not recommended for underground wiring of illumination.

Section 4 — Calculating Voltage Drop

Introduction

This section explains voltage drop and how to calculate it for roadway illumination branch circuits.

Voltage drop can be calculated manually, using the methods described in this section or by using the NewVolt spreadsheet calculator, which is available from the TxDOT Traffic Operations Division (TRF).

Maximum Allowable Voltage Drop

Typical service line voltage for illumination are 240V or 480 VAC. However, since copper wire has some amount of resistance, a voltage drop (or loss) will occur in the wire itself. This energy is lost in the form of heating in the wire.

Magnetic regulator ballasts for HPS of the type specified for roadway lighting (and shown on Roadway Illumination Details) will operate properly at 10 percent under rated line voltage. (This is not true for all electrical equipment. For equipment other than roadway lighting, see the equipment manufacturer's documentation.) Good design practice allows the utility company 2 percent variation from rated line voltage, leaving 8 percent available for voltage drop in branch circuits. Therefore, the maximum allowable voltage drops are derived as follows:

- 480V 0.08 = 38.4V
- 240V x 0.08 = 19.2V.

The drivers in LED luminaires operate on a range of voltages. The typical ranges are 120V-277V and 347V-480V. Although LED luminaires can operate on larger voltage drops than 8%, TxDOT recommends designing circuits with a maximum allowable voltage drop at 8% for LEDs also.

Formula

Voltage *(V)* is equal to current *(I)* times resistance *(R)*, expressed as:

$$V = I \times R$$

Therefore, voltage drop *(Vd)* in any given run may be calculated as:

$$Vd = \frac{\text{Current in the}}{\text{run (amps)}} \times \frac{\text{Conductor resistance}}{\text{(ohms per meter or ft.)}} \times \frac{\text{Length of the run}}{\text{(meters or feet)}}$$

Discussions of each of the factors in this formula follow.

Current in the Run

When calculating voltage drop manually, the designer must determine the current in each run (that is, from the last light pole to the next-to-last, etc., all the way back to the service pole). The current depends on the number and type of fixtures. The following table shows the current required for the various types of fixtures.

Design Amperes for Various TxDOT Standard Luminaires

Luminaire Wattage and Type*	— Line Voltage —		
	120 V	240 V	480 V
150W HPS	1.67 A	0.83 A	0.42 A
250W HPS	2.50 A	1.25 A	0.63 A
400W HPS	3.75 A	1.88 A	0.94 A
150 W EQ LED	0.83 A	0.42 A	0.21 A
250W EQ LED	1.42 A	0.71 A	0.35 A
400W EQ LED	2.08 A	1.04 A	0.52 A
12-400 W HPS HM	45.0 A	22.5 A	11.3 A
6-400W LED HM	30.0 A	15.0 A	7.50 A
150 or 165 W IF	1.4 A	0.71 A	n/a
*HPS = High Pressure Sodium; LED = Light Emitting Diode; IF = Induction Fluorescent; HM = High Mast			

Conductor Resistance

To calculate voltage drop, you need to know the resistance of the conductor (wire) used in the branch circuit. Resistance is a function of wire size and length. Resistance for both wires going to the luminaire must be considered.

The following table shows wire resistance for various American Wire Gauges (AWG). Since both wires are the same size in typical circuits, the table shows “loop resistance”; thus the designer need only calculate the distance between luminaire poles.

Wire Resistance by Gauge

Wire Size	**Loop Wire Resistance***	
(AWG)	(ohms/foot)	(ohms/meter)
12	0.003360	0.011023
10	0.002036	0.006680
8	0.001308	0.004291
6	0.000820	0.002690
4	0.000518	0.001700
2	0.000324	0.001063
0	0.000204	0.000670
00	0.000162	0.000532

* Values shown are for uncoated copper conductors in conduit at 25°C

NOTE: Loop resistance accounts for the wire run in both directions, requiring the designer to measure only the one-way distance between luminaire poles.

Larger wire sizes have lower resistances. Using larger wire is one way to reduce the voltage drop in the circuit.

Length of Run

When using the preceding table to obtain conductor resistance per meter or foot, the “length of the run” used in the voltage drop formula will simply be the one-way distance between the poles.

Because of the way luminaires are wired, the height of the pole is of no consequence in voltage drop calculations. Only at the last pole would the height be a factor, and then only if the pole were very tall (high mast, for instance).

Calculation Example

On a 480 volt branch circuit, the run from the last light pole to the next light pole is 200 feet. The twin-arm light pole supports two 400W EQ LED fixtures. The conductor is 8 gauge wire.

Using data from the tables provided in this section, we obtain the following information:

- current in the run = 2 × 0.52 amps or 1.04 amps

- loop resistance of the conductor = 0.001308 Ω/ft.

Using the formula for calculating voltage drop, we find

$$Vd = amps \times 0.001308\ \Omega/ft \times 200ft$$

and therefore

$$Vd = 0.27volts$$

Total Voltage Drop

Each run of the branch circuit will have a voltage drop. Therefore, as you work toward the electrical service, the total voltage dropped in the wiring increases as the drop for each successive run is added. This total must not exceed 8 percent at the pole farthest from the electrical service.

Split Branch Circuit

Sometimes a branch circuit splits and runs in two directions. When this happens, the designer must remember that each run split off the circuit has a separate voltage drop.

Chapter 8 — Temporary Lighting

Contents:

Section 1 — Design and Layout

Purpose

The purpose of temporary roadway lighting is to improve the ability of motorists to navigate the construction area.

Difference Between Temporary and Work Zone Lighting

Temporary roadway lighting is not the same as work zone lighting. Work zone lighting is installed so that the contractor may work at night. If work zone lighting is installed, care should be taken to ensure that the visibility of passing motorists is not reduced below an acceptable level. Temporary roadway lighting helps reduce the negative effect of work zone lighting.

Special Considerations

Some special considerations affecting the design of temporary lighting include:

- cost of system
- ease of installation
- ease of maintenance
- ease of moving the temporary poles.

Because the purpose of temporary lighting is to make it safer to travel through the construction area, the lighting should be installed in such a way as to limit glare and avoid the placing of hazardous obstacles near the travel ways.

Roadway delineation should be considered along with any temporary lighting requirements.

Types of Temporary Lighting

Some possible types of temporary lighting systems include:

- standard steel poles with or without breakaway bases
- wood poles, 30- or 40-foot mounting height, protected from traffic, with standard highway light fixtures
- permanent high mast illumination installed early in project.

Illumination Levels

Illumination levels should be higher than normal, where practicable, in detour areas, gore areas, and other construction zone obstacles (impact attenuators, etc.).

Illumination levels and uniformity may be lower than normally required in areas where the motorist has no special navigational decisions to make.

Lighting systems should not create excessive glare, a potential problem with low mounting heights.

Electrical System Integrity

Electrical safety and integrity must be maintained in temporary lighting. Follow these guidelines:

- Where breakaway poles are used, breakaway electrical devices should also be used.
- Overhead wiring may be considered where non-breakaway poles are used.
- Voltage should not exceed 277 VAC to ground for temporary lighting units mounted at 18 feet or less.
- It is sometimes cost effective to use permanent lighting service pole locations for the temporary system.
- Usually fused fixtures and non-fused breakaway disconnects are preferable for temporary lighting.

Placement of Light Poles

All poles located within the clear zone should be of the breakaway design or should be otherwise protected from vehicle impact (behind concrete barriers or guard rail). (See Chapter 6, Section 7, “Pole Placement Guidelines,” for more details.)

Installation

When practical, temporary lighting should be installed before the existing lighting is disabled.

Plans and Specifications

Temporary lighting plans should show:

- the type and number of units required
- locations, spacings, and offsets of poles
- bracket and pole details
- electrical connection details, such as:

- electrical services
- conduit and wire or cord runs
- strain pole connections and guys (if used)
- breakaway disconnects (if used).

Temporary lighting should be coordinated with traffic control plans, which should show where and when the poles are to be placed or relocated.

Specifications for fixtures, wiring, poles, and services should be included with the plans when non-standard items are used. Ensure that circuit voltage drop is compatible with the types of fixtures selected.

Section 2 — Financing

General

Roadway construction contracts should make maintenance of the roadway lighting system — including temporary lighting — the contractor's responsibility. The state, however, is typically responsible for the electrical energy charges.

Method of Payment

There are two methods for measuring and paying for temporary illumination according to Item 617, "Temporary Roadway Illumination."

By the Month. Measurement and payment by month is the most frequently used method of paying for temporary lighting. This method is also the most expensive for the state, as the contractor is forced to include in his bid unexpected costs for contingencies such as knocked down poles. For the monthly method, the plans and specifications must be precise, because variations require field changes. Roadway illumination assemblies, temporary wiring, foundations, electrical services, and all other materials and labor are subsidiary to this item.

By Each. Temporary lighting may be measured and paid for by each unit or part of a unit. When using this method, the measurement is by each roadway illumination assembly installed or relocated. Temporary wiring, foundations, electrical services, and all other materials and labor are subsidiary to this item.

TxDOT is responsible for electricity used by the temporary lighting.

Reusable Equipment

If equipment installed for a temporary lighting system can be reused, the contractor should be required to turn over to TxDOT such equipment quantities as paid for in the contract and not damaged by motorists, in good condition, delivered to a site as directed by the engineer.

Chapter 9 — Construction and Maintenance Guidelines

Contents:

Section 1 — Overview

Introduction

This chapter addresses issues of concern to construction and maintenance personnel. Design personnel can also benefit from the information provided here.

Consistency

Consistency in the areas of illumination, electrical plans, project electrical inspection, and electrical maintenance is important. Districts can better achieve consistency if one office has specific control of all illumination and electrical plans and one or more inspectors specialize in illumination and electrical projects.

Assistance

The TxDOT Traffic Operations Division (TRF) is available to help with design, construction, maintenance, and questions upon request. Districts should feel free to take advantage of their illumination and electrical systems expertise.

Section 2 — Breakaway Light Poles

Frangibility Requirement

The FHWA adopted Section 7 of the 1985 AASHTO publication entitled “Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals” for implementation beginning in July 1990. This section requires more stringent breakaway characteristics. TxDOT’s previous design of roadway illumination assemblies (based on a 1975 AASHTO specification) does not meet these requirements.

Breakaway light poles rely on frangible transformer bases to provide the breakaway feature. The 1985 AASHTO specification provides for a maximum change in momentum of a 1800 pound car to break the pole away. The 1975 AASHTO specification provided for a similar change in momentum except that the test vehicle weighed 2,250 pounds.

Structural Requirement

While providing the necessary frangibility, the base must also be structurally adequate to support the illumination pole for design wind speeds. Transformer bases meeting the ’85 AASHTO specification may not adequately support some 50 foot steel poles, notably those designed to meet the ’75 AASHTO specification.

Replacement Guidelines

Lighting systems built under the previous requirements should be maintained with ’75 AASHTO standard poles and transformer bases currently in stock.

Replacement transformer bases for lighting systems built under the ’85 AASHTO requirements should be specified to be the same model number as the bases being replaced. This model number is required to be incised on the base.

Two variables of pole construction affect structural compatibility with the ’85 AASHTO transformer bases top: bolt circle and base plate thickness. No tolerances for these variables have been established. For this reason, TxDOT does not recommend the direct replacement of ’75 AASHTO standard transformer bases with ’85 AASHTO standard transformer bases for 50 foot steel poles.

Whenever a pole is knocked down, the transformer base should be replaced even if it is still intact.

New Installation Guidelines

Current breakaway requirements can be met on new installations by using the new transformer base and pole designed for that base, both approved by the FHWA to meet ’85 AASHTO standards.

TxDOT typically uses breakaway poles wherever possible, even when not required. For these types of new installations, where breakaway poles are used but not required (outside the clear zone or behind barriers), transformer base poles meeting the ’75 AASHTO guidelines may be used when currently in stock but should not be considered breakaway.

Do not use shims or washers to level breakaway base, because this may change the breakaway characteristics of the base. Ensure that the top of the concrete foundation is level.

Relocated Poles

When relocating breakaway roadway illumination poles, Item 610 requires a new transformer base to be installed. The old breakaway base should be destroyed to prevent reuse.

Poles Placed by Maintenance Forces

New light poles placed by maintenance forces should meet all safety related guidelines set forth in Chapter 6, Section 7, “Pole Placement Guidelines,” of this manual and the ’85 AASHTO breakaway requirements. This includes breakaway poles installed by maintenance forces at new locations.

Guidelines Apply to Cities

Cities installing light poles or maintaining lighting systems on state right-of-way must abide by these same guidelines.

Districts should keep city maintenance personnel informed of the different system requirements and the allowable uses of the various transformer bases.

Identifying Transformer Bases

The old and new transformer bases can be distinguished from each other by height and model number. The old bases are 20 inches tall, while the new ones are 17 inches tall. All new base model numbers have “-17” as the last three digits.

Striking Height

Tests have shown that breakaway luminaire supports do not operate properly when the vehicle strikes the pole too high above the ground. Breakaway poles should, therefore, not be placed in areas where they are likely to be struck more than 28 inches above the top of the foundation. Limiting the negative side slopes to 1:6 between roadway and luminaire supports should ensure acceptable striking height.

Anchor Bolts

Torque anchor bolts to manufacturer’s recommendation. This will help to ensure proper operation of the pole and breakaway device.

Section 3 — Group Relamping

Background

Group relamping involves the replacement of all lamps in an illumination system on a regular schedule. This period is known as the group relamping interval. Group relamping should be considered in the maintenance of existing non-LED illumination systems so as to better utilize TxDOT resources.

Advantages

Group relamping improves the illuminance level while possibly reducing the costs involved in operating the system. Several important elements determine the cost of maintaining an illumination system, including the cost of labor, equipment, and traffic control. Increased costs require TxDOT employees to seek innovative and less expensive ways to perform maintenance functions. Group relamping is an attractive alternative to spot replacement of lamps, because the costs for labor, traffic control, and equipment use are greatly reduced. Group relamping also lends itself well to contracting.

Strategy

Group relamping should be scheduled every three to five years. Group relamping should be planned in advance of the need for lamp replacement. Adequate traffic control, in accordance with the *Texas Manual on Uniform Traffic Control Devices* (TMUTCD), should be provided to assist motorists around the work zone and to provide added safety for maintenance crews. Other maintenance functions such as ballast replacement, igniter (starter) replacement, or fixture replacement and cleaning should be accomplished during group relamping.

Prior to performing group relamping activities on a three to five year interval, a cost analysis should be performed to determine if LED luminaire head replacements may be more feasible. Considering the fact that LED luminaires are becoming more economically priced, last longer, and are cheaper to operate, it may be more feasible to replace the conventional heads with LED heads rather than relamping with conventional bulbs.

Cleaning Luminaires

Cleaning of the luminaires, which involves wiping the dirt from reflectors and refractors, should be performed during group relamping. This periodic cleaning of the fixtures reduces the depreciation of light due to the accumulation of dirt and allows the delivery of more light per lighting dollar.

Allowing the illumination system to provide more consistent illuminance throughout the life of the lamps provides the motorist with better visibility and TxDOT with a more cost efficient lighting system.

Section 4 — High Mast Lighting Inspection and Servicing

Introduction

Inspect high mast lighting poles and assemblies and provide proper preventive maintenance. The inspection and servicing routine outlined in this section should be performed every time the lamps are changed or the ring is lowered for any reason. Districts should lower the ring, inspect and maintain the high mast pole assembly, and clean the luminaires on a regular interval such as every three to five years, in addition to repairing as needed.

Documentation (Inspection Form)

Personnel carrying out inspections of high mast lighting should document their findings using the Inspection Record for High Mast Lighting Pole Assembly form (TxDOT Form 1409) or a similar form. Districts must retain these completed inspection forms for the duration of the District's inspection interval.

Items to Inspect

The entire lighting assembly and pole should be inspected each time the ring is lowered for maintenance. Items to be checked and maintained during these inspections are listed on Form1409 in the form of a check list.

Replacing Fixtures

Replacement fixtures for high mast lighting must be obtained by special order. There are many different types of fixtures on the various high mast poles. Each fixture is selected based on critical photometrics. Each fixture must be replaced only with an exact equivalent.

Fixtures must be aimed and oriented in exactly the correct direction.

The fixture catalog number can be obtained from the fixture or from submittals made on the construction project. These submittals also show how to aim the fixture.

Responsibility of Cities

High mast lighting assemblies under the maintenance responsibility of a city, should also be inspected and serviced as set forth in this section. This work may be performed by the city or its agent. When this inspection and servicing is performed by the city or its agent, districts should occasionally check that the work is performed correctly.

Districts should provide a copy of the submittals, and “as built” plans to cities that are maintaining high mast lighting.

Assistance

Further assistance with high mast lighting inspection and servicing may be obtained from TRF.

Construction and maintenance videos are available through TRF.

Section 5 — Other Maintenance Considerations

Duct Cable

Duct cable is a conduit system and must be treated as such. If the system is damaged the duct may be spliced, however, the electrical conductors in the duct cannot be spliced inside the duct. Depending on the length of the duct run, maintenance personnel may want to remove the existing wire and pull new conductors or consider placing a ground box and splicing the conductors.

If the conductors are spliced, splicing procedures in the Electrical Details standards should be used to make the splice. Heat shrink tubing or gel caps are the only recommended splice insulators. Where two or more conductors enter one heat shrink tube, wrap the conductors with heat shrink tape. Heat shrink tubing must then be applied to insulate the splice. It is important to note that when duct cable is severed to make a splice, the ends of the duct must be cut straight and neat. Ends must also be reamed to remove sharp edges.

Grout

Prior to about 1975, grout was required to be placed between the illumination pole base plates and concrete foundations. Since then, it has been determined that such grout placement under pole or sign bridge base plates causes moisture to become trapped. This, in turn, contributes to excessive corrosion of the pole, support, base plate, anchor bolts, nuts, and other appurtenances.

It is imperative, therefore, that this grout be removed from under existing poles and not placed under newly installed poles. Anchor bolts should then be cleaned and painted with zinc rich paint. If severe deterioration is discovered, a more detailed investigation should be made into the remaining strength of the bolts.

Rehabilitation of Old Circuits

For older roadway illumination systems where maintenance is excessive due to faulty circuits, rehabilitation of the circuits by TxDOT should be considered to reduce maintenance costs.

When practicable, existing two-wire circuits should be replaced with a three-wire system that includes a continuous grounding conductor.

Maintenance Level of Service

The *Maintenance Management Manual* establishes guidelines for planning and performing various maintenance activities in accordance with available funds. Three possible funding levels are defined: desirable (the highest), acceptable, and tolerable (the lowest). Maintenance priorities are assigned based on the level of funding, and maintenance forces are directed to "substantially maintain" the various highway components accordingly. Chapter 3 of the *Maintenance Management Manual* explains the concept in detail, and Section 2 includes the maintenance level of service guidelines for highway illumination.

For general guidelines on maintenance practices related to highway illumination, see the *Maintenance Operations Manual*, Chapter 4, Section 3.

Maintenance Responsibilities of Cities

Maintenance of freeway illumination systems provided by some cities under agreement with TxDOT sometimes falls below acceptable levels. Unless an adequate level of lighting maintenance is being provided by a city, no further agreements for city maintained illumination should be executed with that city until corrective action is taken.

Problems

Maintenance problems involving electrical and illumination design and materials should be brought to the attention of TRF so that possible alterations can be made to the appropriate specifications and standards.

Chapter 10 — Resources

Contents:

Section 1 — Forms

High Mast Lighting Pole Assembly Inspection Record

Highway Illumination Forms

TxDOT Form Number	Form Name
1409	High Mast Lighting Pole Assembly Inspection Record

This form may be photocopied as necessary. Copies may also be obtained from the Traffic Operations Division (TRF).

Automated versions of this form is available through the online version of this manual (click on the form number).

Section 2 — Texas Administrative Code

Purpose

Texas Administrative Code, Title 43, Rule 25.11 describes the criteria governing the installation and financing of continuous lighting and safety lighting systems on segments of the state highway system.

Section 3 — Texas Health and Safety Code

Purpose

The Texas Health and Safety Code Chapter 425 is a State law designed to help minimize light pollution and sky glow. With certain exceptions, it requires outdoor lighting installed or maintained with state funds to be a cutoff luminaire.

Section 4 — Electrical Code Policies

Memorandums

The memos on the following pages contain further details concerning TxDOT's policies on the electrical codes to be followed when installing lighting on State ROW.

MEMORANDUM

Texas Department of Transportation

TO: District Engineers **DATE:** November 10, 2005

FROM: Amadeo Saenz, Jr., P.E.

SUBJECT: Illumination and the National Electrical Code

It has come to our attention that lighting is being installed on TxDOT right of way that does not meet TxDOT specifications and could be a potential hazard to the public. Electric utilities are installing lighting on TxDOT construction projects according to utility specifications, the National Electrical Safety Code (NESC). TxDOT specifications call for lighting to be installed according to the National Electrical Code (NEC). To enhance public safety, the NEC, not the NESC, must be followed on TxDOT projects.

Electric utilities are required by the Public Utility Commission to install their equipment according to the NESC. The purpose of the NESC is to provide safety for qualified utility personnel during the installation, operation and maintenance of electrical supply equipment. The purpose of the NEC is to safeguard persons and property from hazards arising from the use of electricity. It is our opinion that the NEC provides better safeguards for the general public when it comes to the installation of lighting on our roadways.

There have been numerous TxDOT projects where the plans instruct the contractor to install the conduit only as per the NEC. The local utility then follows up and installs the metal light poles and conductors according to the NESC. These light poles are powered directly from the transformer on the utility pole. There is no electrical service or circuit breaker, nor an equipment grounding conductor normally required throughout the conduit system. This meets NESC requirements but does not provide the personal protection that the NEC provides.

Many of these installations have included decorative lighting near pedestrian areas and bike paths. A ground fault, short circuit, or broken neutral conductor, at any time during the life of the pole, could cause a deadly voltage to be present on the outside of the metal light pole when wired according to the NESC. Poles wired according to the NEC require a circuit breaker and separate equipment grounding conductor which provide better protection for the general public.

It is our duty to ensure that all installations are as safe as possible for the general public. All lighting and electrical installations on our highway system must be installed to TxDOT specifications, which include the NEC. If a project is off system but under

District Engineers -2- November 10, 2005

TxDOT's oversight, then the lighting and electrical installation must be installed to TxDOT specifications. Otherwise, the work should be performed separately from that contract. We are confident that this will both increase public safety and also protect TxDOT from the liability of having lighting that does not meet our own specifications.

If you have any questions, please contact Greg Jones at (512) 416-3121 or Carlos Lopez at (512) 416-3200.

cc: Carlos Lopez, P.E., TRF
Greg Jones, TRF
ADM
CST
DES
MNT
TTA
District Traffic Engineers
AGC
ATSSA
TEEX

Texas Department of Transportation

MEMORANDUM

TO: District Engineers **DATE:** July 11, 2008

FROM: John A. Barton, P.E. John A Barton, P.E.

SUBJECT: Clarification of National Electrical Code Standards Being Applied to Off-System Projects with State Oversight

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Please refer to the attached memorandum dated November 10, 2005. We have recently had requests from some cities to allow the installation of conduit on off-system projects that are under state oversight.

We have consulted with the Office of General Counsel to provide clarification on this issue. All work on off-system projects (locations not within TxDOT right of way) that are under TxDOT oversight must be done in accordance to our standards. Once the project is completed and accepted by the owners (city, county, etc.), the owners are responsible for the maintenance and operations of the facility.

Based on this decision, TxDOT will allow the installation of conduit and partial electrical systems for off-system projects provided that the work in the plans is built in accordance with our current standards which include the National Electrical Code. All subsequent construction, operations and maintenance will be the responsibility of the owner.

If you have any questions, please contact Greg Jones at (512) 416-3121 or Carlos Lopez at (512) 416-3200.

Attachment
cc: Greg Jones, P.E., TRF
Carlos A. Lopez, P.E., TRF
ADM
AUD
CST
DES
MNT
TTA
District Traffic Engineers
AGC
ATSSA
TEEX

Section 5 — Clear Zones

Clear Zone Specifications

Table 2-12 from TxDOT Roadway Design Manual

Location	Functional Classification	Design Speed (mph)	Avg. Daily Traffic	Clear Zone Width (ft)[3,4,5]	
				Minimum	Desirable
Rural	Freeways	All	All	30 (16 for ramps)	
Rural	Arterial	All	0 - 750 750 - 1500 >1500	10 16 30	16 30 --
Rural	Collector	≥ 50	All	Use above rural arterial criteria.	
Rural	Collector	≤45	All	10	--
Rural	Local	All	All	10	--
Suburban	All	All	<8,000	10[6]	10[6]
Suburban	All	All	8,000 - 12,000	10[6]	20[6]
Suburban	All	All	12,000 - 16,000	10[6]	25[6]
Suburban	All	All	>16,000	20[6]	30[6]
Urban	Freeways	All	All	30 (16 for ramps)	
Urban	All (Curbed)	≥ 50	All	Use above suburban criteria insofar as available border width permits.	
Urban	All (Curbed)	≤ 45	All	4 from curb face	6
Urban	All (Uncurbed)	≥ 50	All	Use above suburban criteria.	
Urban	All (Uncurbed)	≤ 45	All	10	--

[1] Because of the need for specific placement to assist traffic operations, devices such as traffic signal supports, railroad signal/warning device supports, and controller cabinets are excluded from clear zone requirements. However, these devices should be located as far from the travel lanes as practical. Other non-breakaway devices should be located outside the prescribed clear zone or these devices should be protected with barrier.

[2]Average ADT over project life, i.e., 0.5 (present ADT plus future ADT). Use total ADT on two-way roadways and directional ADT on one-way roadways.

[3] Without barrier or other safety treatment of appurtenances.

[4] Measured from edge of travel lane for all cut sections and for all fill sections where side slopes are 1V:4H or flatter. Where fill slopes are steeper than 1V:4H it is desirable to provide a 10 ft area free of obstacles beyond the toe of slope.

[5] Desirable, rather than minimum, values should be used where feasible.

[6] Purchase of 5 ft or less of additional right-of-way strictly for satisfying clear zone provisions is not required.

Section 6 — Glossary of Terms and Formulas

Introduction

The following terms and formulas appear in this manual and in discussions of highway lighting. For electrical terms not listed here, consult the National Electrical Code (NEC).

AASHTO

American Association of State Highway Transportation Officials

Alternating Current (AC)

Current and voltage alternates from maximum positive to maximum negative in a sinusoidal pattern.

Ampere (A)

The unit of electric current.

Ballast

A device that includes a transformer that modifies incoming voltage and current to provide the circuit conditions necessary to operate electric discharge lamps.

Blanket Agreement

An agreement covering installation, operation, and maintenance responsibilities between a municipality and the Texas Department of Transportation (TxDOT) for all safety or continuous lighting within the municipality.

Breakaway Support

A light pole support designed to shear easily under vehicular impact. The breakaway feature can be an aluminum transformer base, a frangible insert between pole base foundation, a slip base, or other device. The breakaway support must meet current AASHTO and FHWA requirements.

Candela or Candlepower (cd)

The unit of luminous intensity emitted by a light source in a given direction.

Capacitance (C)

Ability to store energy in an electrostatic field. Measured in farads or microfarads.

Clear Zone

The area provided along highways to allow vehicles veering off the travel lane an opportunity for safe recovery or stopping. The clear zone width is always measured from the edge of the travel lane and depends on several roadway factors. The *Roadway Design Manual* contains a full discussion of the clear zone ("Horizontal Clearance to Obstructions") and provides the minimum and desirable widths for various roadways.

Complete Interchange Lighting

The lighting, within the limits of the interchange, of the main lanes, direct connections, ramp terminals, and frontage road-crossroad intersections. (See partial interchange lighting.)

Conductor

A flexible wire that may be stranded or solid, insulated or bare, and that can carry electrical current.

Continuous Lighting

Roadway lighting providing uniform illumination on all main lanes and direct connections and complete lighting for all interchanges.

Conventional Lighting

A highway lighting system in which the luminaires are typically mounted no higher than 50 feet. (See also high mast lighting.)

Cutoff

A luminaire light distribution is designated as cutoff when the candlepower per 1,000 lamp lumens does not numerically exceed 25 (2.5 percent) at an angle of 90 degrees above nadir (horizontal), and 100 (10 percent) at a vertical angle of 80 degrees above nadir. Cutoff type luminaires usually have flat glass lenses. Cutoff ratings have been replaced with BUG (Backlight, Uplight, Glare) ratings by the IES.

Direct Current (DC)

Flow of electricity in a single direction.

Electrical Details (ED)

TxDOT's standard sheets showing specifications for electrical specifications and standard construction practices for the installation of conduit, conductors, ground boxes, electrical services, and other electrical equipment.

Electrical Service

Point of receiving power from utility company. Typical service voltages used on highway electrical systems are 120/240 VAC and, 240/480 VAC.

FHWA

Federal Highway Administration.

Floodlight

An aimable luminaire generally employed for spot or wide-angle lighting.

Footcandle (FC)

English unit of measurement for the illumination (E) on a surface. (See "lux" for metric.) One footcandle is the illumination on a surface that is one foot from and perpendicular to a uniform point source of one candela. Combining the inverse square law and the cosine law, the formula for footcandles (FC) is:

$$FC = \frac{CD \times \cos A}{D^2}$$

where CD is the candlepower, A is the angle of incidence of the light beam (see diagram under "lux,") and D is the distance of the surface from the light source.

Frangible

The property of a material designed to be readily or easily broken.

High Mast Illumination Details (HMID)

TxDOT's standard sheets showing specifications for high mast illumination rings, lowering devices, and related mechanical and electrical systems.

High Mast Illumination Pole Foundations (HMIF)

TxDOT standard sheets showing specifications for high mast illumination foundations and drill shafts.

High Mast Illumination Poles (HMIP)

TxDOT standard sheets showing specifications for high mast illumination poles.

Illuminating Engineering Society of North America (IESNA, also IES)

A non-profit society of lighting engineers and professionals. The IESNA writes many of the industry standard specifications for lighting fixtures.

High Mast Lighting

Lighting units mounted at heights of 100 feet or more.

Inductance (L)

Ability to store energy in electromagnetic field. Measured in henrys or millihenrys.

Kilowatt (KW)

A measure of real power (generators, lamps, and heating elements are rated in watts or kilowatts).

$$KW = Volts \times Amps \times \frac{power\ \ factor}{1000}$$

(1KW = 1.34 horse power)

Kilovolt-amp (KVA)

A measure of apparent power. Equipment is rated in KVA when heat dissipation is a concern (transformers are rated in KVA)

$$KVA = Volts \times \frac{Amps}{1000}$$

Lamp

A replaceable light source in a glass enclosure. A lamp may be high pressure sodium, metal halide, fluorescent, incandescent, or induction fluorescent. Also called a "light bulb."

Light Source

The device that converts electric energy to visible light.

Lumen (lm)

The unit of luminous flux.

Luminaire

A device that directs, controls, and modifies the light produced by a light source. It consists of a light source, reflector, refractor, housing, and such support as may be integral with the housing

Lux (lx)

Metric unit of measurement for the illumination (E) on a surface. (See footcandle for English unit.) One lux is the illumination on a surface one meter from and perpendicular to a uniform point source of one candela. The formula for lux is:

$$lx = \frac{CD \times \cos A}{D^2}$$

where *CD is the candlepower, A* is the angle of incidence of the light beam, and *D* is the distance of the surface from the light source.

Mast Arm

An attachment to a light pole on the end of which a luminaire is mounted.

Mounting Height

The vertical distance between the base of the pole and the luminaire.

National Electric Safety Code (NESC)

A standard for the safe installation, operation, and maintenance of electric supply and communication lines and equipment, for use by electric utilities.

National Electrical Manufacturer's Association (NEMA)

An organization of electrical manufacturers that develops specifications and industry standards.

National Fire Protection Association (NFPA)

An organization devoted to eliminating death, injury, property, and economic loss due to fire, electrical, and related hazards. The NFPA develops and maintains safety standards such as NFPA 70: National Electrical Code, and NFPA 70E: Standard for Electrical Safety in the Workplace.

NFPA 70: National Electric Code (NEC)

An NFPA standard for the safe installation of electrical wiring and equipment in the United States. The NEC is considered the minimum acceptable standard for a safe installation. Its purpose is the practical safeguarding of persons and property from hazards arising from the use of electricity. An electrical installation that complies with the NEC will be essentially free from electrical hazard.

NFPA 70E: Standard for Electrical Safety in the Workplace

An NFPA standard for safe work practices to protect personnel by reducing exposure to major electrical hazards such as electrical shock, electrocution, arc flash, and arc blast.

Ohm (O)

The unit of electrical resistance.

Partial Interchange Lighting

The lighting of acceleration and deceleration lanes, ramp terminals, crossroads at frontage road or ramp intersections, and other areas of nighttime hazard. (See "complete interchange lighting.")

Pole

A galvanized steel or aluminum shaft to support the lighting unit (also called "lighting standard").

Power (P)

Measured in watts. Formula as follows:

- for DC circuits: $P = IE$
- for AC circuits: $P = IE$ (pf).

For power loss due to resistance in lighting circuits, the power factor can be considered equal to one. This power can also be calculated: $P = I^2R$.

Power Factor (pf)

Time relationship between current wave and voltage wave in an A.C. system.

PVC

Polyvinyl chloride, a material used for underground non-metallic conduit.

Reflector

Polished aluminum device used to reflect light.

Refractor

Prismatic glass element used to refract light.

Regulated Output Ballast

A form of electrical transformer that maintains the wattage of the lamp at a nearly constant value, though the line voltage may fluctuate as much as ±10 percent. Such ballasts or transformers may be integrally mounted within the luminaire or separately mounted in a ballast enclosure.

RMC

Rigid metal conduit.

Roadway Illumination Assembly

The luminaire and supporting members (pole, mast arm, etc.) with other related lighting equipment attached.

Roadway Illumination Details (RID)

TxDOT's standard sheets showing specifications for roadway illumination to be used with TxDOT standard specification Item 610.

Roadway Illumination Poles (RIP)

TxDOT standard sheets showing specifications for roadway illumination poles to be used with TxDOT standard specification Item 610.

Safety Lighting

Roadway lighting installed at interchanges, highway intersections, and other points of nighttime hazard to the extent necessary to provide for the safe and orderly movement of traffic.

Starter or Starting Aid (also called igniter)

A device producing a high voltage pulse to begin arcing in a lamp.

Transformer

An electrical device that changes one AC voltage to another.

Transformer Base

A breakaway device for light poles, also called a T-base. It is a hollow cast aluminum base, the bottom of which is bolted to a concrete foundation and to the top of which the bottom flange of the pole is bolted.

Uniformity

The ratio of the average level of illuminance to the minimum level of illuminance on the roadway.

Volt (V or E)

The unit of electromotive force, electrical pressure, or difference of potential. Analogous to water pressure. One volt will cause one ampere of current to flow through a resistance of one ohm.

Voltage Drop

A result of current flowing through a resistance.

$V = I \times R$

Example: A current of 30 amperes flowing through 300 feet of No.8 conductor whose resistance loop is 0.3924 ohms will result in a voltage drop of 11.77 volts.

Warrant

Warrants are applied to determine whether or not the lighting system is justifiable at a particular location on an eligible highway.