Traffic Control Devices Design Manual

July 2017

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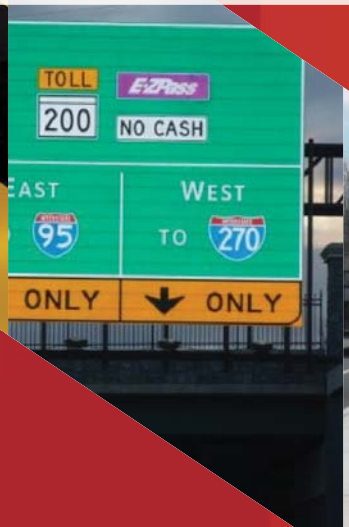

MDOT

MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION

VISION STATEMENT

"Statewide Traffic Control Devices shall provide Maryland travelers with appropriate and consistent guidance, warning and regulatory information at the proper time and location promoting safe driving decisions and maneuvers."

TABLE OF CONTENTS

VISION STATEMENT I

TABLE OF CONTENTS I

INTRODUCTION .....

PURPOSE OF THIS MANUAL 1
GOVERNING STANDARDS 1
All Traffic Control Devices 1
Signing 2
Pavement Markings 2
Signals 2
Lighting 2
USE AND APPLICATION OF STANDARDS AND MANUALS 2
ORGANIZATION OF THIS MANUAL 3

PRINCIPLES OF DESIGN .....

PRIMARY GOAL OF TCD DESIGN 1
BACKGROUND CONCEPTS 1
Considering Driver, Vehicle, and Roadway 2
Considering Fabrication and Construction 3
Policies, Directives, Standards, and Guidelines 4
WORDS OF WISDOM 4

SIGN AND PAVEMENT MARKING DESIGN .....

PROJECT INITIATION 1
FIELD REVIEW 1
Prepare a Base Map 1
Information to Collect 2
Data Collection Methods 4
TYPES OF SIGNS 5
SIGN CHARACTERISTICS 6
CONCEPTUAL PLANS 8
Developing a Concept 8
The Signing "System" 8
Guide Signs 8
Warning and Regulatory Signs 9
Reducing Clutter 9
Concept Review 10
SIGN SIZE AND DESIGN 11
Sign Legibility 11
Sign Layout 11
Sign Layout Example 15
Combining Messages 15
Diagrammatic Signs 17
Sign Lighting 18
Considering Construction and Fabrication 20
SIGN SUPPORTS 21
Mounting Hardware 21
Selecting a Support 22

Overhead Structures 22
Ground Mounted Supports 25
Checking the Design 40
Roadside Hazards 40
Delineation Design 42
Lateral Clearance of Signs 44
MATERIALS 44
Reflective Sheeting 44
Aluminum Backing 48
Pavement Markings 48

SIGNAL DESIGN .....

DATA COLLECTION 1
Office Data Collection 1
Field PI 3
Field Data Collection 3
SIGNAL DESIGN COMPONENTS 7
Signal Structures 7
Signal Heads 15
Detection 19
Pedestrian Ammenities 26
Signal Preemption 32
Wiring and Grounding 33
Conduits and Handholes 35
Cabinet and Controller 37
Power and Communication 40
SIGNAL SYSTEMIZATION 42
Wireless Communications 42
Communication Links 43
SIGNS 44
PAVEMENT MARKINGS 45
LIGHTING 45
PLAN PREPARATION 45
Developing a Concept Layout 45
Reviewing the Preliminary Design 46
Signal Plan Sheet 46
General Information (GI) Sheet 48
PREPARATION OF AS-BUILTS 50

LIGHTING DESIGN .....

DATA COLLECTION 1
Office Data Collection and Preparation 1
Base Plan 1
Photometric Concept Layout 1
Information to Collect in the Field 1
Field Data Collection Methods 2
LIGHTING CONCEPT 2
Developing a Concept 2
Function of Lighting 3
Classification of Roadway 6
Select Luminaire and Light Source 6
Lighting Structures 10

Preliminary Calculations.....11
Defining the Design Criteria.....12
Preliminary Layout.....12
Reviewing the Concept.....13
ROADWAY LIGHTING DESIGN.....15
Lighting Calculations.....15
Final Pole Layout.....19
SPECIAL LIGHTING DESIGN.....20
Rest Areas.....20
Parking Facilities.....20
Pedestrian Lighting.....21
Sign Lighting.....22
High Mast Lighting.....23
LIGHTING ELECTRICAL SYSTEM.....24
Power Source.....24
Base Method Lighting Control Cabinet.....27
Circuit Layout, Wire Size and Voltage Drop.....27
Control Panel.....35
Connector Kits.....35
Lighting Legend.....36

ENGINEERS ESTIMATE.....

ESTIMATING QUANTITIES.....1
PRODUCING THE ESTIMATE.....10
WRITE-IN ITEMS.....14
NEGOTIATED ITEMS.....14

PROJECT PROCESS.....

TYPES OF PROJECTS.....1
Shop Forces Project.....1
Areawide Projects.....2
Insert Projects.....3
Advertised Projects.....4
Developer Projects.....5
SUBMITTALS PROCESS.....6
Final Review.....6
PS&E.....6

INTRODUCTION

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PURPOSE OF THIS MANUAL

A design manual is a consolidated source of information governing the technical content of plan sets and outlining the steps required in the plan development and approval process. This manual provides a tool for answering designers' questions, training new employees, and documenting the design process.

This manual is intended to act as a guide in the development of Signing and Pavement Marking plans, Signal plans and Lighting plans. It documents the design procedures and steps required to bring a project from the Design Request stage through final PS&E documents. This book is not a standards manual, and does not duplicate information found in other State and Federal manuals. Instead, it is intended to be used in conjunction with the applicable standards noted below. When using tables, charts standards and figures from this manual, always check with the Traffic Engineering Design Division to ensure that you are using the latest version.

GOVERNING STANDARDS

All designs for new signing and pavement markings, signals and sign or highway lighting must comply with the latest edition of the following guidelines:

All Traffic Control Devices

- *Maryland Vehicle Law*
- *Maryland High-Voltage Line Act: Article 89, 58-63, Annotated Code of Maryland*
- *Specification for Consulting Engineer's Services, Volume II, Section VIII, "Traffic Engineering"*
- AASHTO's *A Policy on the Geometric Design of Highways and Streets*
- AASHTO's *Roadside Design Guide*
- AASHTO's *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*
- AASHTO's *Highway Safety and Operations Guide*
- MSHA's *Manual on Uniform Traffic Control Devices (MdMUTCD)*
- MSHA's *Book of Standards For Highway & Incidental Structures*
- MSHA's *Standard Sign Book*
- MSHA's *Standard Specifications for Construction and Materials*
- MSHA's *General Provisions for Construction Contracts*
- MSHA's *Procedures and Standards for Commercial, Industrial, and Subdivision Access to State Highways*
- MSHA's *Access Manual*
- MSHA's *Special Provisions Inserts, Special Provisions, and General Provisions for Construction Contracts*
- FHWA's *Manual on Uniform Traffic Control Devices (MUTCD), latest edition*
- NFPA's *National Electric Code (NEC)*
- IEEE's *National Electric Safety Code (NESC)*
- One Call Concept Statute "Miss Utility"
- FHWA's *Roundabouts: An Informational Guide*
- MSHA's (HDD) *Accessibility Guidelines for Pedestrian Facilities along State Highways*
- MSHA's *Bicycle Policy & Design Guidelines*
- MSHA's (OOTS) *Roundabouts Design Guide*
- MSHA's *ITS Design Manual*
- MSHA's *Street Name Sign Policy, Procedures, and Guidelines*

- TRB's *Accessible Pedestrian Signals: Synthesis and Guide to Best Practice*
- MSHA's *Guidelines for Traffic Barrier Placement and End Treatment Design*
- MSHA's *List of Qualified Products*
- MSHA OOTS *Traffic Control Device Application Guidelines*

Signing

- MSHA's *Guidelines for Form Single Lane Applications*

Pavement Markings

- MSHA's *Pavement Marking Material Selection Policy and Guidelines*
- MSHA's *Guidelines for Using Edge Line Extensions and Yield Lines*

Signals

- International Municipal Signal Association (IMSA) *Specifications for Traffic Signal Equipment.*
- Institute of Transportation Engineers (ITE) *Specifications for Traffic Signal Equipment*
- MSHA's *Median Area Analysis for Traffic Signal Pole Locations.*

Lighting

- *Illuminating Engineering Society of North America (IESNA)*
- AASHTO *Roadway Lighting Design Guide*
- *American National Standard for Roadway Lighting, IES, RP-8*
- *American National Standard for Sign Lighting, IES, RP-19.*
- *American National Standard for Tunnel Lighting, IES, RP-22.*
- *Roadway Lighting Handbook,* FHWA
- MSHA's *Lighting Guidelines*

USE AND APPLICATION OF STANDARDS AND MANUALS

Because of the breadth of information that designers are required to follow on the national and local level, Maryland SHA has prepared a series of standards and manuals which should be used by all designers to guide the design process and ensure that MSHA specific practices are followed. The designer should have a thorough understanding of the use and application of each of these manuals to their projects.

Maryland Manual on Uniform Traffic Control Devices (MdMUTCD):

The MdMUTCD governs the uniformity of design, placement, operations and maintenance of Traffic Control Devices (TCD's) throughout Maryland. It provides the adaptations to the Federal Highway Administration Manual on Uniform Traffic Control Devices based on past experience in the state. This manual should always be the first reference used when designing TCD's throughout the state.

Book of Standards for Highways and Incidental Structures:

This manual provides the standard details governing the fabrication and installation of TCD's throughout the state. It standardizes the type, size and installation requirements for TCD's and provides guidance on handling of special circumstances.

Standard Highway Sign Book:

This manual provides the standard fabrication details for signs in use throughout Maryland. It includes details for fabricating all standard signs, the symbols used on those signs, sign arrows, copy size and the standard alphabets used in sign legends. It also provides the information on the size and fabrication of standard sign blanks, provides the sizing of signs for each roadway classification (i.e. standard or freeway/expressway), outlines the

colors of each sign and indicates the sign sheeting used on each sign.

ORGANIZATION OF THIS MANUAL

The TCD Design Manual provides detailed guidance on the design process, content of plan sets, and decision making guidance that should be undertaken for signing, pavement markings, signals and roadway lighting projects in Maryland. This manual is intended to standardize the delivery of TCD design plans of all types of projects (i.e. Areawide, Insert, Shop Forces, Developer, Design-Build), regardless of who the designer is or where they sit.

It should be noted that this manual does not specifically include guidance on the design of Intelligent Transportation Systems (ITS) devices. However, many of the guidelines for other TCDs can be applied to ITS devices as well. For more details about ITS device design, the MSHA *ITS Design Manual* should be used.

This manual has been written for the designer. As discussed previously its primary purpose is to define how traffic control devices (TCD's) are designed in Maryland. To that end, it is organized in a way which discusses *overarching traffic design topics* first then *individual TCD Design topics* i.e., design of signing and pavement markings, signals, and finally sign/highway lighting. The *Appendices* have been reserved to capture those items that support the designer to produce high quality designs.

Overarching traffic design topics are those traffic engineering basics which govern no matter what TCD is being discussed.

Specific TCD design elements are organized by the steps in which we recommend design taking place. For example, the first and most important step in approaching the design of any TCD is the field review. The first major milestone that will minimize re-work (not eliminate) is the development of a concept plan or layout.

Appendices have been reserved for the glossary, accepted practices for applications of TCD's, sample plans, and process definitions, etc. The Appendices should be edited frequently once standards are approved and adopted into the Maryland Manual on Uniform Traffic Control Devices (MdMUTCD) or Book of Standards.

PRINCIPLES OF DESIGN

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According to the latest approved version of the MdMUTCD, Traffic Control Devices should "promote highway safety and efficiency by providing for the orderly movement of all road users on streets, highways, bikeways, and private roads". TCD's such as signs, signals and pavement markings should only be used where required by MdMUTCD guidelines or the Maryland Vehicle Code, or where engineering study determines that the use of the TCD is necessary. They are used to convey control, guidance, and navigation information, but are not used to confirm the "rules of the road." Excessive and unnecessary use of TCD's reduces their effectiveness and should be avoided.

Effective design of highway signs, pavement markings, traffic signals, and highway lighting requires sound engineering practices and judgment as well as a basic knowledge of human abilities, decision-making processes, consistency in applying TCD's, and construction methodologies. A good TCD plan will incorporate principles of driver expectancy, visibility, and decision sight distance into the development of a comprehensive traffic operation's scheme. By close observance of standards, any given system of traffic control devices (and accepted practices) will have the same, consistent meaning and require the same action on the part of the motorist regardless of where it is encountered.

On the other hand, do not discourage the development of new standards, use of new technologies, or development of new or seemingly radical concepts. Such developments should be approved by the Director prior to application.

PRIMARY GOAL OF TCD DESIGN

The primary goal is to produce Traffic Control Device Designs which are:

1. **Defendable** because they comply with national and state standards and criteria.
2. **Best suited to the situation** and represent the best possible plan for all road users.
3. **Effective and consistent**, avoiding clutter, maintaining uniformity, and providing positive guidance.
4. **Responsive** to the *intent* of the original design request.
5. **Constructible** within the field condition, utility, and right of way constraints.

BACKGROUND CONCEPTS

The MdMUTCD identifies five basic requirements that should be met by effective traffic control devices. These are:

1. Fulfill a need.
2. Command attention.
3. Convey a clear, simple meaning.
4. Command respect of road users.
5. Give adequate time for proper response.

In order to meet these requirements, the MdMUTCD recommends that responsible jurisdictions do the following:

- Design devices to command attention, provide a clear and concise meaning, provide adequate legibility for driver response, and be applied in a uniform manner.
- Place devices within the driver's field of vision, and positioned such that drivers have adequate time to read, comprehend and react. Placement should be in proximity to the corresponding roadway situation to provide a degree of correlation.
- Apply devices to meet traffic requirements at that location.

- Maintain devices to high standards to ensure visibility and legibility. Devices that are no longer needed or applicable should be removed.
- Apply devices uniformly to aid in driver recognition and understanding. This means treating similar situations the same in terms of device design, application and placement.

Considering Driver, Vehicle, and Roadway

Driver Needs

The driving task is affected by aspects of human nature and human ability, including visual acuity, perception-reaction times, driver confidence, distractions, familiarity with roadway, and driver expectations. On a continual basis, drivers are processing information regarding traffic flow, vehicle control (speed, direction, etc.), navigation (where am I going and how will I get there?), and information gathered from the signs, markings, signals, and other devices located along the roadway. With many driver distractions such as audible navigation systems and other technologies, information presented to drivers must command attention and be sufficiently legible such that drivers can recognize, read, understand, and formulate an appropriate response.

Visibility/Legibility

Two aspects of visibility that concern sign and signal designers are: how far can the driver see a sign or signal (distance), and for how long can the driver read the sign or recognize the signal color (time). These are affected by light levels, travel speed, the relative positioning of the sign and the vehicle, “background (visual) clutter” and the condition of the sign or lens. It is important for sign and signal designers to have a basic understanding of the relationships between driver, visibility, and decision-making when selecting TCD locations.

Driver Expectancy and Human Factors

As described in *A Users’ Guide to Positive Guidance* by Federal Highway Administration, Driver Expectancy is “a driver’s readiness to respond to situations, events, and information in predictable and successful ways”. Simply stated, motorists respond better to situations they expect than to situations they do <u>not</u> expect, and unexpected situations lead to improper responses and driver error.

The Positive Guidance manual gives 10 general principles for presenting information to motorists and minimizing driver expectancy violations. These principles are:

- **Design for Drivers.** Information should be presented and communicated at the driver’s level of understanding. Motorists are not familiar with technical jargon and concepts.
- **Accommodate Target Groups**. This may be as simple as using 20/15 Copy on Guide Signs to improve visibility for elderly drivers. Target groups should be identified where appropriate, and their needs should be incorporated into the design.
- **Be Responsive to Task Demands and Driver Attributes**. Highway information should convey the highway’s operating conditions, be sensitive to driver motor-sensory skills, and be responsive to the demands placed on drivers.
- **Satisfy All Information Needs**. All information needs relative to the driving task should be satisfied.
- **Maintain Design/Information System Compatibility**. Information displays and designs should look “compatible” with the rest of the roadway environment.
- **Avoid Surprises and Expectancy Violations**. Surprises cause poor driver reactions and performance, and should be either eliminated or given advance warning. Best practices are to provide a

simple implementation of a TCD device that is easy to comprehend and will invoke the desired reaction by the driver.

- **Eliminate Information Error Sources**. This includes missing or obscured information, misplaced traffic control devices, and obsolete/non-standard devices.
- **Avoid Overload and Under Load**. Drivers tend to make mistakes when required to process too much information and when not enough information is given i.e., where time to comprehend a message and the reaction time to make a corrective action are violated.
- **Provide a Steady Pace**. Information should be well spaced, avoiding localized areas of information overload.
- **Use Primacy when Information Competes**. Information should be prioritized, with control information given precedence over navigation.

Classification of Roadway

The IESNA advises when selecting a roadway classification, the area or roadway should best fit the descriptions contained within this document and not how classified by others.

- **Freeway:** A freeway is a divided roadway with full control of access (no crossings at grade). This definition applies to toll roads as well as non-toll roads. Freeway classification is further subdivided into A and B. Freeway A has greater visual complexity and high volumes. This is common in urban areas and will operate through some of the early evening hours of darkness at or near design capacity. Freeway B represents all other divided roadways with full control of access.
- **Expressway:** An expressway is a divided major roadway for through traffic, with partial control of access and generally with interchanges at major crossroads. This commonly includes parkways as well.
- **Major:** A major roadway is a principle "arterial," "thoroughfare," or "preferential" for through flow of traffic. These roadways connect areas of principal traffic generation and are sometimes subdivided into primary and secondary.
- **Collector:** A collector roadway services between major and local roadways. These are streets used mainly for traffic movements within residential, commercial and industrial areas that give direct service to abutting properties.
- **Local:** A local roadway is direct access to residential, commercial, industrial or other property. They make up a large percentage of the total street system, but carry a small proportion of vehicular traffic.

Uniformity of Application

The uniform application of traffic control devices on a nationwide or statewide level reinforces driver expectancy and conditions them for what lies down the road. Simplicity of sign messages and consistency of signing, signals and marking schemes reduces comprehension times of motorists. Drivers learn to associate specific traffic control devices with similar types of situations, improving recognition and comprehension times. For this reason, FHWA has developed the *Manual on Uniform Traffic Control Devices (MUTCD)* and Maryland SHA has published the *Maryland Manual on Uniform Traffic Control Devices (MdMUTCD)* and the *Standard Sign Book*. These manuals are the backbone of uniformity, outlining how signs are applied and how to design an effective system. Contact TEDD for the latest adopted version of the MdMUTCD and associated manuals.

Considering Fabrication and Construction

The fabrication and construction of TCD's will influence their design. In order to effectively design any TCD it must be able to be

fabricated and constructed. This is a key element to consider in the design process. For example, if an overhead structure is planned to be designed and placed on a bridge, it needs to be confirmed that this is physically possible due to structural constraints. Some things to consider during construction are utility locations (to avoid conflict), structural limitations, material availability, and other highway elements such as drainage structures, barriers, slopes, roadway curvature, etc.

Policies, Directives, Standards, and Guidelines

Maryland SHA has several tools to use for defining the use, application, and installation of traffic control devices. Policies, Directives, Standards, and Guidelines are four documents, which can be used to define how MSHA applies traffic control devices. All are used to guide the design and installation of signs, signals, and sign/highway lighting; however, each provides different information and offers a different degree of flexibility in implementation.

A policy defines MSHA practice for the use and application of traffic control devices. Written policy statements are usually published and distributed for implementation on a statewide level. A policy is a regulation, method or procedure adopted by MSHA from which there is little deviation. For instance, it is MSHA policy to install Accessible Pedestrian Signals (APS) and Countdown Pedestrian Signals (CPS) at all signalized crosswalks. The MdMUTCD is an example document that sets MSHA policy.

A directive is a statement governing the design and installation of traffic control devices for particular situations or for particular devices. Directives are similar to policies and can cover similar information, however they can be implemented as an interim measure prior to final publication of an official policy. Directives are approved by and originate from the Director of the Office of Traffic & Safety.

Standards are used to define specific information regarding traffic control device fabrication, construction drawings, details, or requirements, and typical installation information intended for frequent and repetitive use in the state of Maryland. MSHA standards define foundation sizes for steel supports and show breakaway modifications for both wood and steel sign supports. They also show vertical and lateral sign clearances, extruded aluminum panel dimensions, and standard sign layouts. Standards define a broad range of information, which is used as the basis for designing and constructing all projects. This provides uniformity on a statewide basis while allowing some flexibility on each project. Standards are typically found in the Book of Standards for Highway and Incidental Structures and in the Standard Sign Book. The approvals come from MSHA and FHWA.

Guidelines state a preferred practice or methodology that relates to an interpretation of a policy or standard, which should be applied where possible and practical. They are not absolute statements and require a great deal of Engineering Judgment in the design process. The Director of the Office of Traffic & Safety approves guidelines. An example guideline covers the application of message dividers on guide signs.

WORDS OF WISDOM

In the spring of 1997, former Director Hicks wrote an article in The Traffic Peek, offering advice for traffic engineers. The following advice is taken from that article.

Take theory, the laws of physics, and basic human behavior knowledge:

- Apply them to the real world.
- Remember that safety is our #1 goal.

- Recognize the value of consistency and uniformity, and provide them.
- Do not be afraid to innovate, but follow the guiding principles.
- Understand and fulfill an acceptable standard of care.
- Teach the principles and explain them through Public Relations and Public Involvement & Education programs.
- Recognize the speed-distance relationships and apply them.
- Remember the Malfetti graph.
- Follow the fundamental principles of traffic control.
- Consider and respond thoughtfully to the politics of the situation.
- Address the problem and meet the needs of the road users – motorists and pedestrians; be responsible.
- Develop alternatives for every situation.
- Recognize the basic human factors and the capabilities of the driver and pedestrian.
- Recognize that man can think about only one task at a time.

Some thoughts on Human Factors:

- Drivers respond first to stimuli, the whole scene of what they see, comparing that with what they have learned through experience.
- The driver comparison of what they see with their stored knowledge is instinctive and super-fast, in split seconds; this is where following standards and consistency and uniformity come into play.
- Drivers drive on “automatic-pilot” in a semi-conscious state with regard to the driving task; a second reason for consistency and uniformity in applying traffic regulations, control devices, and geometrics.
- Drivers should be confronted with what they expect to find:
    - First corollary: drivers finding what they expect are prepared and greater safety and comfort is the result.
    - Second corollary: drivers not finding what they expect experience discomfort, make poor or wrong decisions, get lost, have crashes, run red lights, or otherwise experience or do the things that discredit our road system and cause it to fail.
- Drivers should be provided with control devices, delineation, geometrics, and highway design features that provide positive direction and controls that reassure and give a high degree of confidence and a feeling of well-being.
- Travel paths should be responsive to how the drivers wish to travel, not the reverse.
    - Corollary: fit the road to the driver, not the reverse.

A good rule to follow – Louis J. Pignataro in his traffic engineering text *Traffic Engineering Theory and Practice*, 1973 says ”A good general guide to the application of control devices is to utilize the minimum degree and control necessary to provide safe and efficient movement of vehicles and pedestrians”.

SIGN AND PAVEMENT MARKING DESIGN

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PROJECT INITIATION

The first steps undertaken for a signing and marking design project are also the most important in determining project success. These steps include:

1. **Project Type:** Signing and marking projects generally fall into one of five categories: Areawide, Insert, Advertised, Developer, and Shop Forces. A detailed description of each project type, along with the typical contents of the final plan submission package is contained in the Project Process chapter of this manual. It is important to understand at the very beginning of the design process what the type of project is and what the final set of plans should contain.
2. **Design Request (DR) Review:** The DR will be initiated by the District Traffic office. The designer should read the DR and all supporting documentation and call the District Traffic team to verify project intention and objectives. For Developer or Design Build (DB) Projects, the Developer or DB Team may be responsible for developing the initial draft of the DR for the District's approval.
3. **Determine Available Information:** Verify if there are as-built plans, CADD files, right-of-way information, utility information, and other sources of data which can be used to improve the quality of your design.
4. **Verify Everything in the Field:** Perform your initial site visit and verify that everything in the field matches both the DR as well as the available plans and background information.

FIELD REVIEW

The initial field review is one of the most important steps in the design of any signing and marking project. This is when the designer collects and reviews the information necessary to ensure that a complete, comprehensive, and cohesive system is developed. The field review allows the designer to also determine traffic patterns including lane drops, lane reductions, lane transitions, lane continuity, turn lanes, etc. These traffic patterns will affect the signing and marking design.

The installation or modification of highway signs can often have impacts well beyond the roadway corridor being studied. Prior to the field investigation, it is important for the designer to have a clear understanding of the project objective. This means discussing the project with the team leader, reviewing the DR, and contacting the DR's author in the District Traffic office and meeting in the field if necessary. The goal of the designer should be to ensure that any changes made do not cause inconsistency or confusion in the signing system. This also presents the opportunity to identify any existing problems that can be fixed as a part of the construction project.

Prepare a Base Map

Field data collection and conceptual design are made easier if a base map is prepared. Good sources of mapping are recent TEDD or Highway Design Projects in the area or aerial mapping from MD iMAP (imap.maryland.gov/Pages/imagery.aspx). If these are not available, there are other options available. The "Grid Maps" are available in electronic format from the Geospatial Technologies Team, and they make a good base map. If more detail is required, it may be necessary to obtain a professional survey if time and budget permit, or digitize a set of old plans and then perform a thorough field check. If less information will

suffice, a schematic or "Stick Diagram" can be constructed from maps, a video log from either field videos, VISIDATA or other sources, and the field review.

The level of detail required for the plan will vary depending on the project. In fact, many Areawide and Shop Forces projects do not require scaled drawings, provided that sufficient location and construction information is given on the plans. In general, new construction plans are designed on base mapping provided by the Highway Design Division.

Information to Collect

Signing: Initial Site Visit

Once the project objective is known, the signing requirements and impacts can be estimated. For every change, impacts to signs and messages beyond the immediate project area need to be considered in addition to the actual project construction. For example, removing a supplemental sign may impact a supplemental sign on a neighboring approach roadway. Before performing the initial site visit, it is important to understand how your project fits in with existing signs and messages in the region surrounding your project. This requires verifying that sign messages, trailblazers, and sequential signs are continuous and have a consistent layout. Additionally, it is important to call Miss Utility to have all underground utilities marked within the project vicinity to verify in the field that there will be no conflicts with proposed work. This is especially important if new sign supports or structures are being proposed.

1. Collect sign size, support type and size, position, and location (i.e. station and offset) information for all signs within the corridor. Even if your project is not modifying warning, or regulatory information, these signs may influence your choice of sign location. Always take pictures and make note of any signs or supports needing replacement; bring these signs to the TEDD Project Manager's attention. Signs can be added to the project, but may require a scope change. Always check signs along all corridors approaching your project and look for signs which will be impacted by your project. Guide signs, distance/ destination signs, supplemental signs, and trailblazers are frequently impacted by signing changes.
2. Along with the elements listed above, there are several key elements of existing sign features that must be documented during the initial field visit. These features will aid the engineer in both recreating the signs for the plan sheets as well as determining if parts of the sign or the whole sign need to be replaced or overlaid. These are:

- Sign message
- Text sizes and fonts
- Sheeting type and color
- Sign condition (shadow copy, fading, damage)
- Outdated materials (button copy, engineering grade sheeting Type 3, and signs that lack fluorescent yellow/fluorescent yellow-green)

3. Always take pictures of the job site! This may eliminate a field visit later. Photographs allow the engineer to take visual evidence of existing conditions back to the office to aid in the development of the design without having to go back in the field for clarification.

   Programs such as Google Earth and VISIDATA are also good resources for verifying existing field information, however always remember that their information is dated and they do not replace the need for field reviews.

4. By this point, the designer should have a good feel for the number and location of signs to be installed on the project. For each one, identify two or three possible locations in the field. Take note of lateral clearance problems, right-of-way, utility conflicts, sign spacing, sign visibility, availability of electric service and traffic barrier types at these locations, since these will influence your choice of final location and support type. **Wherever possible, it is preferred to locate new signs behind existing traffic barrier or outside the clear zone of the roadway. When replacing an existing sign, if conditions allow, it is ideal to install the proposed sign behind the existing sign to be removed.**

5. If a potential site is behind traffic barrier, measure the entire approach length in front of the sign location, the lateral distance from the nearest edge of the sign to the back of the traffic barrier, the distance from the travel lane to the traffic barrier, and the shoulder width. The length of need must be checked to ensure adequate protection of non-breakaway supports. Refer to the MSHA *Guidelines for Traffic Barrier Placement and End Treatment Design* for guidance on length of need calculations. Also, make note of the traffic barrier end treatments and ensure that the additional sign will not impact their proper operation.

6. Look for drainage facilities and utilities that will influence the selection of proposed locations.

7. Check that the selected locations meet MdMUTCD guidelines for sign spacing.

8. Identify the location and offset of all ditches near your sign locations. Sign posts or foundations, sign lighting cabinets, meter service pedestals, and electrical handholes should never be located in the centerline (bottom) of a ditch. Instead, sign supports and foundations should straddle ditches if necessary. Ideal locations for support placement should be at an elevation along the ditch line above the line extended from the crest of the roadway to the shoulder. This will ensure that the foundations will not be eroded and the anchoring system for the TCD structures will not corrode due to flooding.

9. Check the sign messages on all approaches to the corridor. The final system should have consistent messages on all signs approaching the system as well as on the system itself.

10. Identify the locations of traffic signal and roadway lighting equipment. For projects with overhead signing, identify potential power source locations if sign lighting will be required on your project. Prior to performing fieldwork, call Miss Utility to mark all underground utilities in the vicinity so that any potential conflicts can be identified during the fieldwork.

11. Drive the entire corridor and look for opportunities to reduce the total number of signs. Check for unnecessary or unwarranted signs and look for sign messages that can be combined with others in your plan. **Remember that signs on county/city roadways must be coordinated with county/city staff.**

Signing: Subsequent Site Visits

For most projects, it will be necessary to make a second site visit. Follow-up visits will usually be necessary to finalize locations, get cross section information, check traffic barrier locations, and check roadside clearances. This is because the sign sizes are not known at the initial visit and often change throughout the course of the design. On smaller jobs, the roadside elevations can be taken at the initial site visit, however this is not always practical on large jobs.

Pavement Markings

The primary purpose of taking a pavement marking inventory is to identify changes in the traffic pattern so that the appropriate changes may be made on the design plans. The field review should collect information regarding existing pavement markings and lane usage. The markings should be noted for turn lanes, auxiliary lanes, lane reductions, and lane drops. This should include the presence of lane lines, center lines, edge lines, dotted lines, transverse lines, channelizing lines, stop lines, arrows, words, and symbols. This information will be important in verifying that the overall treatment is consistent with current standards for both signing and marking. It is also important to note marked crosswalks, two way left turn lanes, raised pavement markers (RPM's), shoulder rumble strips, and raised rumble strips used for warning conditions.

Data Collection Methods

Sign Sizes

Sheet aluminum signs generally have to be measured to determine size. Extruded aluminum signs, however, can be "counted" based on the panels they are constructed from. Each panel is either 6" or 12" tall, with 6" panels generally located at the top when they are used. Note, 6" panels should be used only for special purposes where utility conflicts, right-of-way conflicts, or installing a proposed sign on existing sign support(s) impose design constraints. Each panel also has bolt holes along the top and bottom edges, and these are also 12" apart. When signs are even foot widths (i.e. 12'-0"), the holes are offset 6" from each edge. Where signs are half-foot widths (i.e. 12'-6"), the holes are offset 3" from each edge. Once again, half-foot widths should be used only for special purposes.

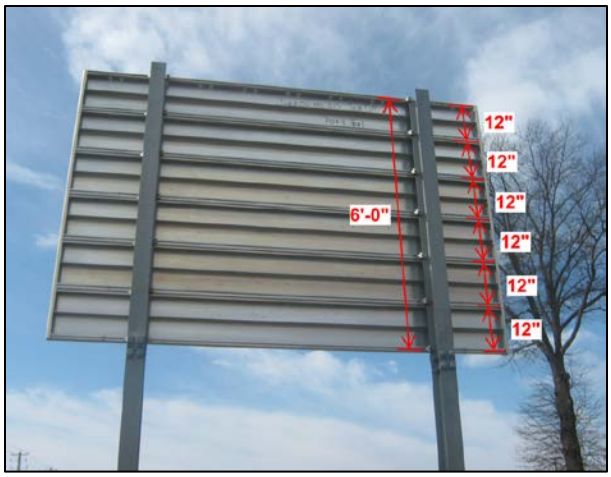


Figure SN.1 - Extruded Aluminum Sign Height

Figure SN.2 - Extruded Aluminum Sign Width

Elevations

Elevations are required to determine ground mounted support sizes and lengths as well as overhead and cantilever sign structure clearances and support sizes. They also help determine lateral placement of signs to avoid ditches, utilities, and other site features. Measuring and recording elevations is usually a two-person process involving a survey rod and a lock-level; however, for new construction, this information is available from the profiles, cross sections, and typical sections. The person holding the lock-level usually stands on the edge of shoulder on the side of the roadway on which the sign will be installed and takes measurements at the edge of shoulder, edge of travel lane, hinge

points, and the top and bottom of roadside slopes and ditches. The first measurement, taken at the edge of shoulder, is used to calculate the "eye height" of the observer, and will be used to calculate elevations and slopes. A measurement should be taken at the edge of travel lane for the purposes of estimating the elevation of the high point on the roadway. Curved sections of roadway may be super-elevated and elevations should be taken at both shoulders where practical. Measurements should be taken on both sides of the roadway for overhead structures as foundations will need to be installed on both sides. In cases where there is a median, the overhead sign structure may only span from one side of the roadway to the median. In this situation, elevations must be taken in the median too. Other methods of measuring elevations are available that utilize more common field equipment items.

Consider the following example, where the elevation of a ditch is being calculated. The observer has already taken readings for eye height at 5.2 Feet, top of slope at 7.2 Feet, and bottom of slope at 9.2 Feet.

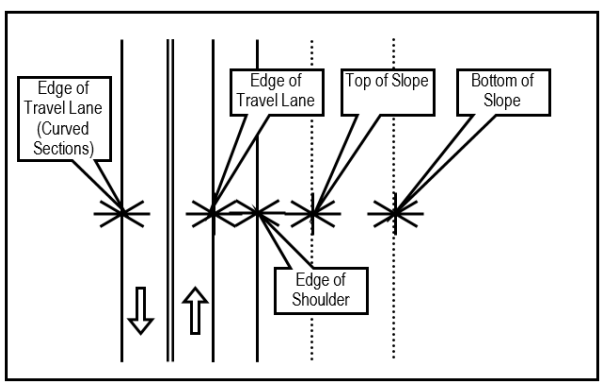


Figure SN.3 - Typical Elevation Requirements

Taking horizontal measurements from the distance between the top of slope and bottom of slope allows the rise and run to be determined and the cross section to be drawn. For example, if the horizontal distance is 5 Feet and the vertical distance is 9.2 – 7.2 = 2 Feet, the slope (Rise/Run) would be 2/5 and the cross section could be drawn accordingly.

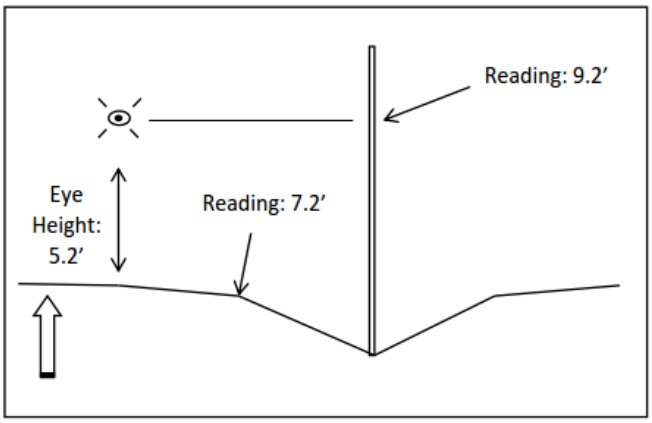


Figure SN.4 - Roadside Elevation Readings

TYPES OF SIGNS

Signing along Maryland roadways falls into eleven (11) categories:

1. **Regulatory** signs have either a black legend on a white background, a red legend on a white background or are white legend on a red background in the case of stop and yield signs. They provide motorists notice of traffic laws and regulations.

2. **Warning** signs have a black legend on a fluorescent yellow background and they alert drivers of roadways conditions that may not be readily apparent.

3. **Guide** signs generally have a white legend on a green background and show route designations, destinations, directions, and distances. Guide signs also include route marker assemblies, generic service signs, and general information signs.

4. **Specific service signs** are white legend on a blue background guide signs located along freeways and other eligible roadways to direct motorists to services

(gas, food, lodging and camping). The Specific Services Signing Program (LOGOs) is administered by the Traffic Development and Support Division (TDSD) and TEDD is responsible for the design/installation of LOGO signing.

5. **Recreational and cultural interest signs** are guide signs that direct motorists to areas of attraction or traffic generators that are open to the general public including museums, parks, art galleries, and historical sites.

6. **School Signing:** School signs generally have a black legend on a fluorescent yellow-green background; however regulatory signing in school zones has a black legend on a white background. School signs are used to notify motorists when they enter a designated school zone, warn motorists of school crosswalks inside the designated school zone, and provide notice of the posted speeds inside the school zone.

7. **Emergency Management Signs** are used to guide and control traffic during an emergency. This includes evacuation signing and directional signing to temporary shelters.

8. **Maintenance of Traffic (MOT)** signs generally have a black legend on a fluorescent orange background. These signs are temporary; however, some have long term uses. An example of longer term MOT signing is for a large roadway construction project in which traffic is rerouted and guide signs and exit panels need to be modified to include fluorescent orange panels.

9. **Tourist Area Corridor (TAC) signs** are a system of guide signs and trailblazers meant to more efficiently direct tourists to groupings of attractions within an area. This program will eventually replace the Attraction Signing Program currently under the Specific Service Sign. This program is run by the TEDD.

10. **Other Signing Programs** are also implemented as supplemental signing throughout Maryland. These include, but are not limited to:

    - Ag-Tourism – This program is run by the Maryland Department of Agriculture (MDA) and TEDD.
    - Farmer's Market – This program is run by the MSHA District offices.
    - Maryland History – This program is a combined effort of MSHA Architectural Historians and the Maryland Historical Trust (MHT).
    - Jurisdictional Gateway – This program is a combined effort of the MSHA's Office of Traffic and Safety, Office of Environmental Design, and the District Offices.
    - Maryland Scenic Byways – This program is run by the MSHA Office of Planning and Preliminary Engineering.
    - Community Based Guide Signs – This program is run by TEDD.
    - Dedication Signing – This program is run by MDOT Headquarters and TEDD.
    - Adopt-a-Highway – This program is run by each MSHA District Office.
    - Sponsor a Highway – This program is run by the MSHA Highway Operations Team.

11. **Other Non-standard signing:** In addition to the categories above, MSHA has several programs for implementing non-

standard signing. These programs cover a wide variety of subjects and include signs such as “State Law – No Texting – No Hand Held Cell Phone”, “Move Over – Slow Down – For Emergency Vehicles on Shoulder” and “Buckle Up – It’s our law” signs. A process involving submitting an application to TDSD for director approval must be followed in order to implement non-standard signing.

SIGN CHARACTERISTICS

The four main characteristics of signs are their size, shape, color, and text size, all of which are determined based on human factors. Sign sizes, colors, shapes, and text sizes have been tested in order to ensure optimum driver comprehension and reaction times. More information about text sizes can be found in the “Sign Size and Design” section of this manual and the “Size of Lettering” section of the most recent edition of the MdMUTCD. Utilizing standard sign characteristics also reinforces the uniformity of application which was discussed in the Principles of Design chapter.

The size of all signs should be designed to fit the location and situation and not just the roadway type. The MdMUTCD offers guidance on sign size, but the designer should also consider human factors and the criteria specific to the situation.

Important MdMUTCD Points

The MdMUTCD provides the engineer with guidance for the application and design of guide signs, regulatory signs and warning signs. The Typical Applications in the MdMUTCD are not provided for all situations and it is up to the designer to apply the concepts and use engineering judgment to determine what is best for their specific situation. The following are a list of important points provided by the MdMUTCD:

1. Yield signs shall be installed on entrance ramps only when the acceleration lane does not provide for an adequate merge area.

2. Keep Right signs shall be installed on supports at an angle of 15 degrees (except where a divided highway begins) towards traffic turning left around the nose of the median. The Keep Right sign should be installed 6’ to 10’ from the nose of the median and may have an Object Marker installed in front and lower than the Keep Right sign.

3. Freeway ramp terminal signing includes options for Do Not Enter, Wrong Way, No Left Turn, and One-Way signing. Refer to typicals in the MdMUTCD and use judgment in determining the proper layout for each situation.

4. The placement of warning signs shall be based on the minimum Perception-Response Time (PRT). PRT is the time needed for:

- Detection
- Recognition
- Decision
- Reaction

5. When electronically controlled RED signal ahead warning signs are used, Signal Ahead signs are installed as a backup.

6. W3-3 (NEW) assemblies with corresponding Street Name Signs are Fluorescent Yellow and are installed along major roadways in advance of new signal installations for a period of 90 to 120 days.

7. A “Form Single Lane” treatment should be considered wherever a two lane ramp reduces to one lane before merging with

the mainline roadway, where two through lanes reduce to one lane on a multi-lane highway, or for dual-left turns onto a single lane roadway. Both travel lanes must also be designed to taper at the same rate into each other without favoring either lane. Refer to the latest MSHA "Form Single Lane Application Guidelines" for additional details.

CONCEPTUAL PLANS

Developing a Concept

The conceptual plan is developed before the actual design of any signs has begun. Prior to the concept stage, the base mapping should have been obtained and a roll map produced. Information from the field review should be drawn on the plan, including existing signs, existing traffic barrier, existing markings, existing utilities, and existing lane usage. Where possible, information that may influence the selection of final locations should also be included.

The concept plan should lay down on paper what the designer feels is the desired and preferred system of signs and proposed traffic patterns. The focus should be on the location, order, presentation, and coordination of sign messages, both within and outside the project limits. The concept does not need to address exact details of what sign sizes will fit in the field, however obvious problems should be noted and addressed. At this stage, the designer should choose between overhead and ground mounting of the signs, as this may influence other signs in the system. It should also be indicated if there are changes in the traffic pattern, as this will influence the signing, such as number of lanes feeding from an existing system into the proposed system and vice versa.

The Signing "System"

Signs are designed to operate as part of a system that makes use of driver memory and learning to reinforce messages and improve understanding and reaction. The conceptual plan should address the design on a system, or a "Big Picture", level to ensure continuity with existing messages and treatments. The development of a concept plan usually involves the following steps.

Guide Signs

1. *Note the Area Type*: Urban, suburban, and rural characteristics often influence the type, size, frequency and support structures for signs along a roadway. Also, note roadway geometrics, travel speeds and traffic volumes.

2. *Determine Functional Classification:* Use the latest approved version of the Highway Location Reference (HLR) to determine if the highway is a freeway, expressway, urban interstate, rural interstate, conventional roadway, or a low volume roadway.

3. *Identify Routes and Destinations:* Identify the primary routes, road names, primary destinations, supplemental destinations, and services that need to be signed. This information will be available from the field review, maps, neighboring roadways, and the district traffic office. A list of Maryland's Control Cities by route number can be provided by TEDD. The control cities along interstates may also be found in List of Control Cities for Use in Guide Signs on Interstate Highways from AASHTO.

4. *Identify Problem Areas:* Check the roadway for unusual circumstances that may cause driver confusion or difficulty. These include lane drops, lane reductions, splits, and confusing geometry. The design must address these situations.

5. *Identify Signs Which Cannot Be Moved*: A number of signs are either tied to a specific location or are part of programs which are run by other divisions. As a result, these signs either should not be moved or the

relocation should be coordinated with other divisions. This includes Maryland Historical Markers which designate a specific historical site and the Adopt/Sponsor a Highway signs which typically can be moved to a nearby location, but it requires coordination with the Office of Maintenance. These types of signs should only be moved if there is no other alternative and the design should be closely coordinated with the lead Division.

6. *Choose a Scheme or System*: The selection of a scheme or system type will depend on roadway classification and configuration. Typical configurations include the conventional full complement of the 1 Mile, ½ Mile, exit direction trio, or may include sequential signs, arrow-per-lane and diagrammatic signs. Lower classification roadways, such as two lane and local roadways, will usually be adequately covered by route markers, distance/destination signs and advance street name signs.

7. *Sketch and Locate Proposed Signs*: Using the scheme chosen above and the messages identified in Step 2 as a guide, make hand sketches of the proposed signs and locate them approximately on the plan. Most often this is done with a roll map and "Post-It Notes", particularly for large projects.

8. *Check Opportunities to Reduce Clutter:* When the initial layout is complete, re-evaluate the concept looking for logical ways to eliminate signs, combine signs, and reduce costs. This process should always keep the needs of the driver as a primary objective.

Warning and Regulatory Signs

1. *Place Warning Signs*: Identify where warning signs are needed and sketch them on the plan. While it is not necessary to address every warning sign at the concept level, it is important to consider unusual situations such as lane reductions, lane drops, sharp curves, low design speed ramps, etc. Refer to the MdMUTCD for application of these signs.

2. *Place Regulatory Signs*: Similar to warning signs, it is not necessary to address all regulatory signs at the concept level. It is sufficient to identify what types will be used and what criteria will be used for most cases. It is usually important to identify one-way and wrong way treatments, lane use control signs, stop/yield signs, and the post interchange sequence (speed limit and confirmatory route marker assembly).

3. *Place Route Markers, Service Signs, and Others*: If they have not already been addressed, review the application of route marker and service signs. This is also the time to review the need for any other signs, such as historic signs.

Reducing Clutter

There are many demands competing for the installation of highway signing. In addition to the standard complement of regulatory, warning, and guide signs, there are programs for service signs, logo signs, supplemental generator signs, historical markers, historic signs, and tourism signs. A designer should be concerned with preventing signs from being lost in a background of visual clutter.

The latest edition of the MdMUTCD states "Regulatory and warning signs should be used conservatively because these signs, if used to excess, tend to lose their effectiveness." On the other hand, a frequent display of route signs and directional guide signs will keep the driver informed of the vehicle's location and will not lessen the sign's value.

One of the purposes of the conceptual plan is to check that new projects not only recognize

this problem, but also attempt to reduce it. In this type of environment, it is important to prioritize information into what the driver needs to know and what is supplemental and not required for the driver. Reasonable accommodations should be made to install signs that are not necessary to the driver's safety, however this should not be done at the expense of the basic principles of human abilities and time-distance relationships. In order to prioritize signs and resolve any conflicts that arise as part of the design process, the following sign hierarchy should be followed when developing a signing plan:

1. Signing for motorist right of way (stop/yield)

2. Regulatory Signs

3. Warning signs to alert drivers of the unexpected

4. Guide Signs

5. Supplementary destination guide signs and additional program related signing (Tourism, Historic, Adopt a Highway, etc.)

Concept Review

The designer will develop what he or she feels is the desired sign message layout prior to the conceptual plan review, when these recommendations will be reviewed. A concept plan is beneficial for smaller projects, whereas a detailed "Post-It-Note" roll map is useful as a concept for large scale projects as a method to adjust messages and concept layouts of signs.

The concept review is an important step in the design process, because it sets the foundation for the messages and sign types to be used and then gathers comments and input from all interested parties early in the design process. The designer, the designer's team leader, director's staff, and the district traffic office at a minimum usually attend the Concept Review meeting. Depending on the complexity and level of input desired, it is also helpful to have the Division Chief, Assistant Division Chief, representatives from another design team, and where applicable the design consultant and the Highway Design Division Lead present.

The exact type of review necessary will depend on the project size and scope. Obviously, if the project is replacing a single sign knock-down, a formal meeting is not necessary. This type of review can take place by fax, mail or e-mail. For larger projects involving new construction or signing replacements through a corridor, a concept review meeting can take several hours.

Review Items

A reviewer should consider the following items when participating in the review of a concept plan:

1. Verify that all signs outside the project limits are consistent with the proposed signing and that all sign messages and layouts are consistent.

2. Check that the level of signing is appropriate for the facility in question. Keep in mind that the level of signing for a Freeway differs significantly from a two-lane highway.

3. Check route numbers, cardinal directions, route names, and destinations. They should be accurate and consistent with other signing in the area and with the latest approved version of the HLR.

4. Check that supplemental destinations are addressed where needed.

5. Check service signs for applicability and consistency. Make sure that logo and generic signs do not address the same service at an interchange.

6. Check unexpected or unusual circumstances and see that they are adequately signed. This should include lane drops, lane reductions, turn restrictions, confusing geometry, etc.

SIGN SIZE AND DESIGN

The MdMUTCD describes standard signs and outline criteria for their application. The MdMUTCD also gives general criteria governing the design of guide signs. The Maryland Standard Sign Book should be used for all standard signs. The purpose of this section is to give guidance on the design of signs and application of the rules from the MdMUTCD as well as Maryland SHA practice.

Sign Legibility

Sign legibility will play a key role in designing the sign layout. It helps to determine the required text size for different driving scenarios. The MdMUTCD states that 30 feet of legibility distance per 1 inch of letter height should be used. Thus, a sign with 8" letters would be legible to drivers at 240 feet distance under the guidelines. Table SN.1 summarizes legibility distances for common letter heights. The MdMUTCD also contains charts that state the minimum legend size per roadway type.

Table SN.1 - Sign Legibility Distance

Letter Height (Inches)	Legibility Distance (Feet) based on 30 ft/in
4	120
6	180
8	240
10	300
10.67	320
12	360
13.33	400
15	450
16	480
20	600

An important concept related to how long a driver needs to see a sign is Decision Sight Distance. The AASHTO "A Policy on Geometric Design of Highway and Streets" defines this as "the distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or hazard in a roadway environment that may be visually cluttered, recognize the hazard or its threat potential, select an appropriate speed and path, and initiate and complete the required safety maneuver safely and efficiently". Decision Sight Distances are inherently longer than other sight distance criteria because they allow time for a driver to comprehend the information presented by the roadway environment (i.e. the sign or hazard) and make a judgment regarding course of action.

Sign Layout

The first step in sign layout is determining the class of facility the sign will be used along. This will be used to select letter heights from the charts in the Guide Signs chapters of the MdMUTCD. For warning and regulatory signs, letter heights range from 1¼ in. on parking signs to 8 in. on some warning signs depending on visibility needs. Once a letter height has been selected, the MdMUTCD offers the following guidelines for legend design:

- The minimum height of legend for ground mounted expressway signs is 8 inches.
- Capital letter heights shall be 6 inches and lower case letters shall be 4.5 inches minimum on conventional roads.
- Capital letter heights shall be inches and lower case letters shall be 3 inches minimum for all low volume or urban roads (25 mph).
- The spacing between lines of copy should be approximately three-fourths of the average upper case letter height for adjacent lines of copy or the height of the

corresponding lower case letter. Examples of spacing can be found in Table SN.2.

- Spacing between lines of copy and the top and bottom borders should be approximately equal to the average letter height of the adjacent line of copy.
- Spacing between legend and vertical borders should be approximately equal to the largest letter.

Table SN.2 - Sample Sign Layout Spacing

Legend height (inches)	Interline Spacing (inches)	Spacing between legend and top/bottom border (inches)	Spacing between legend and vertical border (inches)
8/6	5.25	7	8
10.67/8	7	9.335	10.67
13.33/10	8.75	11.665	13.33
16/12	10.5	14	16
20/15	13.125	17.5	20

Sign layout is an iterative process that can be broken down into 6 steps. Given that signs are generally fabricated in heights and widths of even 12” multiples, strict application of the above spacing recommendations does not usually produce a design that can be used for fabrication. It is usually necessary to adjust the interline and edge spacing to obtain a workable design; the MdMUTCD should be referenced for guidance on interline spacing and layout during the design. This process is usually performed using MSHA’s SIGNTOOL program or other sign design program. These programs make alternative layouts easy to develop and modify. A typical design process would involve the following steps:

1. Select appropriate letter heights for the legend and symbols based on the facility class.
2. Using TEDD’s CADD Standards manual, place all of the legend and symbols. Designers are referred to the SIGNTOOL Users Manual, the sign program users guide and the CADD Standards Manual for information regarding the proper use of Microstation, signing programs and SIGNTOOL software.
3. Space the various lines of legend according to the spacing guidelines provided in Table SN.2.
4. Place a border following the spacing guidelines between legend and border provided in Table SN.2.
5. Check the computed height and width against manufacturing capabilities. Generally, the sign shop fabricates extruded signs in even foot multiples (both height and width). Using the spacing recommendations as a guideline, additional space can be added or possibly deleted to develop the required height and/or width.
6. When selecting the corner radius and border thickness, use Table SN.23 and Table SN.34 as a guide. Border thickness and corner radius are selected based on text size and the smallest sign dimension, either height or width. Note that the top corner borders of exit panels should have a radius of 6” and are an exception to Table SN.3. Additionally, the bottom border corners of exit panels shall be square, not rounded. See Figure SN.5 as an example.

Figure SN.5 - Sign Border Example

Table SN.3 - Sign Border Radii

Smallest Side Dimension (Feet)	Corner Radius (Inches)
2	3
3	3
4	6
5	6
6	9
7	9
8 +	12

Table SN.4 - Sign Border Thickness

Text Height	Text Series	Border Thickness
8"	EM or E	*See note
8"	D	1.25"
8"	C or B	1"
6"	EM, E or D	1"
6"	C or B	0.75"
4"	All	0.75"
*Smallest Dimension ≤ 4: 1.25" Smallest Dimension > 4: 2"		

General Principles

There are many general principals, or possibly rules of thumb, which are applied to sign design on a daily basis. Some important ones to always keep in mind are:

- When designing for a cloverleaf interchange, the top destination should be for the closer exit ramp and the bottom destination for the further or second ramp.
- For diamond interchanges, the top destination should be the one requiring a left turn and the bottom destination for a right turn at the end of the exit ramp.
- Cardinal directions on guide signs should be top-aligned with the route marker shield to which it applies.
- JCT, ALT, USE, TO, and FOLLOW messages on guide signs should be center-aligned with the route marker shield to which the message applies.
- Where EXIT ONLY panels will be constructed on extruded panels, maintain 12” multiples for the height. Refer to the “Advanced Guide Signs” Section of the MdMUTCD for design of exit panels for advance guide signs for left exits.
- For multilane exits at Major interchanges with either option and/or split lanes, an Overhead Arrow-per-Lane or Diagrammatic sign should be used based on MdMUTCD guidance.
- When designing guide signs for left exits in lieu of diagrammatic signs, the action messages starting with the furthest sign should be “LEFT X MILE”, “LEFT EXIT”, “NEXT LEFT”, followed by the exit direction sign. The action message shall have black legend and border on a fluorescent yellow background.
- The exit panels for left exit guide signs are white legend and border on a green background with a fluorescent yellow overlay on the panel with “LEFT” in black legend. The panel should be left justified above the guide sign.
- Don’t center all lines of a multi-line message. Where the road name, destination, or other message is more than one line, the second line is indented, not centered. The vertical space between two lines of a split message is reduced in relation to other vertical spacing. Never split a single destination or roadway into more than two lines.
- Spacing between legend and symbols is (for example a shield and a cardinal direction) should be equal to the capital letter height.
- Road names should not be hyphenated and placed on two lines.

Text Heights

The tables in the “Guide Signs – Freeways and Expressways” chapter of the MdMUTCD provide guidance for text heights for different

sign messages and roadway types. The tables provide minimum text heights for different categories of freeway and expressway signs: Major (Category A and B), Intermediate, Minor, and Overhead. To avoid confusion about which category should be used for particular locations, it is beneficial for the designer to initiate a discussion with the MSHA Project Manager at the beginning of the project design. Further guidance to clarify and supplement the information provided in the MdMUTCD is included below.

When using the MdMUTCD tables, if a sign fits into one of the "Type of Interchange" categories and is also an overhead, the larger minimum text height of the two applicable columns should typically be used.

Generally, for overhead signs, exit direction signs should be one text size larger than the advance guide signs. For example, if the advance guide signs have a 16" capital letter text height, the exit direction should have 20" capital letter text heights. This applies to signs on conventional roads as well as freeways and expressways.

The sizes shown in Table SN.5 should be used for overhead signs on conventional roadways. Table SN.6 includes the minimum sizes that should be used for ground mounted guide signs on conventional roadways.

Table SN.5 - Conventional Overhead Sign Minimum Text Heights

Legend	Size
Exit Panel (word/number)	10"/15"
Shield	36"
Cardinal Direction (1st Letter, Rest of word)	15"/12"
Auxiliary and Alternative Routes (i.e. JCT, TO, ALT, etc.)	12"
Destination (Upper/Lower)	16"/12"
Distance (number/word)	15"/10"
Fractions (Numeral/Overall)	10"/15"
Action Message	10"

Table SN.6 - Conventional Ground Mounted Sign Minimum Text Heights

Legend	Size
Shield	24"
Cardinal Direction (1st Letter, Rest of word)	10"/8"
Auxiliary and Alternative Routes (i.e. JCT, TO, ALT, etc.)	6"
Destination (Upper/Lower)	10.67"/8"
Distance (number/word)	10"/8"
Fractions (Numeral/Overall)	8"/12"
Action Message	6"

Table SN.7 - Standard Capital Letter Heights (Series B, C, D, and E)

Standard Letter Heights (Inches)	
3*	8
4*	10
5*	12
6	16

***3, 4, and 5 Inch letter heights are not used on guide signs**

The following table includes the uppercase and lower case configuration for standard E-mod letter heights. In signs where the words are both uppercase and lower case this should be used. The lower case heights shown are the minimum because text heights will vary by letter.

Table SN.8 - Standard E-mod Letter Heights (inches)

Initial Upper Case	Lower Case
6	4.5
8	6
10.67	8
13.33	10
16	12
20	15

Sign Layout Example

As an example sign layout, consider an Advance Guide Sign for an intermediate interchange located along I-81 in Washington County. The MdMUTCD recommends the following letter sizes for Freeway guide signs:

Table SN.9 - Letter Heights for Design Example

Legend	Size
Exit Panel (word/number)	10”/15”
Shield	36”
Destination (Upper/Lower)	16”/12”
Distance (number/word)	15”/10”
Fractions (Numeral/Overall)	10”/15”

Referring to the sign layout guidelines mentioned earlier, an initial layout might produce the following spacing shown in Figure SN.6.

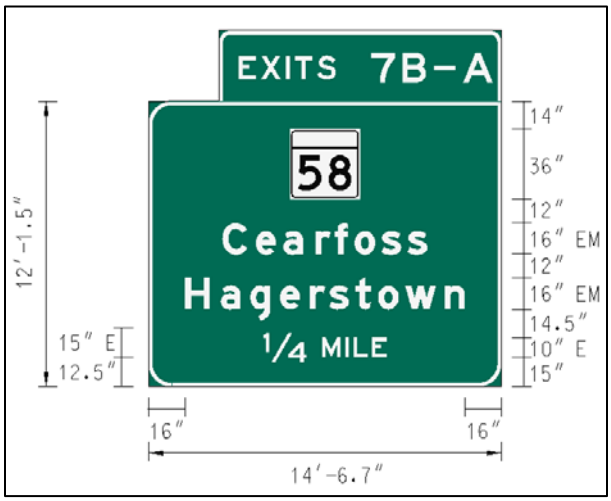


Figure SN.6 - Initial Layout for Design Example

A quick application of the above rules led us to choose 12” for the interline spacing, 14” for the spacing to the top of the sign, and 16” for lateral spacing from the edge (vertical border) of the sign. The total height calculated, 145.5” should be modified to an overall total of 12’-0” (or 144”). Because the width of the sign is only about 5” less than 15’-0”, the edge spacing should be increased evenly to reach 15’-0” since it is preferred to have the sign width rounded to a whole number.

Refining your Design

A refining technique for improving sign legibility is to reduce spacing between associated messages and increase spacing between route – destination – information messages.

In this example, a logical location to subtract the required inch and a half from the overall total height would be between “1/4 MILE” and the bottom of the sign because while the spacing is slightly compromised for the “1/4” fraction, the spacing is still adequate for the “MILE.”

Figure SN.7 - Final Layout for Design Example

Combining Messages

The goal of sign designers should be to install the fewest signs necessary to provide motorists with required informational needs. Combining messages is one way to reduce the required number of signs while grouping messages having a common theme. Cloverleaf interchanges are frequently designed with an overhead structure

containing both the Exit Direction sign for one interchange ramp and a second "¼ MILE" sign for the subsequent ramp. Since these ramps often serve a common route number or route name, these messages can be combined to produce a single sign. This may allow the structure size to be reduced, reduces the total number of signs along the highway, or creates room for a different sign to be installed. In either case, care should be taken not to overload the driver with information. The MdMUTCD's rules regarding legend and number of destinations per interchange still apply. Two of the primary objectives of combining messages are:

1. Group messages to provide motorists with a more effective and concise presentation.
2. Reduce the total number of highway signs and minimize driver information overload.

Message Dividers

Message dividers are most commonly used to separate road names, points of interest, destinations, and services on distance and destination signs. They also are used on combined guide signs, where road names are used on the primary guide signs or to separate action messages for different ramps. Figure SN.8 and Figure SN.9 show example message divider applications.

These signs are governed by the following rules:

- The divider color and dimensions are the same as the sign border. See Table SN.3 and Table SN.4 for border dimensions.
- Where a partial divider is used, it is 2/3 of the sign height for vertical dividers or sign width for horizontal dividers. This is also referred to as a 2/3-bar.
- Where distance/destination panels are stacked for different classifications of guide signs (ie. services and recreational), a single divider (usually white) is used between the different colored backgrounds.
- Message dividers should imply the degree of association between various items. For example, if services are associated with a particular point of interest, no divider is used. If the services are separate but available at the same exit, then a divider is used.
- For EXIT ONLY panels, both a black and white border is used to separate the fluorescent yellow panels from the green panels.

Figure SN.8 - Typical Message Dividers

Figure SN.9 - Typical Message Dividers

Negative Contrast

Negative contrast signs are those with a light background and a dark legend (such as an 'EXIT ONLY' panel). They are intended to stand out from the rest of the sign in order to

alert drivers of what is ahead. These types of supplemental signs are used for interchange entrances and exits. Figure SN.10 shows an example of a guide sign with negative contrast in the "ONLY" panels.

Figure SN.10 - Negative Contrast "ONLY" Panels

Positive Contrast

Positive contrast signs are those with a dark background and a white legend (such as a standard guide sign as shown in Figure SN.9). They are intended to provide the user with clear messages of what is ahead.

Clearview Fonts

Clearview fonts should no longer be used. Refer to the February 25th, 2016 MSHA memorandum with the subject "Guidance – Federal Highway Administration Termination of Interim Approval of Clearview Font" for information regarding Clearview Font usage.

Arrows

The MdMUTCD and the FHWA Standard Highway Signs book define six standard arrows, the "UP" and "Down" arrows, intended for use on interstate guide signs, and the "Standard Arrows" which can be used on all signs. In addition, Maryland SHA also uses several curve and turn arrows which have been developed for unique situations. The MSHA Standard Sign Book gives dimensions and details for all arrows used in Maryland.

"UP" arrows are used to designate exiting or turning movements on exit direction signs. The Type A Arrow (as defined in the Standard Signs Book and the MdMUTCD) are used along interstate highway as well as other freeways and expressways. The Type A up or Interstate Arrow should not be used along conventional roadways. The Interstate "Down" or "lane designation" arrows tell motorists what lanes to use to reach a particular destination or follow a specific route. They are commonly used for "EXIT ONLY" signs. These arrows are intended to point at the center of the lane to which they refer. The latest approved version of the MdMUTCD requires that Down Arrows must be vertical and point at the approximate center of the lane to which it applies. Down arrows can NOT be rotated as previously allowed. This frequently happened at a choice lane, where the MdMUTCD now recommends considering Overhead Arrow-per-Lane or Diagrammatic signs instead.

The Type D or "Standard Arrow" is only used for guide signs which are post mounted along conventional roadways and ramps. This includes distance/destination, warning, and regulatory applications. Dimensions for standard letter heights are given in the Appendix of the Standard Sign Book, however non-standard sizes can be scaled for application to warning and regulatory signs. The MdMUTCD recommends that the arrowhead width be equal to the capital letter height.

Diagrammatic Signs

Diagrammatic signs are a special category of signs in the MdMUTCD that are intended to graphically depict roadway conditions ahead. They are installed at the advance guide sign locations (i.e. 1-MILE and ½-MILE) and are commonly used to indicate freeway splits, left exits, choice lanes, route discontinuity, and lane drops. The MdMUTCD states that "Diagrammatic guide signs have been shown to be less effective than conventional or Overhead Arrow per Lane guide signs at conveying the destination or direction(s) that each approach lane serves, regardless of

whether dedicated or option lanes are present." Diagrammatic signs shall not be installed at the Exit Direction sign location.

In addition to visualizing the roadway geometry, diagrammatic signs can be combined with LEFT EXIT panels to clearly identify left exits. These signs tend to be extremely large (the one along southbound I-270 is one of the largest signs in Maryland), and as such are found mainly along Interstates and Freeways. The MdMUTCD section on freeway signing gives criteria governing the design of diagrammatic signs and specifies dimensions for lane widths, lane line widths, and arrowhead sizes. It is important to note that the manual specifically states that these signs SHALL NOT be used at cloverleaf interchanges except for the following cases as detailed in section 2E.22 of the MdMUTCD:

- "Where the outer (non-loop) exit ramp of the cloverleaf is a multi-lane exit having an optional exit lane that also carries the through route"
- "At cloverleaf interchanges that include collector-distributor roadways… that are accessed from the mainline by a multi-lane exit having an optional exit lane that also carries the through route"

Figure SN.11 - Typical Diagrammatic Sign

Sign Lighting

Existing sign lighting shall remain in-place until the sign and/or structure gets replaced. When high-performance Type XI sheeting has been installed on overhead guide signs, refer to the Maryland SHA Lighting Guidelines, 2017. Sign lighting is not required unless specific conditions, such as tight curves or complex geometry restrict vehicles from illuminating the signs with their headlights. Other conditions that may require sign lighting include the presence of fluorescent panels or background visual clutter which may include lighting behind the sign.

MSHA uses individual luminaire supports (traditional lighting) where sign lighting is required. Sign Lighting Maintenance Systems are still installed in many locations throughout the state, but is not used on new projects. With the use of LED luminaires, maintenance is less frequent because LED luminaires have a greater service life than High Pressure Sodium (HPS) luminaires. On all new projects, sign lighting, if needed, will only be installed along interstate highways and controlled access freeways and in accordance with the Maryland SHA Lighting Guidelines, 2017.

For traditional lighting, the luminaires are mounted on steel beam supports that are attached to the overhead truss (see Figure SN.12 and Figure SN.13 examples). Also, see the lighting design section of this manual.

The basic elements of sign lighting design are:

1. Selecting the number and wattage of light sources and LED drivers.
2. Identifying a power source.
3. Determine circuitry.
4. Maintenance considerations.

Figure SN.12 - Sign Lighting Individual Supports

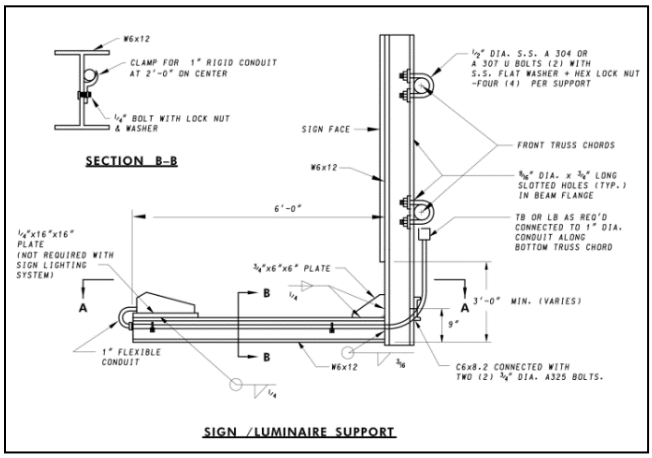


Figure SN.13 - Sign Lighting Supports

Light Source Selection

All new sign lights installed in Maryland are LED, and the number of light sources is based on the sign height and width. TEDD has a standard Sign Lighting Schedule, which is included in the Appendix of this manual. Since design of the LED fixtures varies considerably, the approval of the sign lighting installation is based on the photometrics submitted by supplier.

Power Sources

Signs are typically powered from the roadway lighting circuits where roadway lighting is present and spare capacity exists. Connections to existing circuits can be made in the base of light poles, or spare circuits can be run from an existing cabinet to the signs. In either case, the existing circuits should be reviewed to ensure sufficient spare capacity exists.

Where there is no roadway lighting, a separate cabinet and power drop will be necessary for the sign lighting. For most situations, a Pole Mounted Lighting Cabinet (see MSHA's *Standard Specifications for Construction and Materials*) will be sufficient to power the sign lighting. A remote service consists of an enclosure, a 60 amp Main breaker, 2-20 amp circuit breakers, and a photocell. This is sufficient to provide 2 circuits operating at 240V, which can power 1 or 2 signs. Where the total load is more than 32 Amps, the cost of multiple Pole Mounted Cabinets versus a Base Mounted Lighting Cabinet should be examined. The decision between a Base Mounted and Pole Mounted Cabinet is a cost trade-off between supplying individual Pole Mounted Cabinets which each may be half the cost of a Base Mounted Cabinet, plus additional trenching and cable to reach a central location. Refer to Spec. Section 807, Electrical Service Equipment, for utility connection information. However, where a Pole Mounted Cabinet is insufficient, it will be necessary to install a Base Mounted Cabinet.

Determine Circuitry

Sign lighting design is a balance between total circuit load and circuit voltage drop. The three rules governing lighting circuit design are: sign lights should be run from two different circuits, the total voltage drop in each circuit should be less than or equal to NEC guidelines (5% of the source voltage currently), and the maximum circuit load in amperes is determined by NEC guidelines (currently 80% of the circuit breaker trip size for roadway lighting). For connections to existing roadway lighting, it is important to

determine if there is sufficient capacity in both the cabinet and the circuits that will be used. Where a remote service is used, it is important to check the total load, because they are not intended to handle large lighting systems.

More information regarding sign lighting and circuit design can be obtained from the lighting section of this manual.

Maintenance Considerations

Sign lighting maintenance is a key concern given the costs that are associated with roadway work and Maintenance of Traffic (MOT). MSHA tracked the costs of changing bulbs for a sign on the Capital Beltway. That particular job required less than $1,000 in new bulbs, but over $10,000 in MOT costs for lane closures. However, LED luminaires have minimized the frequency of changing bulbs, so the costs of maintenance have also decreased.

As well, to reduce maintenance costs locating guide signs with sign lighting over a shoulder may be considered if it makes sense from an engineering point of view. Obviously, this cannot apply to all situations. While advance guide signs and exit direction signs function the same over the shoulder versus over the travel lanes, exit only and lane designation signs (i.e. those signs with down arrows) need to be pointing at the center of the appropriate lane. Another situation requiring judgment would be the inside of curves, where a sign located over the shoulder may not have sufficient sight distance for motorists.

Considering Construction and Fabrication

Fabrication

There are different processes by which signs are fabricated depending on what type of sign is being made. The process used affects not only the cost of construction, but also what can and cannot be made.

In Maryland, larger signs are constructed on an extruded aluminum background and the legend is direct applied. Direct applied copy, including letters and numbers, is generally less expensive than other fabrication methods and can either be fabricated in the MSHA Sign Shop or ordered from a vendor. Some elements of the sign legend, including route marker shields and other symbol legends, are installed using rivets under a method referred to as Demountable Copy.

Demountable Copy uses a legend that is fabricated individually on sheet aluminum and then riveted to the extruded panels. This allows minor copy changes to be made in the field using only a drill and a rivet gun. While demountable copy is allowed in Maryland, it is not used by the MSHA Sign Shop and the industry in general is no longer using it. The use of demountable copy is typically limited to a handful of legend symbols that are used on large guide signs, including:

- Route marker shields
- Generic service symbols
- TOLL plaques
- E-ZPass® plaques

Specific Service or Logo signs are unique in that they are fabricated to be completely demountable. The copy, logos, dividers, and any arrows or other symbols are all demountable. Because these signs can change frequently, fabricating all of the components to be demountable allows for easy reconfiguration and modification of the signs.

The use of extruded panels for large guide signs allows modification to part of a sign without replacing the entire sign. Since the typical green background of larger signs is directly applied to each individual extruded panel before the panels are assembled to make the sign, panels can be added or

removed simply by unbolting the extrusions in the field.

Smaller signs and signs involving artwork typically use silk screening as part of the fabrication process. This involves making a master screen or template and using it to apply ink to the reflective sheeting background. The master is made using a photographic process and a full-scale mock up, which allows one screen to be used for the production of many signs. Each color of legend must be applied in a separate process (and using a separate screen), allowing dry time between colors. Screening offers a high degree of consistency and quality while producing a large number of signs in a short time frame.

Construction

Guide sign legend can be modified when the sign has demountable copy as discussed earlier and when the sign is in relatively good condition. Instead of replacing an entire sign, it makes more sense to replace just the weathered, damaged, or inaccurate portion of a sign. Copy changes are an economical way to modify signs; however, designers should be careful when doing so because:

- Over time, the sheeting behind copy weathers at a different rate than sheeting that is exposed to sunlight and the elements. This can produce ghost images after legend is modified. When this occurs, replacement or a sheet aluminum overlay should be considered.
- Making substantial changes is time consuming. Where signs are mounted over the travel lanes, changes should be limited to a short line or a few symbols. For substantial changes to the sign message or to ensure all legends, symbol sizes, and spacing adhere to MdMUTCD requirements, consider a sheet aluminum overlay instead. Sheet aluminum overlays are less expensive to fabricate than extruded signs and can be installed quickly if they are small, minimizing lane closure time and crew expenses. However, construction means and methods should be evaluated to determine the benefits of using sheet aluminum overlays. For example, overlaying an entire overhead sign may not be the best option because it may require multiple pieces of sheet aluminum, which increases construction time and may result in a lower quality sign that has many visible joints and may not have consistent reflectivity. Further, if overlays are used on a temporary basis holes from the rivets will remain when the overlay is removed.
- While lane closures are introduced, look at the option of upgrading not only the sign, but also sign lighting, if still warranted, and other adjacent signs.
- Button copy is an older type of legend where the letter is made of plastic and round reflectors are mounted on top of the letter to provide reflectivity. Background sheeting on these signs is usually Engineering Grade, an older type with relatively low reflectivity. Button copy signs should be replaced whenever they are located within your project limits.

SIGN SUPPORTS

Mounting Hardware

The type of hardware used for sign mounting depends primarily on the aluminum panels that the sign is constructed from. Extruded aluminum panels are typically attached to supports using post clips that are held in place by bolts that run through the channel at the back of each extrusion. These clips can attach directly to the flanges of steel I-beam supports or can attach to aluminum angles that are bolted to wood supports. Sheet aluminum signs are typically bolted directly to the sign post; however larger sheet aluminum

signs come in 4-foot wide panels that must be assembled prior to installation.

Selecting a Support

There are two decisions that must be made in selecting a sign support. First, it must be determined whether the installation will be overhead or ground mounted. Then, within each category, an appropriate and economical selection must be made. Maryland's policy is to use overhead guide signs along controlled access expressways and freeways and where there are three or more lanes per direction. In most other situations, ground mounted signs will suffice; however, overhead signs may also be used to improve visibility or provide additional emphasis in problem situations. Except for special situations, warning, regulatory, and route marker signs are always ground mounted.

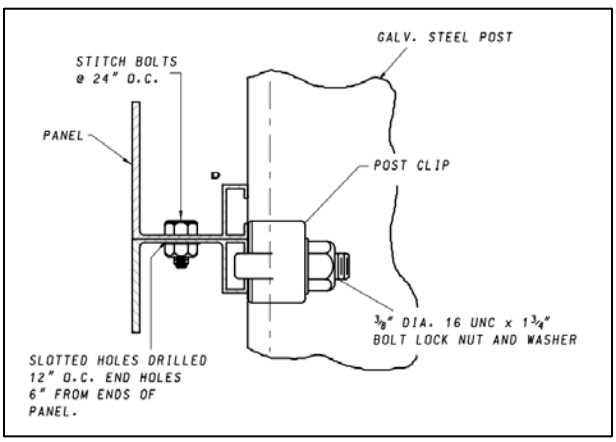


Figure SN.14 - Typical Extruded Panel

Overhead Structures

The decision to use overhead structures is based on the factors outlined in the Overhead Sign Installations section of the latest approved version of the MdMUTCD. If it is decided that guide signs will be installed overhead, then a choice must be made between Overhead Sign Structures and Cantilever Sign Structures for each location. Overhead Sign Structures have two roadside supports (also referred to as End Frames) and typically span over all lanes in a given direction. Cantilever Sign Structures have one end frame (or roadside support) and typically span up to two lanes.

In some instances, overhead and cantilever structures need to be installed on top of a bridge (for vehicles traveling on the bridge) and the foundation will need to be designed and constructed as part of the bridge overpass. Coordination and approval is required from the Office of Structures for these designs.

Throughout the state there are several signs which are installed on the face of a bridge (thus viewed by vehicles traveling under the bridge). New bridge mounted signs are not allowed per current MSHA policy.

Choosing the Right Sign Structure

This decision requires some judgment, as there are issues of function, cost and maintenance that are important. Overhead Sign structures cost more to install and maintain; however, the sign function and driver needs must be the first priority. Each situation needs to be evaluated on an individual basis to ensure that information is presented in the most appropriate manner. The following questions, which are listed in priority order, should be asked in making this decision:

1. Does the type of sign or site conditions (i.e. sight distance, etc.) require that the sign be at a particular location over the travel lanes? This is true for exit only, lane designation, and diagrammatic signs.
2. If the installation is ONE sign, can it be located over the shoulder and still function properly? This is true for most advance guide and exit direction signs.
3. Will the total sign width (for 2 or more signs, include space between signs) fit on a typical cantilever span (Usually 10 to 45

feet)? The span length calculation must include the shoulder setback and the required sign position above the roadway.

Overhead Sign Structures

Overhead sign structure spans are measured from centerline to centerline of the end frames. Typical span lengths range from 70 feet to 120 feet in length; however, structures up to 140 feet are included in the Book of Standards. The Administration requires the use of a minimum 70-foot span even if a shorter span would suffice. All new spans are designed as a box truss. Box truss spans allow signs to be attached on both sides of the span (i.e. both directions of traffic) and can support two span sections with a common center support on divided highways.

When determining the span length, consideration should be given to clear recovery areas, ditches, steep slopes, etc. It may be better to increase the span length than introduce a hazard in the recovery area. On divided highways, the center support should be located as close as possible to the center of the median, to allow for future roadway widening. If possible, the designer should determine if there are any outside widening projects scheduled for the roadway and locate proposed sign structure supports outside the impacts of the widening.

The following criteria must be met for the Design Sign Area of an Overhead Sign Structure:

1. Design sign must extend, at a minimum, the width of the roadway.
2. For actual signs beginning or ending outside the limits of the roadway, the design sign shall extend to the limit of the actual sign.
3. Design sign height shall be the height of the tallest actual sign on the structure. An exit panel shall be considered in addition to the main design sign panel.
4. Design chart sign size of standards shall be equal to or greater than the calculated design sign size.
5. The horizontal centerline of the design sign shall be placed at the horizontal centerline of the truss. The exit panel will be on top of the design sign.

Figure SN.15 - Box Chord Truss Overhead Sign Structure

Cantilever Sign Structures

Cantilevers are typically used to hold one or two signs, depending on the sign area. They have only one support, and spans are measured from centerline of end frame to end of truss. Typical spans range from 10 to 45 feet. Signs on the structure typically overhang the end of the truss. The maximum allowed overhang is 1 foot. Factors influencing the Design Sign Area and span length are:

1. Design sign height shall be 1.25 times the height of the tallest sign.
2. The design sign width shall be the width of the actual sign. When two signs are required, the design sign width shall be the out limits of the actual signs including the space between the signs.
3. An exit panel in addition to design sign of main panel shall be included in the design. The horizontal centerline of the design sign shall be placed at the horizontal centerline of the truss. The exit panel will be on top of the design sign.

4. The design sign size from the Book of Standards shall be equal or greater than the design sign size as calculated above.
5. Sign position over roadway.
6. Roadside features (curbs, shoulders, ditch lines, sidewalks, etc.).

Cantilever Sign structures also come in several truss arrangements, however Maryland most commonly uses the box and plane trusses. (See Figure SN.16 and Figure SN.17).

Figure SN.16 - Typical Box Truss Cantilever

Figure SN.17 - Typical Plan Truss Cantilever

Requesting Structure Design

Structure design can be requested once the designer knows the sign size, roadside elevations, and the horizontal location of the sign over the travel lanes. This is done by filling out the Structure Input Sheets with cross sections, which are included in the TEDD Document Manager and sending them to the Structural Design Team. Depending on the individual project, all the information necessary to complete the forms can be obtained from either the Field Review or the Highway Plans and Cross Sections. See Figure SN.18, Figure SN.19, and Figure SN.20 for examples of the forms used for new structures.

One item designers need to be careful of is the positioning of the sign above the roadway, which will be guided by the function of the sign. Lane designation signs will need to be positioned with down arrows pointing to the center of the lane to which they refer. Other signs have more flexibility. When the location is known, the designer can then calculate the distance from the center of the structure end frame to the edge of the sign. This is the exposed arm length (LA) on the Cantilever Input Sheet and Sign Offset (D) on the Overhead Input Sheet.

Using Existing Structures

When signs are being changed and/or removed on an existing structure, the structural capacity must also be checked. The structure verification form, also a part of TEDD Document Manager, should be used to supply the Structures Section with the information necessary to analyze the structure. On this form, the designer fills out the information pertaining to the size and location of all existing and proposed signs on the structure and any information regarding the contract under which it was installed. It is important to also submit the structure verification form when signs are removed from an existing structure or when a sign structure is removed entirely. This allows the Structures Section to maintain an accurate inventory of all existing structures and available capacity for future modifications. See Figure SN.21 for the form used for existing structures. The designer should submit the following information with this form:

- New sign layout
- Pictures of the front and back of existing structure
- Existing sign supports
- Existing sign attachments
- Existing foundation

Traffic Barrier and Roadside Design

Overhead sign structures are a roadside hazard that must be protected by traffic barrier. All new structures must either be located behind existing traffic barrier or new traffic barrier must be designed to protect the structure. Where new traffic barrier is proposed on insert projects, the structure locations must be provided to the Highway Design Division so that the traffic barrier can be included in their plans. On Areawide and Advertised projects, new traffic barrier should be designed in accordance with the MSHA's "Guidelines for Traffic Barrier Placement and End Treatment Design" as well as with AASHTO's Roadside Design Guide.

Ground Mounted Supports

Maryland SHA uses two main types of ground mounted supports: steel beam and wood. In unique cases, such as for streetscape projects or where local jurisdictions will maintain signs, tubular steel supports can also be used. Districts and other local jurisdictions should confirm project specific usage of tubular steel supports. Sometimes maintenance crews specifically request the use of tubular steel supports. Wood supports are used for warning, regulatory, and smaller guide signs. Steel supports are used for larger installations. Both support types are available as either breakaway or non-breakaway, but anything that is not protected by some form of traffic barrier (see Roadside Hazards section below) should be breakaway unless it's located beyond the clear zone. The Book of Standards shows what modifications are necessary to make both steel and wood supports meet breakaway requirements. The preferred sign location is outside of the clear zone. **If this condition cannot be met, the sign should be placed as far from the roadway as possible.**

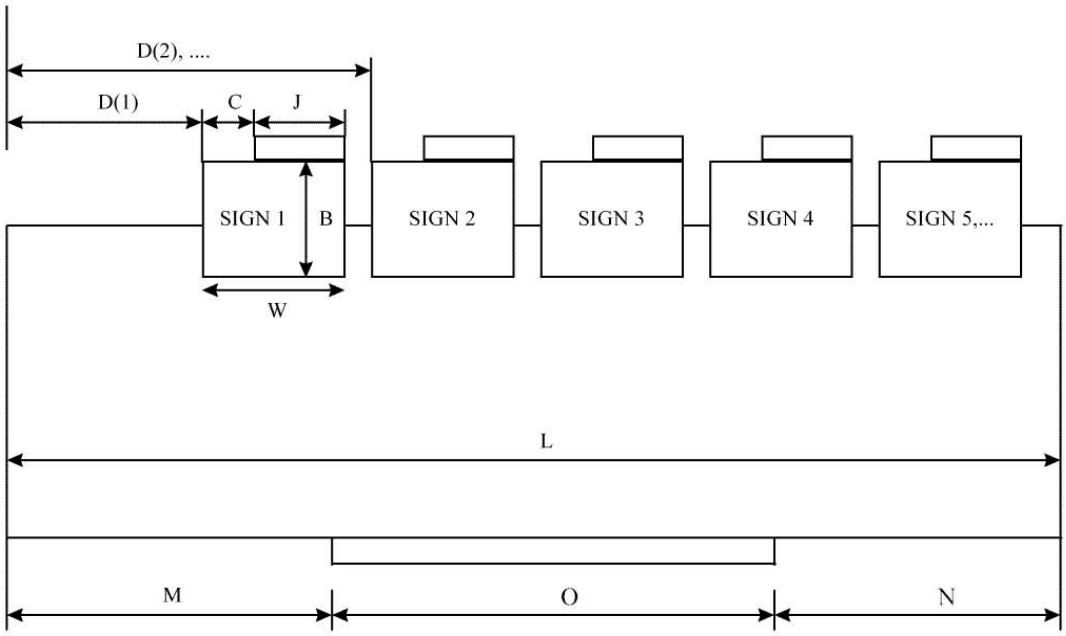
Ground Mounted Selection

There are a number of factors influencing the selection of ground mounted supports. Wood supports are the most economical; however, breakaway modifications have a significant impact on the allowable sign area.

Standard Signs

Warning, regulatory and route marker signs are installed on breakaway wood supports when not protected or within the clear zone. These installations have been standardized in the MSHA *Book of Standards for Highway and Incidental Structures* table on MSHA Standard No. MD 812.04, where the number and size of posts are given for each standard sign blank.

OVERHEAD INPUT SHEET – SINGLE SPAN



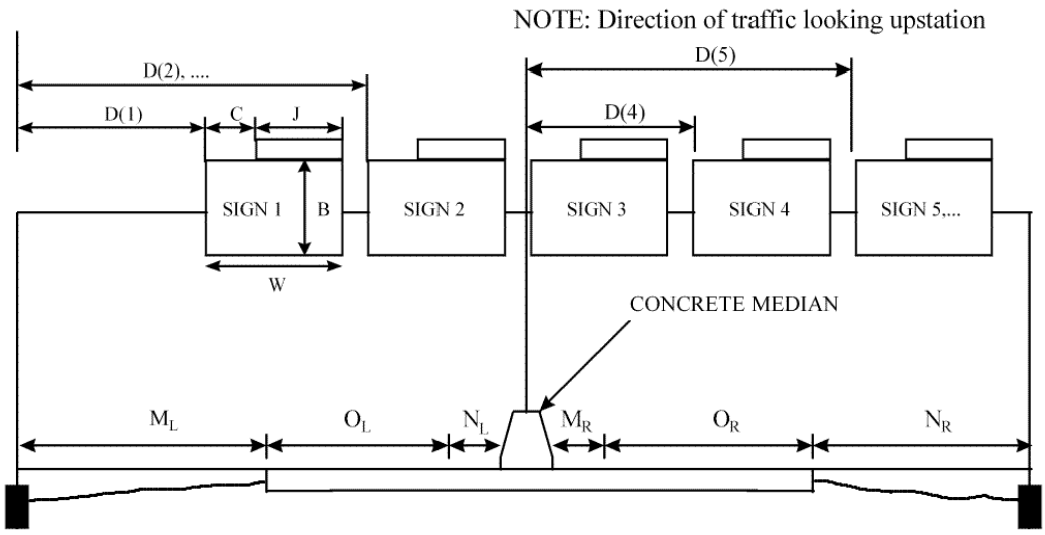
Structure Number: _____ Date: _____
Project: _____
Contract Number: _____ Designer: _____

Left Support Over (-) / Under (+) Roadway: _____
Right Support Over (-) / Under (+) Roadway: _____
Length of Span: _____
Number of Signs: _____
Offset from Left Support to Road Edge (M): _____
Offset from Right Support to Road Edge (N): _____
Road Width (O): _____

D(1)	D(2)	D(3)	D(4)	D(5)	D(6)
B(1)	B(2)	B(3)	B(4)	B(5)	B(6)
W(1)	W(2)	W(3)	W(4)	W(5)	W(6)
C(1)	C(2)	C(3)	C(4)	C(5)	C(6)
J(1)	J(2)	J(3)	J(4)	J(5)	J(6)

Figure SN.18 -Structure Input Sheet for New Structures with Two End Frames

OVERHEAD INPUT SHEET – DOUBLE SPAN



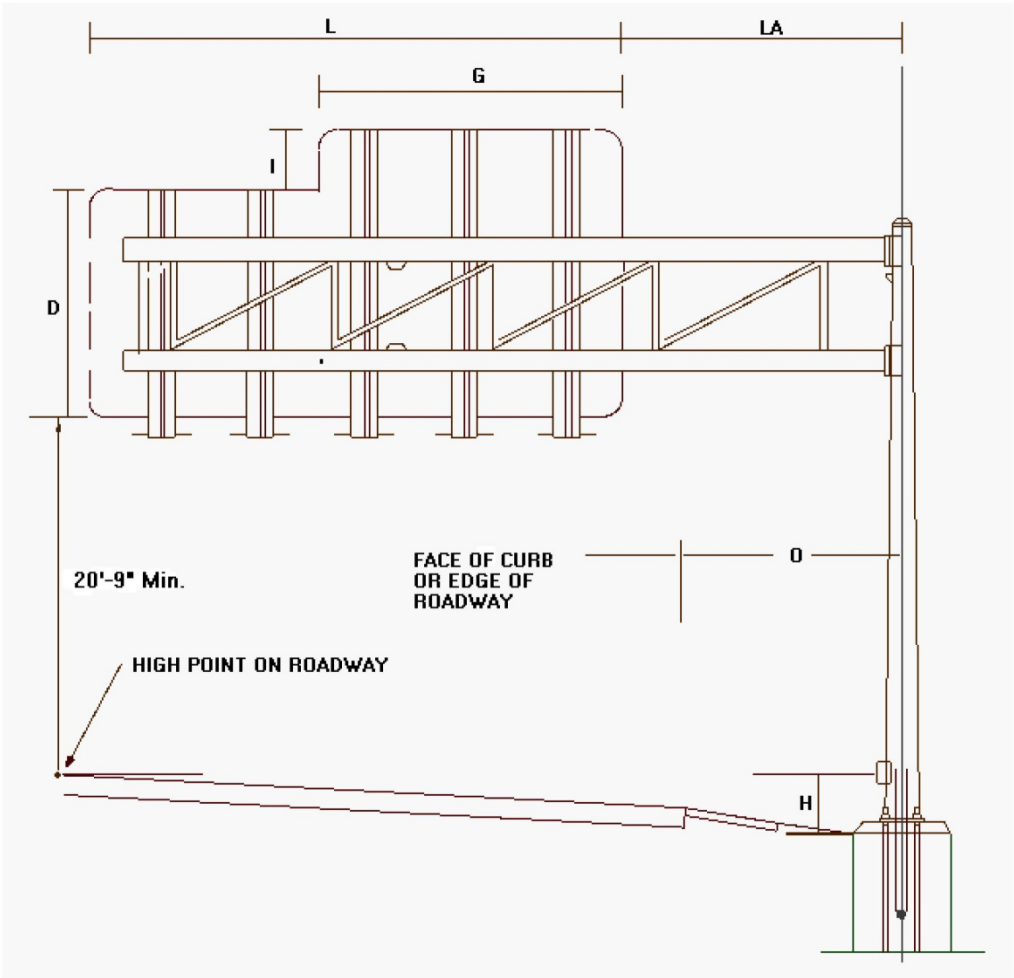
Structure Number: _____ Date: _____
Project: _____
Contract Number: _____ Designer: _____

Left Support Over (-) / Under (+) Roadway: _____
Center Support Over (-) / Under (+) Roadway: _____
Right Support Over (-) / Under (+) Roadway: _____
Length of Span: L: R:
Number of Signs: L: R:
Offset from Left Support to Road Edge (M_L): _____
Road Width - L (O_L): _____
Offset from Center Support to Road Edge (N_L): _____
Offset from Center Support to Road Edge (M_R): _____
Road Width - R (O_R): _____
Offset from Right Support to Road Edge (N_R): _____

D(1)	D(2)	D(3)	D(4)	D(5)	D(6)
B(1)	B(2)	B(3)	B(4)	B(5)	B(6)
W(1)	W(2)	W(3)	W(4)	W(5)	W(6)
C(1)	C(2)	C(3)	C(4)	C(5)	C(6)
J(1)	J(2)	J(3)	J(4)	J(5)	J(6)

Figure SN.19 - Structure Input Sheet for New Structures with Three End Frames

CANTILEVER INPUT SHEET



Date	
Location	
Contract Number	
Structure Number	
Designer	
Sign Depth (D)	
Sign Length (L)	
Exposed Arm (LA)	
Over (-) / Under (+) Road (H)	
Edge Road To Support (O)	
Barrier Wall Mounted (Y / N)	Please select option.
Exit Panel Justification (left / right)	Please select option.
Exit Panel Dimensions	G , I

Figure SN.20 - Structure Input Sheet for New Cantilever Structures

MEMORANDUM

TO: Jialin Tian, P.E., Chief
Traffic Engineering Design Division

FROM: Please select team leader, Team Leader, Structure Design Section
Traffic Engineering Design Division

DATE:

SUBJECT: Verification for Adding/Deleting/Modifying Signs on Existing Structures
Route:
County: Allegany
Contract No.:
Structure No.:
Location:

DESCRIPTION:

The below noted structures have been checked and verified.
Those noted with a Combined Stress Ratio of greater than one are inadequate.

Please submit picture of recent existing signs and drawings of new replacement signs.

NOTE: All existing sign sizes and locations on the structure to be checked must be included in the ensuing table. Once checked, copy must be given to Sign Designer.

Shaded area is to be filled out by Structure Design Section.
* Measured from left post to center of sign on OH spans
* Measured from post to center of sign for cantilever structures
** Distance - Lowest luminaire support bottom to highest point of roadway

Structure No.	Sign Panel Letter	Near/Far Side	**Roadway Clearance	Existing Area Per Panel – W x H	*Location On Span	Proposed Area – W x H	*Location On Span	Structure Design Area – W x H	Design Wind Load - MPH	Critical Stress Ratio (CSR)

By, Sign Designer Checked By, Structural Designer Approved Please select team leader

Figure SN.21 - Structure Verification Form for Existing Structures

Non-Standard Signs

The general process for selecting ground mounted supports for non-standard signs is as follows:

1. Based on MdMUTCD guidelines, select an appropriate location for the sign.
2. Check for existing traffic barrier nearby. If so, use non-breakaway wood or steel. Be careful to ensure that the existing traffic barrier will provide adequate protection in terms of length of need. Use the non-breakaway wood and steel support charts in the Appendix.
3. If no existing traffic barrier is available and the sign is within the clear zone, check the breakaway wood support charts in the Appendix for the appropriate district.
4. If breakaway wood supports are insufficient or will not work due to minimum post spacing requirements or another reason, use the TRANSPO Industries Breaksafe support program to select the appropriate breakaway steel supports.
5. It is important to note that a cross section must be provided for all non-standard proposed ground mounted signs. The cross section shall include the high point of the road, the shoulder, edge of pavement, and elevations at each support. It is beneficial to include the cross section on the signing plan sheets. An example of a good cross section can be seen in Figure SN.22.

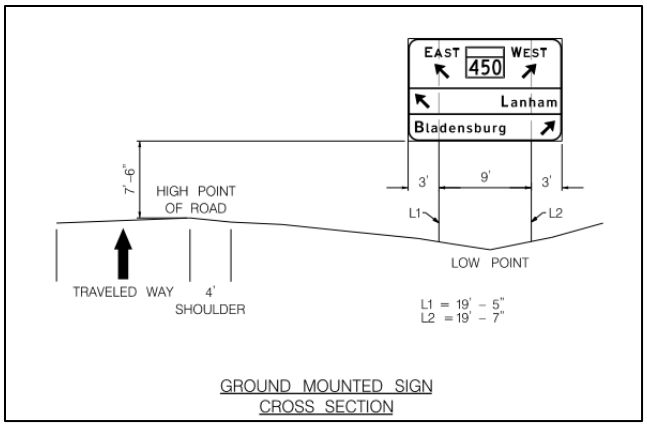


Figure SN.22 - Example of a Cross Section for Determining Sign Support Lengths

Figure SN.23 - Breakaway Wood Support

Figure SN.24 - Non-Breakaway Wood Support

Figure SN. 25 - Non-Breakaway Steel Support

Figure SN. 26 - Breakaway Steel Support

Wood Supports

Supports are sized based on sign area, mounting height, and post length. When using the design tables for wood supports, post length is measured from the ground line to the center of the sign, as shown in Figure SN.27. The designer should ensure that minimum vertical clearances stated in the Book of Standards are met based off of the near edge of pavement not from the ground line. Once the longest post length “L” is known, the tables in the Appendix can be used to determine the required supports. Note, that the actual length of wood support required is the total distance below the ground, from the ground to the bottom of the sign and the sign height.

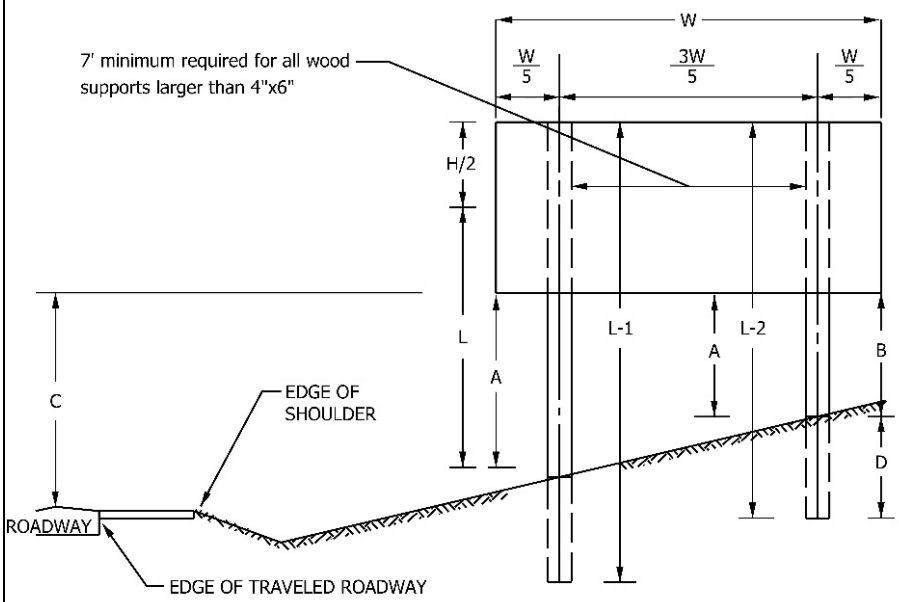
Steel Supports

Larger ground mounted signs require steel supports. This includes signs that are too large and signs that are too narrow to install on 6”x6” or 6”x8” wood posts because of the 7-foot minimum spacing requirement. Steel supports are sized in the same manner as wood supports, with the exception that the post length, which for steel is referred to as LMAX, is measured from the ground line to the bottom of the sign. In addition, steel supports must meet the following guidelines:

- Breakaway steel supports require a minimum ground to breakaway hinge distance of 7’-0” in order for the breakaway to operate properly. (See Figure SN.28) This requires a minimum distance from the ground to the bottom of the sign of 7’-6”.

- The minimum distance from the high point of roadway to the bottom of the sign is 7’-6”. This may force an increase in LMAX.

VERTICAL SIGN CLEARANCE FOR WOOD SUPPORTS



Minimum Vertical Clearance for Wood Supports

A. 7'-0" minimum for non-freeway (5'-0" for rural locations).
B. 2'-0" minimum
C. 7'-0" minimum & preferable. This dimension is to be increased only when required to meet A = 7'-0" B (min) = 2'-0"

Notes:

A. See appendix A-6 for ground mounted wood support tables.
'L' should be used as the design height for wood supports.
B. Secondary signs may be placed 1' less then the specified height above.
C. Both conditions 'A' and 'B' must be met.

Legend

D = 5'-0" for 4"x4" or 4"x6"
6'-0" for 6"x6" or 6" x 8"
H = Height of sign
L = Height from ground to center of sign (for longest support)
L-1 = Length of first support (Identified in the wood support chart on SN-4)
L-2 = Length of second support (Identified in the wood support chart on SN-4)

W = Width of sign

Figure SN.27 - Wood Support Vertical Clearance

- For breakaway sign supports, both the breakaway hinge minimum distance from the ground AND the minimum distance from the high point of the roadway to the ground need to be met.
- There are Type 'A' and Type 'B' breakaway steel couplings. The Type 'A' couplings are designed to work with W6x9 steel supports only and Type 'B' couplings are designed to work with W6x12 or larger steel supports.
- On cut-slopes, the farthest edge of the sign should be a minimum of 2'-0" above the ground line. This may also force an increase in LMAX.
- Where the steel supports are greater than 8 feet apart, additional stiffening angles should be installed in accordance with MSHA Standard No. MD 802.01 from the MSHA *Book of Standards for Highway and Incidental Structures*.
- Generally, avoid installing large signs on a single steel support due to wind twisting affects.

Support Spacing

Sign supports are spaced laterally based on sign width, without regard for material. Standard post clear spacing for two and three post installations are given in **Error! Reference source not found.** and Figure SN.30. It is important to note, however, that post spacing must be adjusted occasionally to maintain federal breakaway requirements. In order to meet breakaway requirements, supports should be designed to meet the following:

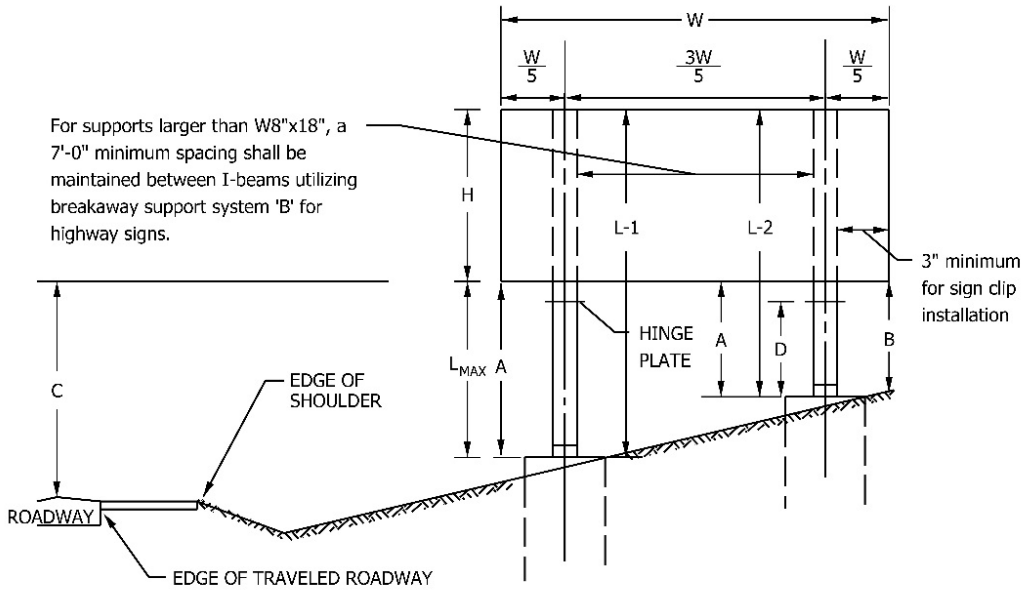
- All wood supports 4"x6" or greater shall be drilled per standards.
- No more than two (2) 4"x4" or two (2) drilled 4"x6" wood posts are permitted within a 7'-0" distance, regardless of the spacing between the supports.
- The minimum clear spacing (inside edge of support to inside edge of support) between all drilled 6"x6" and drilled 6"x8" posts is 7'-0".
- For steel supports, a single post spaced with a clear distance of 7 feet or more from another post, shall have a weight less than 44 pounds per foot. The total weight (for all supports) below the hinges but above the shear plate of the breakaway base, shall be less than 600 pounds (a W6x15 weighs 15 pounds per foot). See Table SN.10 for allowable support lengths.

  Signs on a single steel breakaway support shall be considered as small roadway signs and the max sign area where practical should be limited to 54 S.F. Larger signs induce harmonic resonance resulting in failure of the hinge plates and breakaway coupling. For two steel supports spaded less than 7 feet apart, each post should have a weight of 18 pounds per foot or less.

Table SN.10 - Maximum Steel Support Length Below Hinge

Support Weight (lb/ft)	Max Length (ft) - 1 support	Max Length per Support (ft) - 2 supports	Max length per Support (ft) - 3 supports
9	66.7	33.3	22.2
12	50	25	16.7
15	40	20	13.3
18	33.3	16.7	11.1
21	28.6	14.3	9.5
22	27.3	13.6	9.1
26	23.1	11.5	7.7
30	20	10	-
31	19.4	9.7	-
35	17.2	8.6	-
44	13.6	-	-

VERTICAL SIGN CLEARANCE FOR STEEL SUPPORTS



Minimum Vertical Clearance for Steel Supports

A. 7'-6" minimum for breakaway supports or 7'-0" for non-breakaway supports (5'-0" min in rural locations).
B. 2'-0" minimum
C. 7'-6" minimum & preferable. This dimension is to be increased only when required to meet A = 7'-6" for breakaway or A (min.) = 7'-0" for non-breakaway and B (min) = 2'-0"
D. 7'-0" minimum for breakaway supports

Notes:

A. See 'TRANSPO Industries' software and/or website for breakaway steel support calculations.
B. See Appendix A-6 for non-breakaway steel support tables.
C. Lmax should be used as the design height for steel supports.
D. The total weight below the hinges should be less than 600 pounds.
E. Both conditions 'A' and 'C' must be met.

Legend

H = Height of sign
Lmax = Height from top of foundation to bottom of sign (for longest support)
L-1 = Length of first support (Identified in the steel support chart on SN-4)
L-2 = Length of second support (Identified in the steel support chart on SN-4)
W = Width of sign

Figure SN.28 - Steel Support Vertical Clearance

- Also, for multidirectional breakaway, two I-beams shall not be placed within 7'-0" (measured from inside edge of support to inside edge of support), per manufacturer's requirements. However, two W6x9 supports with type 'A' breakaway couplings can be installed within 7'-0". This is common for Exit Gore signs
- W6x12, W6x15, and W8x18 breakaway supports with Type 'B' systems can be used for intermediate sized signs with no more than two supports spaced within a 7'-0" distance. W6x9 supports shall not be used with breakaway system 'B'; they should use system 'A' instead. For further guidance regarding the size of supports and breakaway system required for a particular sign, refer to TRANSPO software for calculations.
- The hinge plate for breakaway steel supports is located 7'-0" to 7'-2 ¾" above the ground. The bottom of the sign face should be approximately 3.25" to 12" maximum above the hinge plate in order for the breakaway coupling to function properly in the event of being struck, however, 6" above the hinge is the preferred minimum. Supplemental panels must be mounted above the hinge plate, because they will prevent them from operating properly. Where necessary, an aluminum angle can be used to hang a single plate, such as a generic service logo, below the hinge plates.
- NOTE: Standard sign support spacing is based on the distance from center of support to center of support. Therefore, for each steel support size there is a +- minimum sign width to achieve the standard spacing. For example, the minimum sign width for two W6x15 I-beams is 12.5 ft.

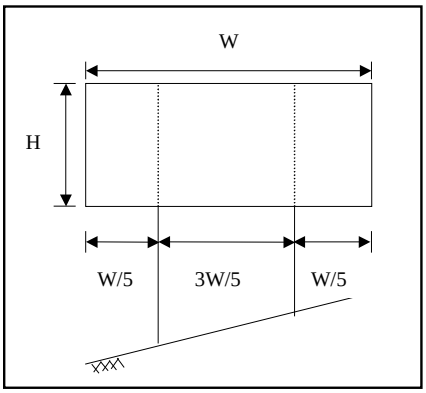


Figure SN. 29 - Standard Sign Support Spacing (Two Supports)

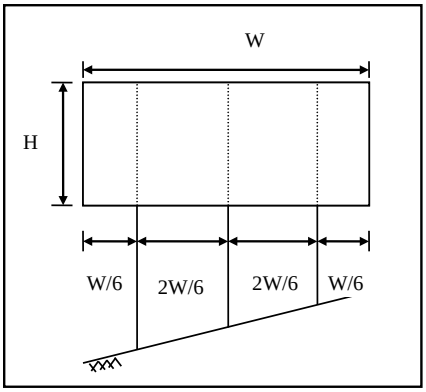


Figure SN.30 - Standard Sign Support Spacing (Three Supports)

Figure SN.31 - Breakaway Steel Support

Figure SN.32 - Breakaway Hinge for Steel Support

Where problems are encountered, designers should consider the following possibilities:

- Increase the sign width to accommodate breakaway spacing.
- Locate traffic barrier nearby and mount on non-breakaway posts.
- Over-design the supports. (i.e. use steel supports instead of wood).
- For additional options see Structural Design Team.

Supports on Steep Slopes

As defined in the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals and the Maryland SHA Standard for Breakaway Poles Adjustment for Ground Slopes, "To avoid undercarriage snagging on convex ground profiles, the top of the footing shall not project more than 4" above any 60" chord aligned perpendicular to the edge of the roadway between a point on the ground surface on one side of the support to a point on the ground surface on the other side of the support." Based on this requirement, a 30" foundation is limited to a 10:1 slope, a 36" foundation is limited to a 12:1 slope, and a 42" foundation is limited to a 13:1 slope. Special considerations have to be made if the slope exceeds these values. The following steps should be taken when this occurs:

1. Determine if there is another suitable location to install the supports where the roadside slope is acceptable and the surrounding terrain is graded, where there is an existing roadside traffic barrier, on an existing structure, or similar non-accessible areas.
2. Determine if grading can be performed to obtain a desirable slope. A 10:1 slope is required in advance of the foundation.
3. Consider the use of a modified foundation:
   a. A Type B sign post foundation can be used if the conditions in the table below are met. When used, a portion of the exposed corner of the footing on the lower side of the slope shall be removed as per MSHA Standard No. MD 801.04-01 from the MSHA *Book of Standards for Highway and Incidental Structures*.

Table SN. 11 - Type B Sign Post Foundation Requirements

Max Slope	Foundation Diameter
7:1	30"
8:1	36"
9:1	42"

   b. A breakaway Type C sign post, or a modified saw tooth foundation, can be used if the conditions in the table below are met. When used, the foundation shall be installed as per MSHA Standard No. MD 801.04-02 from the MSHA *Book of Standards for Highway and Incidental Structures*.

Table SN.12 - Type C Sign Post Foundation Requirements

Max Slope	Foundation Diameter
3:1	30"
4:1	36" and 42"

4. Redesign the sign to be placed on smaller supports.

5. Install traffic barrier and mount sign on non-breakaway posts. Typically, barrier should not be installed for the sole purpose of protecting ground mounted signs. There are few situations that may warrant this as a last resort.

Additional steps should be taken to ensure that a breakaway support would fall in a safe and predictable manner when struck by a vehicle. First, it is important to keep in mind that breakaway supports are designed for impact at a bumper height of 20 inches. To maintain this height, signs should not be located near ditches or on a back slope near the drainage channel where vehicles could be funneled into the sign or become airborne. It is also important to keep sign foundations outside ditch lines so that water is not pushed onto the road surface and the water does not cause excessive wear on the foundation and support. To prevent the chances of an errant vehicle becoming airborne on a fill slope, slopes can be rounded to create a more traversable terrain.

It is also important to determine an appropriate clear zone based on the steep slope. Non-breakaway foundations can be used if they are installed outside of 1.3 times the clear zone or behind traffic barrier.

Figure SN.33 - Improper Supports on Steep Slopes

Foundations for non-breakaway supports, for ground mounted signs or overhead sign structures should be raised 3” minimum above the high elevation of the grade. This will allow rain runoff to flow around the foundation. This eliminates corrosion of the base plate and anchor bolts.

For larger foundations for overhead or cantilever sign structures in fill sections 3:1 or greater, slope stabilization with rip rap should be provided to prevent erosion around the foundations. Small earth retaining walls formed around the foundation can be used to divert run off where the slope in a cut section is 3:1 or greater.

Other Small Sign Supports

Maryland SHA most commonly uses either wood or steel sign supports for the installation of small signs. A variety of other small support types exist which may be more appropriate for certain situations. These include square tube, round tube, and posts made from alternative materials such as fiberglass. These posts are grouped into two categories, yielding and breakaway, depending on how they meet breakaway requirements. Care should be used when using these types of supports to provide a minimum 7’ ground clearance and a minimum 9’ clearance to the top of the sign to avoid impact with the windshield of a car.

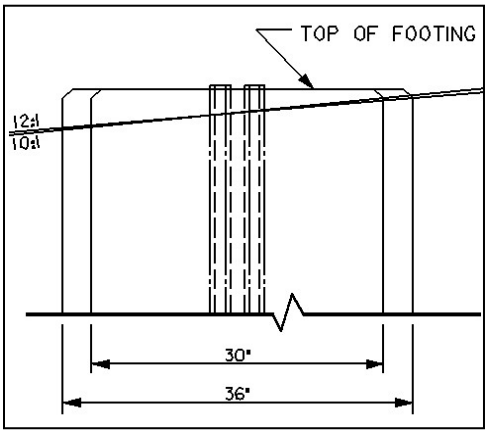


Figure SN.34 - Slope Limits for Foundations

Yielding supports are not currently used in Maryland. They are designed so that the post will bend at the base when struck by a vehicle, causing the sign to hit the ground and pass underneath the impacting vehicle. They are typically smaller metal supports, such as Square Tube or U-Channel, buried directly in the ground without the use of a separate base. These supports have been known to snag on the underside of cars, pulling the post from the ground.

Breakaway supports are designed to break away at the base when struck by a vehicle. They may be weakened to cause fracture or installed with a separate anchor base and post, which are designed to separate under vehicle impact. This allows the sign and support to pass over the vehicle after being struck therefore it is important to maintain proper sign height. This type of support includes some Square Tube installations as well as fiberglass and other post types.

Sign Banding

Sometimes it is more practical to band a sign to an existing light pole or overhead sign support rather than install a brand new sign support. Maryland SHA prefers to use sign banding when applicable because it involves fewer supports which means fewer roadway obstructions and less items to maintain. Table SN.7 specifies the maximum sign sizes and mounting heights for various light pole types.

NOTES:

1. See MSHA Standard No. MD 813.08 **from the MSHA *Book of Standards for Highway and Incidental Structures*** for more information regarding sign banding and installation.
2. 3’ x 3’ or 4’ x 4’ sign panels can be square or diamond shape. Reference the appropriate standard plate for proper attachment devices.
3. All sign panel sizes have been calculated based on the max allowable loading on either poles or breakaway transformer bases.
4. All sign placements shall conform to the MdMUTCD.

Table SN.13 - Allowable Sign Banding Sizes

Pole Type (feet)	Arm Length (feet)	Maximum Allowable Sign Size (Total SF)	Maximum Height to Bottom of Sign (feet)
30	15 or Less	16	7
		9	7-15
	20	9	7
40	15 or Less	16	7
		9	7-15
	20	9	7
	25	16	7
		9	7-15
	30	9	7
	35	16	7
		9	7-15
50	10 or Less	16	7
		6	7-15
Bridge Mount Poles	All Sizes	1.5	7

TRANSPO Design Software

The MSHA standard for the selection of breakaway steel supports is the TRANSPO Industries design program. A screen shot of the input screen can be seen in Figure SN.35. To use the program, the design engineer inputs the sign parameters and the program will automatically select a support size and provide an output. The following should be used for inputs:

1. Wind Speed: A design speed of 100 mph should always be used.
2. Design Life: A design life of 10 years is recommended by AASHTO.

3. Yield Stress: 36,000 psi is to be used.
4. Sign Width: Input the width of the sign under consideration.
5. Sign height: Input the height of the sign under consideration.
6. Maximum Under Sign Clearance: A minimum under clearance of 7'-6" should be used but this input value is based on the maximum under clearance with respect to the roadside slope.
7. Number of Posts: Input the desired number of sign posts here.

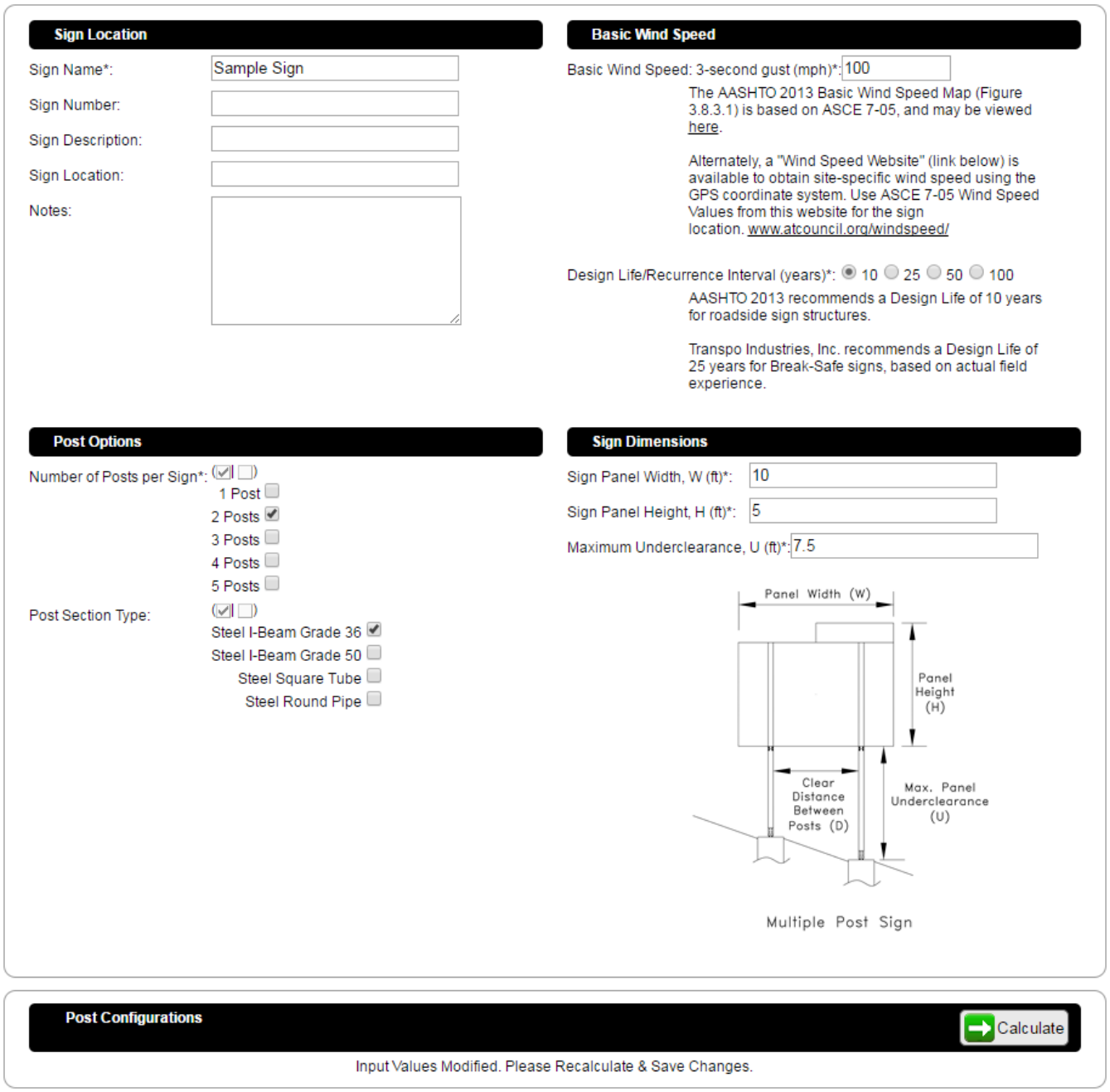


Figure SN.35 - TRANSPO Design Software

Checking the Design

Once the sign and support design is complete and a location has been determined, the following items (that are sometimes overlooked in design) should be reviewed to ensure proper placement:

1. Right of Way
2. Geometrics
3. Landscaping
4. Verify overhead signs do not impede visibility of signals
5. Verify sign structures are not located behind obstructions such as light poles
6. Utilities (overhead and underground)
7. Adjacent Construction Projects

Roadside Hazards

Any objects that are located along the roadside and are not shielded from the driver present a hazard to the motorist. This includes trees, utility poles, sign supports, light supports, and traffic barrier. The AASHTO Roadside Design Guide defines the clear zone concept as an unencumbered roadside recovery area. This distance is typically 30 feet for a freeway, and may vary based on design speed, traffic volumes, and roadway geometry. Clear zone distances can be looked up in the Clear Zone Distances table of the AASHTO Roadside Design Guide and should be used as a guide in determining what objects need to be protected with traffic barrier.

Any sign supports located within the clear zone of a roadway must either meet federal breakaway requirements or be protected by traffic barrier. For ground mounted supports, breakaway modifications are detailed in the MSHA *Book of Standards for Highway and Incidental Structures*. All overhead and cantilever installations within the clear zone must be protected by traffic barrier.

Traffic Barrier Design

The design of traffic barrier is outlined in Chapter 5 of the AASHTO's Roadside Design Guide as well as in the MSHA's Guidelines for Traffic Barrier Placement and End Treatment Design. The process generally involves the following steps:

1. *DETERMINE CLEAR ZONE DISTANCE*. This is selected from Table 3.1 of the AASHTO Roadside Design Guide and/or Table 1 of MSHA's Guidelines for Traffic Barrier Placement and End Treatment Design and is based on design speed, traffic volumes and roadside slope.

2. *DETERMINE IF BARRIER IS WARRANTED*. If the support is within the clear zone and is not breakaway, traffic barrier is required. For ground mounted sign supports, breakaway modifications can be added per the MSHA *Book of Standards for Highway and Incidental Structures* because traffic barrier should not be installed for the sole purpose of protecting a new ground mounted sign.

3. *CHECK IF EXISTING TRAFFIC BARRIER CAN BE EXTENDED TO PROTECT THE SUPPORT.*

4. *DETERMINE LATERAL OFFSET OF TRAFFIC BARRIER*.

Traffic barrier is typically installed 2 feet from the edge of paved shoulder. When practical, traffic barrier should be installed beyond 12 feet on fill slopes (6:1 or steeper) and as far out as possible on cut slopes. The offset from face of traffic barrier to face of sign support or foundation, typically 8 feet for single post installations, is determined by the dynamic deflection distance of the traffic barrier.

Where adequate deflection distance cannot be provided between the back of the traffic barrier and the face of the obstacle, stiffening systems can be used. These include reducing the post spacing (i.e. double posting or quarter posting), and nesting of traffic

barrier. Where stiffening systems are used, they must be installed for an appropriate length upstream and downstream of the roadside hazard. All stiffening systems should be designed in accordance with MSHA's "Guidelines for Traffic Barrier Placement and End Treatment Design".

5. *CALCULATE LENGTH OF NEED*. This is done using the formulas given in the AASHTO Roadside Design Guide and MSHA's Guidelines for Traffic Barrier Placement and End Treatment Design.

6. *SELECT AN APPROPRIATE END TREATMENT*.

When designing traffic barrier, it is important to consider the following:

- It is important to check fixed objects for hazard potential to vehicles traveling in BOTH directions. This is especially true for two lane highways and divided highway medians. This will influence the choice of end treatment and single versus double face traffic barrier.
- Where traffic in the reverse direction is not a concern, the departure section of traffic barrier typically extends 25 Feet past the sign support and terminates with a Trail End Anchorage (sometimes called a Boxing Glove).

End Treatments

The selection of an appropriate end treatment is a critical component of traffic barrier design. A full list of types of end treatments and descriptions can be found in the MSHA *Guidelines for Traffic Barrier Placement and End Treatment Design.* The end treatment is designed to prevent vehicles from spearing, riding on top of the traffic barrier, and rolling over. When selecting an end treatment, the following items should be considered:

- Wherever possible, traffic barrier should be extended and the end buried in the back slope of cut sections, as detailed in MSHA's *Book of Standards for Highway and Incidental Structures*. This is economical and safe and should be considered as a first option for all installations. Typically, an extension of 200 to 300 additional feet is justifiable.
- Many end treatments require roadside grading of 10:1 or flatter. Be sure to check slopes and make the appropriate adjustments.
- It is important to use the correct end treatment for a given situation. Roadside end treatments are not intended to be struck from both front and back, and should not be used in medians where they may be struck from behind by opposing vehicles.
- Enclosed and enveloped treatments are acceptable for median applications.

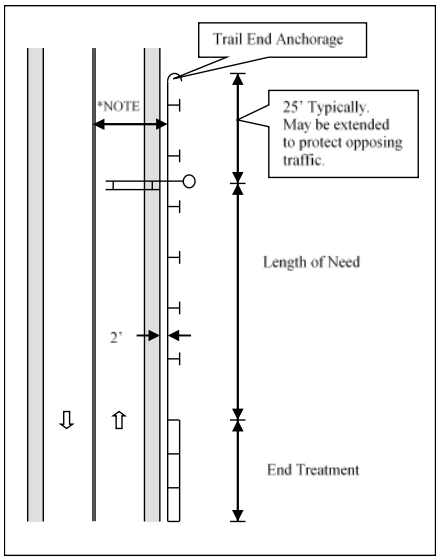


Figure SN.36 - Typical Traffic Barrier Installation

*NOTE: Check the clear zone distance from opposing direction of travel for undivided highways. Extend barrier and install crash worthy end treatment in place of the trail end anchorage if required.

Delineation Design

Delineation devices are effective aids for night driving and are to be considered as guidance rather than warning devices. Delineation devices are used along continuous sections of highway, through locations where there are changes in horizontal alignment, and at other potentially hazardous locations. Refer to the MSHA Roadway Delineation Policy and *Book of Standards for Highway and Incidental Structures* for more guidance. Check with individual districts for additional information since some districts use alternative treatments.

The most common types of roadway delineation devices are: pavement markings, snowplowable raised pavement markers (SRPMs), typical traffic barrier installations, post mounted delineators, w-beam barrier mounted "rail riders" and barrier wall mounted delineators, chevron alignment signs, and object (hazard) markers. Delineators shall be yellow in color when placed on the left, median-side of the road, and white when placed on the right shoulder-side of the road.

DO NOT FORGET TO ADD DELINEATORS TO A PROJECT. Delineators are paid for per each and are not incidental to the price of the traffic barrier of which they are to be mounted. Therefore, delineators must be included on the plans and as a separate pay item in the estimate.

Pavement Markings, Raised Pavement Markers (RPM's)

See the Materials section of this manual for more information regarding RPM materials.

Post Mounted Delineators

These delineators consist of flexible posts with reflective sheeting, as well as wood snow stakes. Placement of delineation is based upon roadway classification, need, and at locations such as intersections, channelizing islands, spot hazards, horizontal curvature, crossovers, auxiliary and turn lanes, lane drops/merges, narrow bridges, narrowed roadway sections, etc.

Single yellow delineators (or snow stakes) should be provided along the left side of expressway and freeway roadways during winter months. Single white delineators shall be provided along the right side of expressway and freeway roadways if RPMs and/or roadway lighting is not present. If RPMs are continuously placed on lane lines and/or roadway lighting is present, right side delineators are optional and left side delineators can be removed during non-winter months.

For non-expressway and non-freeway type divided highways, left and right side delineators are optional if RPMs and/or roadway lighting are present. In the absence of RPMs and/or roadway lighting on these roadways, right side delineation should be placed in rural areas if speeds are 50 mph or greater; left side delineation is optional.

The spacing of delineators along expressway and freeway roadways, when used, shall be 264 feet, except that snow stakes may be spaced at 528 feet. On accel/decel and C/D roads, double delineators shall be used with spacing of 100 feet.

Utility Identification Markers are delineators which are used to mark the location of drainage features and water sources. These should be blue to mark the location of water sources (fire hydrants, streams, ponds, etc.) and green to mark the location of drainage inlets.

Figure SN.37 - Single Yellow Delineator

Figure SN.38 - Single White Delineator

Figure SN.39 - Single White Delineator

W-Beam Traffic Barrier Delineators

W-beam traffic barriers within 6 feet of the shoulder (or road edge if no shoulder is present) along either side of one-way roadways or on the right hand side of two-way roadways shall be provided with barrier mounted delineators, or “rail riders.” Along tangent sections in excess of 500 feet in length, the spacing of delineators shall be 100 feet. For tangent sections less than 500 feet in length and curves of less than 1,000-foot radius, the spacing of delineators shall be 50 feet.

Figure SN.40 - Top Mounted Yellow W-Beam Marker

Barrier Wall Delineation (Barrier Markers)

Barrier walls within 15 feet of the travel lane along either side of one way roadways shall be provided with barrier markers. The spacing of barrier markers shall be 100 feet along tangent sections of roadway and 75 or 50 feet along curves having a radius of less than 1000 feet and less than 300 feet, respectively. Double delineators should be used for accel/decel and C/D roads as shown in Figure SN.41, otherwise a single delineator should be used on the side only for single face barrier.

Figure SN.41 - Top and Side Mounted White Barrier Wall Markers

Lateral Clearance of Signs

- The lateral clearance from edge of roadway to near edge of sign should be consistent with the roadway type and use.
- **The preferred sign location is outside of the clear zone.** If this condition cannot be met, the sign should be placed as far from the roadway as possible.
- The edge of sign should be a MINIMUM of 6 feet behind the face of traffic barrier. Note that this exceeds the offset requirements identified in the latest MSHA *Guidelines for Traffic Barrier Placement and End Treatment Design*.
- The edge of sign should be a MINIMUM of 6 feet beyond the edge of shoulder.
- In urban areas, the edge of sign should be 6 feet preferred minimum and 2 feet absolute minimum behind the face of curb.

MATERIALS

Reflective Sheeting

The use of reflective sheeting on highway signs improves nighttime visibility and gives drivers more time to read, comprehend and react to roadway information. The actual performance of a given sheeting is a function of sheeting type and sheeting manufacturer.

There are eleven (11) types of sheeting used for traffic control. The Standard Sign Book gives sheeting types for all standard signs. Sheeting types are defined by ASTM D-4956 and are given the designations Type I through Type XI. A summary of these types along with descriptions and typical applications is as follows:

Type I: This is an enclosed lens glass-bead sheeting that is commonly referred to as “Engineering Grade”. This type of sheeting has the lowest reflective properties of all categories.

Type II: This is another type of enclosed lens glass-bead sheeting commonly referred to as “Super Engineering Grade”. Typical applications would be for highway signs, delineators, and Work Zone Traffic Control. This type of sheeting is used on No Parking, No Stopping, No Standing, and Hiker-Biker signs.

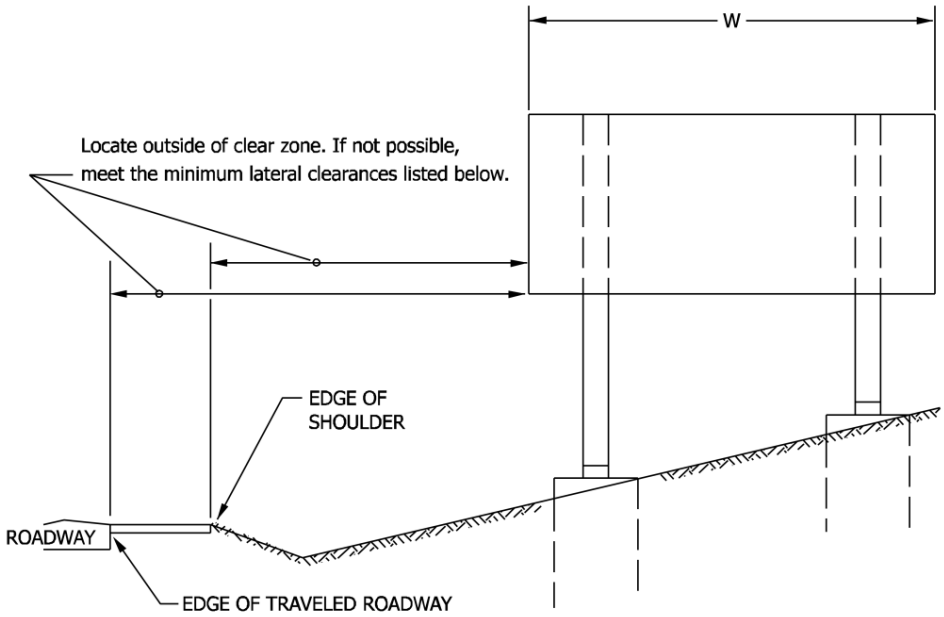
Type III: This is an encapsulated glass-bead sheeting commonly referred to as “High Intensity”. Typical applications are for highway signs, delineators, and Work Zone Traffic Control.

Type IV: This is a non-metallic microprismatic sheeting also referred to as “High Intensity”. Typical applications would be for highway signs, delineators, and work zone traffic control.

Type V: This is a metallic microprismatic sheeting, also referred to as “Super-High Intensity”. This material is typically used on delineators.

Type VI: This is a vinyl microprismatic sheeting typically used for roll-up signs and on traffic cones.

LATERAL SIGN CLEARANCE



Minimum Lateral Clearances (See MD-802.01 and MD-813.02)

A. Preferred location is outside of the clear zone. if this condition cannot be met, the sign should be placed as far from the roadway as possible.
B. Edge of sign 6' from face of w-beam traffic barrier
C. Edge of sign 6' preferable min. (2' absolute min.) from face of curb
D. Edge of sign 6' from edge of shoulder
E. Edge of sign 6' preferable min. (2' absolute min.) from each edge of shoulder in median
F. Edge of sign 6' from each side of shoulder centered in gore area

NOTE:
1. Lateral offsets should be identified on the SN-4 with appropriate object codes.

Figure SN.42 - Lateral Sign Clearance

Type VII: This material designation has been discontinued and has been reclassified as Type VIII.

Type VIII: This non-metallic microprismatic retroreflective element material is commonly referred to as "Super High Intensity". It is a retroreflective sheeting which has the highest retroreflective characteristics at long and medium road distances. Applications for this material are permanent highway signing, construction zone devices, and delineators. This type of sheeting is the minimum acceptable type for rigid temporary traffic signs.

Type IX: This non-metallic microprismatic retroreflective element material is commonly referred to as "Very High Intensity". It is a retroreflective sheeting which has the highest retroreflective characteristics at short road distances. This type of sheeting is used for Stop, Yield, Chevrons, Turn Warning, Do Not Enter, Wrong Way, and Guide signs.

Type XI: This is a high performance sheeting offering excellent visibility at wide viewing angles that is utilized in Type IV thru Type IX sheeting. Trade names for this type of sheeting include Diamond Grade, Long Distance Performance (LDP), which is used for Work Zone signs, overhead guide signs, and Visual Impact Performance (VIP), which is used for Turn Warning, Do Not Enter, and Wrong Way signs. The removal of sign lighting can be considered when Type XI sheeting is used on signs.

The following guidelines should be used when selecting sheeting to be used for standard signs.

- Guide, Exit Gore, and General Information, Warning, and School signs shall meet or exceed the requirements of Type IX sheeting.
- Regulatory Signs fall into three categories:
    - Red Regulatory Signs shall meet or exceed the requirements of Type IX sheeting.
    - R7 and R8 series parking related signs and supplemental panels to R7 and R8 series signs, No Trespassing signs, and signs directed at pedestrian and bicycle traffic shall meet or exceed Type I sheeting.
    - All other regulatory signs shall meet or exceed Type IV sheeting.
- Route markers shall meet the requirements of guide signs if they are used on a guide sign. Route Markers for independent use and their auxiliary panels shall meet or exceed Type IV sheeting.
- Logos and/or graphics shall follow the guidelines for the respective sign classification unless otherwise specified in contract documents or directed by the project engineer.
- Civil Defense signs and other signs not in the categories above shall follow the guidelines for the sign classification that most closely matches the color(s) of the proposed sign.

Color

Sign color is dictated by the guidelines specified in the MdMUTCD for all signs including but not limited to regulatory, warning, guide, services, recreational, and emergency. State standards require the use of fluorescent yellow for all warning messages not used in a temporary traffic control zone, fluorescent orange for all warning messages in temporary traffic control zones, and fluorescent yellow green for all school signs, "school" portions of speed limit signs, and supplemental plaques in school zones.

Night Driving

The mechanics of nighttime visibility differ somewhat from daytime conditions in that the available light levels are a function of vehicle headlights, roadway lighting, sign lighting, ambient lighting from surrounding land uses, and sign sheeting material. The interaction of light between vehicle headlight, sign (or sign sheeting) and driver is referred to as retroreflection. In American Society for Testing and Materials (ASTM) standard E-808, retroreflection is defined as "reflection in which reflected rays are preferentially returned in directions close to the opposite of the direction of the incident rays". In other words, light from vehicular headlights is intentionally directed back at the approaching vehicle. Two of the primary measures of light and sheeting performance, called Observation Angle and Entrance Angle, are depicted in Figure SN.43 and Figure SN. 44.

Both Observation Angle and Entrance Angle are used to determine the performance criteria for sign sheeting. Each point along the roadway, for example 250 feet in advance of a warning sign, corresponds to an Entrance and Observation Angle Pair. The performance of sign sheeting is measured by taking luminance measurements at standard angles (typically Observation Angles of 0.2° or 0.5° and Entrance Angles of –4° and 30°). When these criteria are exceeded under driving conditions, the sign may appear either "dull" or completely black depending on the sheeting type (Type I through XI), manufacturer, and condition. Some situations where this is of concern include Keep Right (R4-7) signs, which are commonly placed at a 15° angle and Added Lane (W4-3), or Merge (W4-1) signs at the end of a loop ramp. In both of these situations, the angle of approaching vehicles may reduce nighttime visibility of these signs for some approaches.

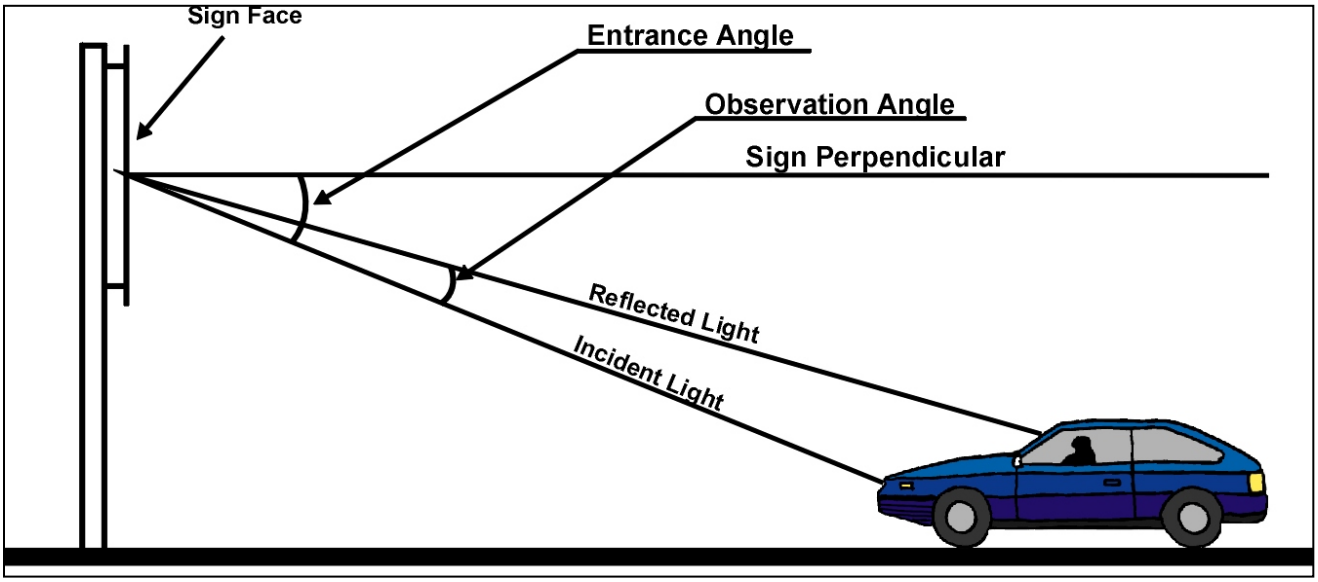


Figure SN.43 - Observation and Entrance Angle (Elevation View)

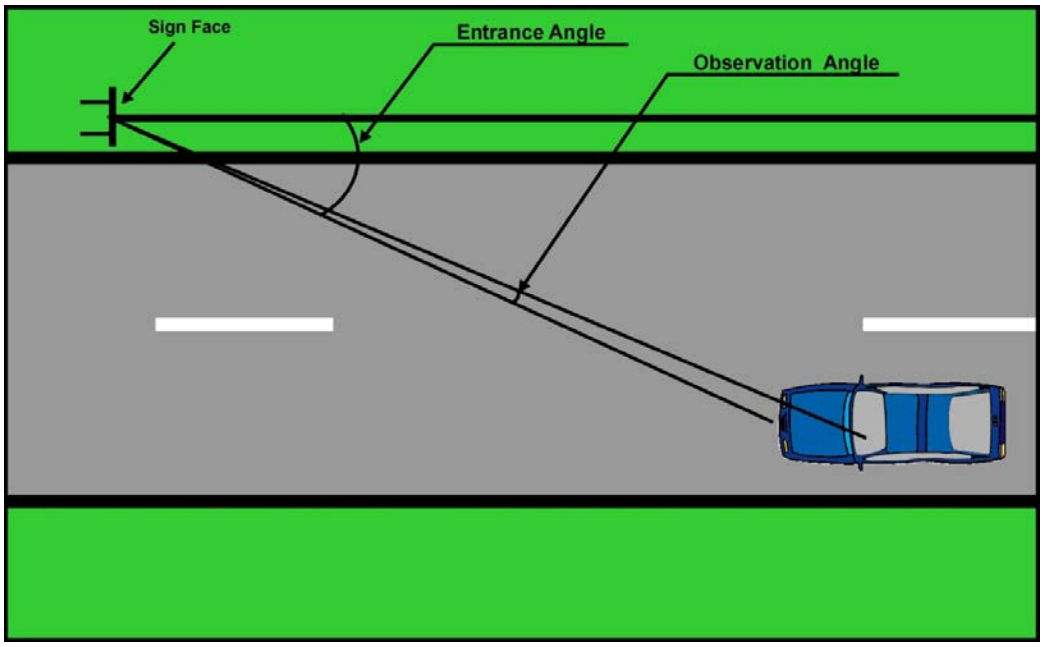


Figure SN. 44 - Observation and Entrance Angle (Plan View)

Aluminum Backing

Signs are constructed as reflective sheeting on an aluminum backing material. In the case of standard warning and regulatory signs, the legend is typically silk screened or "inked" onto a background consisting of reflective sheeting mounted on sheet aluminum. Maryland uses two types of aluminum backing material for sign construction, depending on the purpose:

Sheet Aluminum

Sheet aluminum is used for standard warning and regulatory signs, and for most guide signs with a surface area less than 40 square feet. It is also used for temporary signs that are mounted on skids or wood posts and for overlaying existing signs. The 40 square foot criteria is a rule of thumb based on support type and manufacturing considerations. **The primary consideration is that sheet aluminum cannot be mounted on steel supports using Maryland Standards;** therefore, any sign requiring steel supports must be made from extruded aluminum.

Extruded Aluminum

Extruded aluminum is used for all large guide signs and non-standard warning and regulatory signs over 40 square feet. Extruded panels are available in 6" and 12" heights that are cut to width and bolted together to build the correct sign height. **For signs constructed by the MSHA Sign Shop, heights should be designed to even multiples of 12" as 6" panels are not kept in stock.** Details regarding the construction and dimensions of extruded panels are given in the MSHA *Book of Standards for Highway and Incidental Structures*.

Pavement Markings

Pavement markings covered in this chapter include lines and markings applied to the pavement, raised pavement markers and special pavement treatments such as: rumble strips, tubular markers, contrast markings, and colored raised pavement markers. The design criteria and standardization of application are covered in the MdMUTCD. Pavement marking material selection is specified in the most recent edition of the

MSHA Pavement Marking Material Selection Policy and Guidelines.

The traveled portions of a highway are defined by pavement markings such as centerlines, lane lines, edge lines, channelizing lines, etc. Typical application details are included in the MdMUTCD. On state highways, the approval of the Asst District Engineer-Traffic or the Director of Office of Traffic & Safety is required to make any modifications to pavement markings that would change the functional operation of the roadway.

Materials

Material selection may vary by jurisdiction. For example, District 6 uses paint for most applications and the pavement markings are typically installed by maintenance rather than the contractor. As a result, if there is any uncertainty, material selection should be confirmed with the TEDD Project Manager at an early stage of the project. Additionally, the latest MSHA Pavement Marking Selection Policy should be used in the selection of pavement marking materials as there are always new materials being tested and reviewed. Generally, all markings applied on state highways are reflectorized. The black markings typically used for covering existing markings and as contrast markings are non-reflectorized. The MdMUTCD and the MSHA Pavement Marking Selection Policy dictate the widths and patterns of pavement markings. Pavement markings come in various compositions and each have different characteristics, costs, application methods, durability, and maintenance. Following is an outline describing the different typical permanent pavement marking material:

Waterborne Paint: Waterborne paints are used as permanent markings for rural and urban minor arterial, rural major collector, rural minor collector and rural and urban local roadways. They should not be used as permanent markings on new roadway pavement surfaces but can be used for re-striping over existing longitudinal pavement marking materials on both Portland Cement Concrete (PCC) Pavements and Hot Mix Asphalt (HMA) Pavements. Additionally, waterborne paints may be used in parking lots or for temporary pavement markings. The service life of waterborne paints is 6 months to 1 year, however longer service lives have been experienced in some areas. For application on new HMA surfaces (such as parking lots), two coats of paint may be needed as the paint tends to soak into the surface.

Thermoplastic: Thermoplastic pavement markings are durable markings applied on new asphalt surfaces and for re-stripping existing asphalt surfaces. MSHA uses thermoplastic markings for all longitudinal lines along multi-lane or divided highways other than Interstates/Freeways and any roadway with a lower classification including arterials, collectors and minor local roads. The service life of thermoplastic markings is 1.5 to 3 years. Specially formulated thermo may be applied as a thin retrace over existing pavement markings. The service life of the retrace is 1.5 to 2 years with the typical cost reduced. Thermoplastic is not typically used on PCC Pavements.

Epoxy: Epoxy pavement markings are durable markings applied on new asphalt. MSHA uses epoxy markings for all longitudinal lines along multi-lane or divided highways other than Interstates/Freeways and any roadway with a lower classification including arterials, collectors and minor local roads. Epoxy may be used for restriping if existing markings are 80% removed before the restriping occurs. The service life of epoxy markings is 1 to 3 years. This may be the material of choice where sections of the roadway have both concrete and asphalt pavements.

Pavement Marking Tape: Preformed tape markings are durable markings that can either be inlaid in new asphalt surfaces, applied with a primer on existing asphalt and applied with a primer on PCC surfaces. They are applied for all longitudinal lines on the following types of facilities:

- Bridge decks
- Interstate highway/freeways
- Multi-lane or Divided Highway (Not interstate)
- Single Lane NHS roadway
- Multi-lane or divided NHS roadway

When used on PCC, contrast tape is applied for lane lines for increased visibility. The service life of tapes is 4 to 6 years. These markings typically have a high initial cost. However, their greater durability and visibility compared to other durable markings make them desirable for high volume freeway applications where retracing is expensive and is very disruptive to traffic flow.

Preformed Thermoplastic Pavement Marking Lines: Preformed thermoplastic markings are heat applied using a propane torch for asphalt surfaces and applied with a primer on PCC surfaces. They are used for transverse markings, raised rumble strips, and for arrows, letters, numbers and symbols. These markings can be applied on pavement surfaces above freezing temperature. The material can be fused onto itself with a propane torch for routine maintenance. This material provides very good durability where cross shear resistance is required for stop line and crosswalk applications.

Snowplowable Raised Pavement Markers (SRPMs): Snowplowable markers supplement lane lines and channelizing lines approaching gore areas. They delineate the lanes during inclement weather and under low ambient light conditions. Snowplowable markers typically used along state highways are the raised type on a steel holder. Plastic holders can also be used as per the standard specifications and qualified products list. An epoxy adhesive (rapid setting, low viscosity, water resistant type) should be used to hold the housing and reflector unit in place in a grooved pavement slot to provide resistance to being removed by snow plowing.

Figure SN.45 – Snowplowable Raised Pavement Marker

Snowplowable markers can also be installed recessed or below the pavement surface. Recessed pavement markers (RPMs) are typically installed in but not limited to the heavily plowed western area of the state (Districts 6 and 7). The installation consists of grooving the pavement surface longitudinally and directly installing a reflector unit (lens) within the groove.

Figure SN.46 - Recessed Pavement Marker (RPM)

Special Pavement Treatments:

Rumble Strips: Rumble strips are bands of raised material or indentations formed or grooved in the traveled way, centerline or shoulders of roadways. Rumble strips call the motorist's attention to standard warning or regulatory devices or otherwise alert drivers by transmitting sound and vibration through the vehicle. Locations where rumble strips have been used include shoulders along freeways, ends of freeways, roadway centerlines, approaches to roundabouts, and in advance of sharp curves where other devices have not provided a significant reduction in off the road accidents.

Traveled way rumble strips are ¾ inch or less in height if raised or 1 inch or less in depth if indented and generally extend across the travel lanes. There are significant disadvantages to the use of rumble strips across travel lanes. These include:

- An abrupt rise or depression in the roadway can present problems to bicyclists and motorcyclists. Provisions should be made for cyclists to traverse through or around rumble strips.
- Nearby residents may be subjected to continuous noise and vibration in the residential areas prompting citizen's complaints.
- All motorists are subjected to the noise and vibration where only a few are in need of the affect to be alerted.
- Motorists may make unusual maneuvers to avoid rumble strips.
- Frequent maintenance may be required.

Shoulder rumble strips are usually 1 inch or less in depth and less than 3 feet wide indented along the roadway shoulder. They can be grooves rolled into the hot mix as part of a resurfacing project. The use of shoulder rumble strips may reduce drift-off-road accidents along freeways. They are not suitable as a riding surface for bicycles. Where bicycles are permitted adequate (4'-5') of clear shoulder width should be provided between the rumble strips and the outer edge of the shoulder. For further guidance regarding bike lanes and bike boxes, refer to the latest approved version of the Maryland SHA "Bicycle Policy & Design Guidelines."

Contrast Treatment: Contrast treatment of the pavement surface is used to provide lane guidance information to motorists. Typically for concrete pavements, the shoulders are built with a darker color than the travel lanes. Similarly, black non-reflective stripes can supplement lane lines to enhance visibility of the markings. These contrast treatments are typically used for lightly textured pavement surfaces and relieve the washout effect of the markings during dusk, dawn and under direct sunlight. Contrasting black markings should be the same width and placed longitudinally preceding the lane markings. For information regarding the materials used for contrast treatments, see the most recent version of the Maryland SHA Pavement Marking Material Selection Policy.

Colored Pavements: Colored pavements may be used as a traffic control device or for purely aesthetic purposes. Non-retroreflective colored pavement is used for aesthetics and could consist of brick patterns and other patterned surfaces which may be used in crosswalk designs. For more information and guidelines, see the “Colored Pavements” Section of the latest approved version of the MdMUTCD.

SIGNAL DESIGN

SIGNAL DESIGN

DATA COLLECTION

Data collection is the first step in designing a signal. Collecting data, base mapping (obtaining or developing a base plan), and field review apply to both individual intersection design and signal systems. There are three main steps to obtain the pertinent information to design a signal: Office Data Collection, Field PI meeting and subsequent Field Data Collection. Through these steps, this is the time when the designer gathers information, collects existing data from internal and external sources, visits the project site and looks at potential design options.

Office Data Collection

Before preparing a design, the Designer should collect preliminary data and research existing records to obtain or develop the base plan. After the base plan is developed, the designer can subsequently proceed with field data collection and design.

Examples of data to be collected include, but are not limited to:

- Latest signal plan files / as-builts
- Highway Design plans
- Right-of-way plats
- Utility plans (if available)
- Existing plans from the District

Although not all of the as-built information may be available or completely accurate, the Designer shall do this research to gain information on the history of the location.

Design Request

For all projects, the District office initiates, or reviews the Design Request (DR) for a traffic signal design project, and thus may have some background information on the project, including a traffic study, traffic counts or recommendations on the proposed operation of the signal. For Shop Forces projects, the DR may be prepared by TEDD or by the signal shop. For Developer, Design Build (DB), and Local Municipality projects, the DR is usually initiated by the Developer, DB Team or Local Municipality and submitted to the District. The designer should have a clear understanding of the project and contact the preparer of the DR for further information.

In studying the DR, the designer should identify any other active or dormant projects going on at the location or in the vicinity. If the project is an insert job to a highway or district project, then the proposed geometrics and area improvements should be obtained. This may be acquired through the MSHA lead division or perhaps a local authority. It is important to confirm the scope of the entire project. This information is essential to ensure a constructible design.

If changes are needed to the DR due to issues identified in the field or if changes are made by the Traffic Development and Support Division (TDSD) during the DR approval process, a DR revision should be done to document the change. The Director's approval is required for all DR revisions that involve a functional change, such as for the conversion of Exclusive/ Permissive heads to Exclusive or for the addition of a pedestrian phase.

Base Plan

The base plan is a key to the field work and design of a traffic signal. It must be accurate and able to be used as a base for construction. In order to properly design a signal, the designer needs a base plan showing existing topography, roadway geometrics, pavement markings, utilities, etc. The base plan should be in electronic format.

The best place to start is with the TEDD Signal Archives or the TIMS folder internal to TEDD or Signal Plan Locator on the MSHA website.

For recently modified or constructed signals, there may be an existing electronic file with this information that can then be field verified. The consultant who did the latest plans may also have the electronic file and can be contacted if necessary. The designer should verify within TEDD that the obtained plan is the latest version. For an insert job the electronic base plan may be obtained from the lead division, usually Highway Design Division or Engineering Systems Team.

For older traffic signals, only scanned plans may be available, and survey data may not be available for new signal locations. Survey information is typically available for Insert projects. If survey data is not available, a professional survey or extensive field work to obtain all of the mapping information may be necessary.

Right-of-Way

The location of right-of-way and property lines shall be identified and shown on all signal plans because they may limit the placement of signal equipment and supports. Right-of-way information should be obtained at the earliest phase of a project to identify potential conflicts. Right-of-way information may be obtained from previous plans, however this may not offer the accuracy needed if the existing right-of-way shown is limited and potential conflicts are expected. Further, in many cases ROW information may not be available on the existing plan. In such cases, resources such as “www.plats.net” may be used to search for relevant information or right-of-way plats may be obtained through OHD Plats and Surveys, Plats Section. The Office of Real Estate (ORE) Records and Research Section should be contacted for Right-of-Way information requests. If Right-of-Way cannot be obtained, a metes and bounds survey is performed to determine Right-of-Way boundaries.

When it is determined at the conceptual plan stage that the signal equipment, ramps, etc. need to be installed outside of MSHA/public Right-of-Way, the designer should contact the District Right-of-Way Chief immediately. If it is determined that no other design alternative is possible and ROW needs to be acquired, there are two main types of acquisitions that can be pursued by the District: fee simple and perpetual easements.

Fee Simple means that MSHA will purchase the needed property from a private owner at a price that is agreed upon by both parties. This process can take from 6 months to two (2) years due to all the different steps involved especially when home owner associations are involved. Fee simple acquisitions are required for Federal funded projects; therefore it is essential that the necessary coordination with the District begins when the issue is identified so that the project schedule is not impacted. Fee simple is typically the preferred method of acquisition for financial reasons, however if there are any structures within the property that are damaged or could be a liability, the state may not wish to purchase the property.

The other type of acquisition is a perpetual easement or right of entry. In this case, MSHA does not actually purchase the property that holds the signal equipment. Instead, an agreement is reached between MSHA and the property owner such that MSHA is allowed to access to the private property to maintain the signal equipment and make improvements in the future. This type of acquisition calls for the same process as the one outlined in the previous paragraph for Fee Simple. Perpetual easements may be necessary for local, county, school, or federal owned properties, as they are not always willing to sell the land.

Utilities

Location of underground and overhead utilities should be determined by reviewing utility company or local municipality drawings (if available) or as-built signal plans (where appropriate) and shown on all signal plans. Contact MISS UTILITY for utility designations (http://www.missutility.net/maryland/ or 1-800-

257-7777) for all projects a minimum of 15 days prior to a field PI meeting. When performing the field inventory of marked utilities, do not assume that all utilities have been identified. Stormwater and sewer are not typically marked, so the designer should check with the county for more information, and additional field survey is required.

Field PI

A field preliminary investigation (PI) meeting is required for State originated projects such as Areawide and Insert projects. It is also suggested that a field PI meeting be conducted for Developer and Design Build projects. This is to confirm the DR, identify issues in the field which may increase costs and cause delay to the project and to minimize revisions at the PS&E stage.

The PI meeting should be set up by the MSHA TEDD Project Manager and should involve at a minimum the Project Manager, the Team Leader if the Project Manager is a consultant, the Construction Inspector, the designer, and the DR preparer. The Office of Highway Development ADA representative should also be invited to the meeting if any ADA upgrades are proposed, such as for APS/CPS projects and ADA upgrade projects.

Participating parties should:

- Discuss conceptual locations for the proposed signal equipment and potential design options.
- Review sidewalk and sidewalk ramp concepts.
- Identify which quadrants may or may not suit the cabinet or signal structures and determine what types of equipment are appropriate for the location.
- Discuss existing and proposed features which may present design challenges.
- Locate potential power feeds and areas with strong cellular service.
- Identify if there are any constraints for laying conduit and placing handholes.
- Identify if this location meets criteria for uninterruptible power supply (UPS).

By selecting pole locations in the field, you can avoid conflicting physical features that may not show up on as-built plans or utility drawings. By spotting the location of signal heads, you can ensure that they are not in conflict with other signals or overhead signs (where modifications to an existing signalized intersection are planned), that adequate visibility is available, and can determine whether optically programmed heads are necessary to shield the indications from conflicting traffic. After the field meeting, the designer should prepare PI meeting minutes and can now prepare a Conceptual Design Plan/Layout.

Field Data Collection

Data collected in the office should always be field reviewed and verified and new information (or information that could not be found) should be obtained by field data collection.

Field Survey

The limits of the site review on each approach are usually determined by the location of advance signing, placement of advance detectors, length of turn bays, limits of existing base plans, and signal system limits, whichever is greater.

Survey Methods

There are two main survey methods to collect existing survey/base plan information. The method used will vary depending on the information required for a specific project.

- Professional Survey – A professional survey involves the hiring of an outside company or MSHA survey forces to collect the field information and mapping. A professional topographically survey may be needed on a case-by-case basis. This is the most accurate, all-encompassing

method to collect field data, but is typically the most expensive and time consuming.

When right-of-way data collected during office data collection is not adequate, a metes and bounds survey may be requested through OHD Plats & Surveys, Survey Section. A topographic survey should be simultaneously requested in order to get all pertinent data.

- Tape and Wheel – The designer or designated person does a tape and wheel survey. This is the simple method of visiting the project site and using tape measures, wheels and/or other measuring devices to collect critical information. Using this method information may be collected on lane widths, lane lengths, pole size, locations and sizes of structures, sign sizes, etc. The data collected shall be documented.

Initial Site Visit

Most of the necessary information should be obtained during the initial site visit. The existing base plan should be verified and additional information should be collected to prepare for the proposed signal design.

Existing information to be collected should include at a minimum:

- Existing signal equipment
- Pavement markings
- Signing
- Other traffic control devices and ITS equipment
- Road alignment and geometrics
- Sidewalks, handicap ramps, and ADA compliance
- Utilities (overhead and underground)
- Drainage elements (ditches, pipes, and structures)
- Driveway entrances / exits
- Buildings and setback
- Fences and walls
- Traffic barriers
- Trees and vegetation

Existing Signal Equipment

If there is an existing signal, then collect information on the signal pole structures and configurations, type of cabinet and controller, detection system and signal heads. Determine what equipment may be reused and what needs to be replaced.

Type and number of detection equipment in the cabinet should be determined (rack / shelf mounted detector amplifiers or video detector interface). Wiring sizes and number of conductors should be verified. Information on interconnect and wireless communication should also be collected as well as the location of electrical service feed. Associated utility poles and/or transformers should be identified on the plan with owner's name and pole/transformer identification number.

Check handholes for concrete collars and proper grounding of the frame and cover. Open handholes and check conduit if new wiring will be necessary to verify if existing conduits can be used. Verify if additional knock-outs are present for the installation of new conduit. Check for ground rods in handholes closest to the signal structure. If the existing handhole does not have the items listed, they should be incorporated into the design. Make note of location and fill of handholes and of existing wire in conduits so the conduit fill capacity is not exceeded with new wire. The designer is responsible for checking that the cable is loose and that space is available within the conduit. In locations where new ADA ramps or sidewalk are being installed or existing ramps are being redone, consideration should be given to how the handholes can be lowered. If the handholes are brick, they can be lowered by removing rows of brick. If the handholes are

concrete, they can be lowered to the precast concrete base. However, if the lid and cover are already resting directly on the precast concrete base, adjusting the handhole to grade may be more challenging during construction. If handholes are filled with water, they may still be reusable. However, if the handhole is filled with water above the conduits, it is not recommended to reuse.

Road Alignment and Geometrics

Road alignment (vertical/horizontal) should be noted, along with intersection skew and channelization islands if any. Collect information on lane configuration/use (left/thru /right turn lanes) and widths and turn bay lengths. Note locations of open/closed section as well as presence of on-street parking, parking restrictions, and bus stops.

Utility Locations

Verify utility locations in the field, including location of the proposed electrical feed. Underground utilities shall be picked up in the field by using Miss Utility or professional survey.

Locate and measure the heights of overhead utilities, particularly at the lowest point of overhead utility and any other potential conflict points. This will allow for meeting the NESC and the Maryland High Voltage-line Act requirements for utility clearances and avoiding any conflicts between the proposed signal and existing utilities. These measurements shall be documented and shown on the signal plan in areas that will have points of crossings with signal equipment.

Measuring overhead utility heights is a critical element in the site visit, but it is also the most hazardous. Measuring the height of utilities is commonly done using an overhead cable measuring rod made of fiberglass. The rod is used to measure the height of the different overhead utilities from the ground. DO NOT measure the primary electric lines with the rod due to hazardous high voltage. Further, do not attempt to measure any lines with the rod unless with someone who is trained and experienced.

Another method used for measuring utility heights is a Teleheight. This is a safer method of measuring heights. See Figure SG.1.

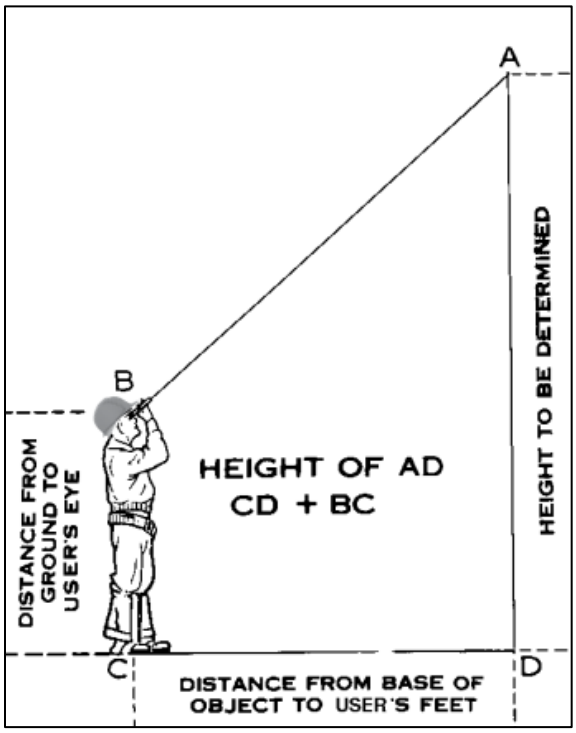


Figure SG. 1 - Using a Teleheight; Source Hubbell Power Systems

It is important to make note of any fuses, transformers, splice boxes or insulators on the utility pole. This will help in identifying what types of lines are on the pole. For instance, generally fuses are located between primary distribution lines and a transformer. The secondary (power feed) lines are usually located directly below the transformer. When noting transformers, the number of cables leaving the transformer should be observed. If two cables are leaving the transformer, it is a single phase, which means that power can be used for the signal. If there are three cables leaving the transformer, it is a three phase, which is not usable power for the signal. Also,

a splice box on lower lines is typically an indication of telephone lines. See the figures below for common attributes associated with utility poles.

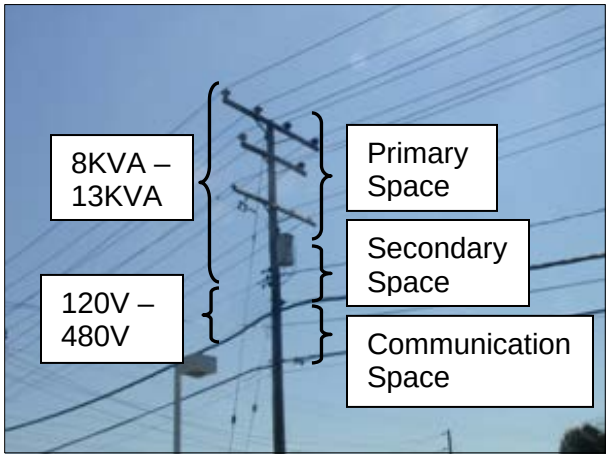


Figure SG. 2 - Typical Utility Pole "Spaces"

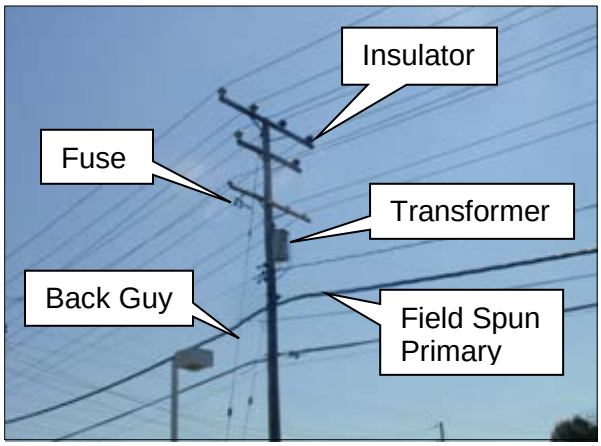


Figure SG. 3 - Typical Utility Pole Components

Figure SG. 4 - Field Spun Primary

By measuring utility lines at proposed pole locations, conflicts with overhead utility lines can be avoided. Documentation of these measurements can also help resolve future utility disputes should the height or location of utility lines change prior to signal installation.

Photographs

Although photographs are not necessarily a formal method of collecting data, a picture can say a thousand words. Taking photographs will put the project site at arm's length once back in the office. Photos can be used to check signal configurations, signs, intersection layout, etc. This is made very simple with the use of a digital camera to have pictures on hand at all times.

Always take photographs while in the field. It is beneficial to take both close-up photos as well as perspective shots from further away. This may save another trip to the site. These should be supplied to MSHA with the final review electronic plan submittal for future use.

Notes

Taking good field notes is a key when at the site. There are many things that a tape and wheel cannot measure. Taking notes to describe what is at the site is an excellent method of data collection. For example it is necessary to know the utility pole number for a

potential power drop service, taking note of this number is the best way to communicate this information with the utility company to request location of a power source. The utility pole numbers shall be shown on the Plan Sheets.

The designer should also document that they have confirmed the equipment locations determined at the field PI meeting (and as shown on the Conceptual Design Plan/Layout) and should notify the Project Manager if significant changes are needed.

Subsequent Site Visits

For most projects, it will be necessary to do at least one subsequent site visit. This should include the verification of all proposed work. Things may change frequently without prior notice, so it is important to verify that the design is constructible and optimal for the given location.

SIGNAL DESIGN COMPONENTS

Signal Structures

Signal Structure Types

There are several types of signal supports that may be used on a project. The decision of which type of structure to use is based on several factors, including location of overhead utilities, intersection geometrics, proposed location of traffic signal heads, aesthetics and local requirements. Consideration to surrounding signal types shall also be conducted. Overall there are 5 types of signal supports. They are:

- Mast Arm (Preferred option)
- Special “T” Dimension Mast Arms for Avoiding Utility Conflicts
- Strain Poles
- Pedestal Poles
- Wood Poles (Temporary Signals Only)

Mast Arms

Mast arm supports are generally preferred because the signal heads are more rigidly held in place and offer rigid support for video detection at locations that generally align better with their detection zones. In addition, they may reduce the number of poles and minimize conflicts with overhead utilities. Mast arm supports shall be used for rigid support of optically programmed signal heads, locations with backplates or that may have backplates installed in the future, overhead hazard identification beacons (HIB) and overhead advance warning signs. Also reference the MSHA *Book of Standards for Highways and Incidental Structures* for all details and dimensions of signal poles and mast arms. The table below shows the different mast arm sizes and combinations. It should be noted that a 10’ mini mast arm can also be used in conjunction with the options shown in the table.

Table SG. 1 - Mast Arm Lengths and Combinations

Single (ft)	Twin (ft)	Triple (ft)
38	50/50	38/50/60
50	50/60	38/50/70
60	50/70	
70		

Special “T” Dimension Mast Arm

Special “T” mast arms provide the same benefits as standard mast arms but have a modified design such that the mast arm has a bend and is mounted to the pole at 15 feet rather than 18 feet. A special “T” mast arm that mounts at 22 feet is also available and is required for applications where a 60” “Red Signal Ahead” sign will be mounted. These are used to avoid utility conflicts. When needed on one corner, it is not required to use a special “T” mast arm on all other corners unless there

are aesthetic concerns or engineering judgment determines that it would make a better design. Lateral offset of the pole should be checked when using the 15 foot “T” mast arms so that proper vertical clearance to the adjacent travel lane is provided.

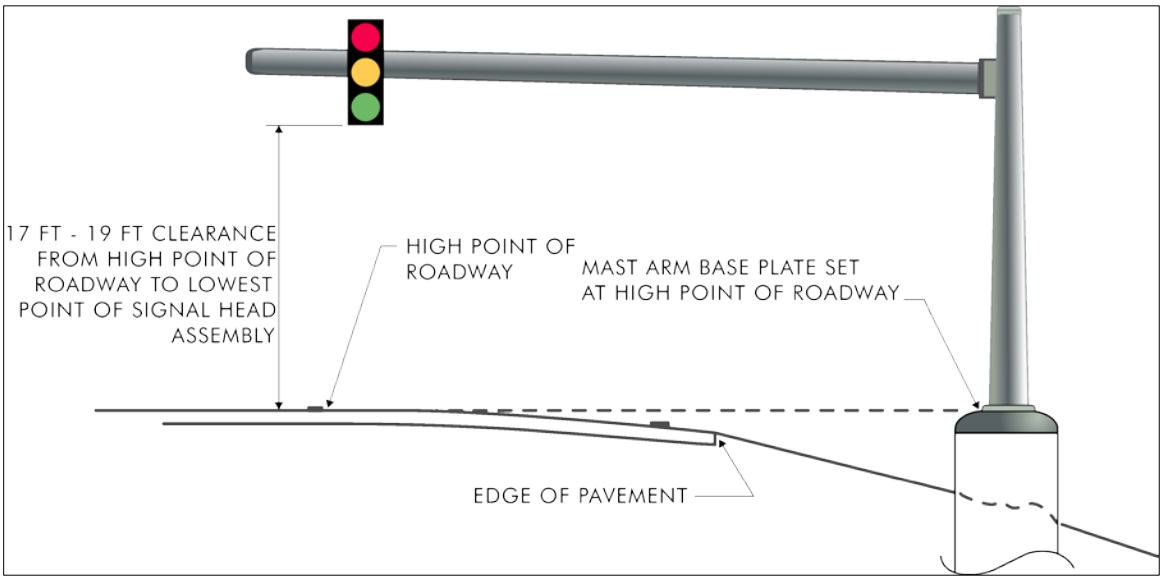


Figure SG. 5- Mast Arm Installation

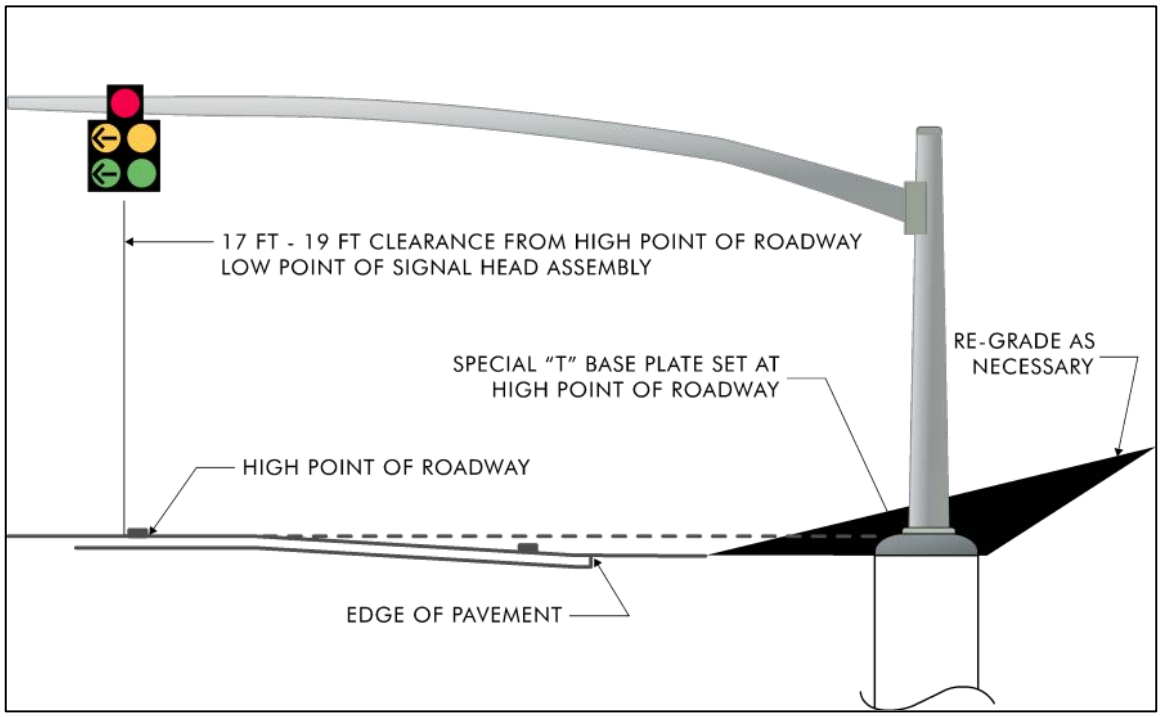


Figure SG. 6 - Special "T" Dimension Mast Arm Installation

Strain Poles

At some locations, strain poles with span wires may be required for proper signal placements. For example, at wide intersections, mast arms may not be long enough to place signal heads in the proper location for optimum visibility.

Table SG. 2 - Strain Pole Sizes by Span Length

Span Length	Strain Pole Size (O.D. x H.)
< 150 ft	12 in x30 ft
150 ft to 200 ft	12 in x 32 ft (two-ply)
> 200 ft	14 in x 32 ft (two-ply)

Pedestal Poles

Pedestal poles are primarily used for mounting pedestrian signal heads, pushbuttons, HIBs, and left-turn signals in the median of divided highways where a breakaway support is desirable. Some other situations when pedestal poles may be used for signal heads include locations where buildings are very close to the road, when overhead utility conflicts exist or for aesthetic purposes in historic areas.

Pedestal poles are generally 5 feet long (for pushbuttons only), 10 feet long (for pedestrian signals), or 14 or 20 feet long for other applications. They can typically support two 16-inch pedestrian signal heads, or a three-section, four-section or five-section vehicular head. All vehicular heads mounted on a 10 feet long pedestal pole must be top mounted and all signal heads mounted on a 20 feet long pedestal pole must be side-mounted. Side mounting on a 10 feet pole is not permitted as the signal will be mounted too low, while top mounting on a 20 foot pole is not permitted as the signal will be mounted too high. When top mounting a five-section head on a 10 or 14 feet long pedestal pole, a modified mounting bracket is necessary. The 5 foot and 10 foot pedestal poles are preferably installed on a modified base with breakaway couplings due to the small footprint and ease of maintenance and replacement. The 14 and 20 foot pedestal poles are installed on a transformer base. See the latest version of the MSHA *Book of Standards for Highway and Incidental Structures* for details and dimensions of pedestal poles.

Bridge Mounted Supports

Current MSHA policy is that no signals should be mounted on the face of bridges. However, as a last resort, in order to use this application for unique situations, MSHA Bridge Design Division must approve it.

Wood Poles

Wood poles are not used for permanent signal design. Wood poles are most commonly used for temporary signals to be included with a Maintenance of Traffic Plan.

Signal Structure Configuration

After determining which type of supports will be used for the project, the next step is designing the configuration of the supports. Some examples of typical configurations are shown on the following pages.

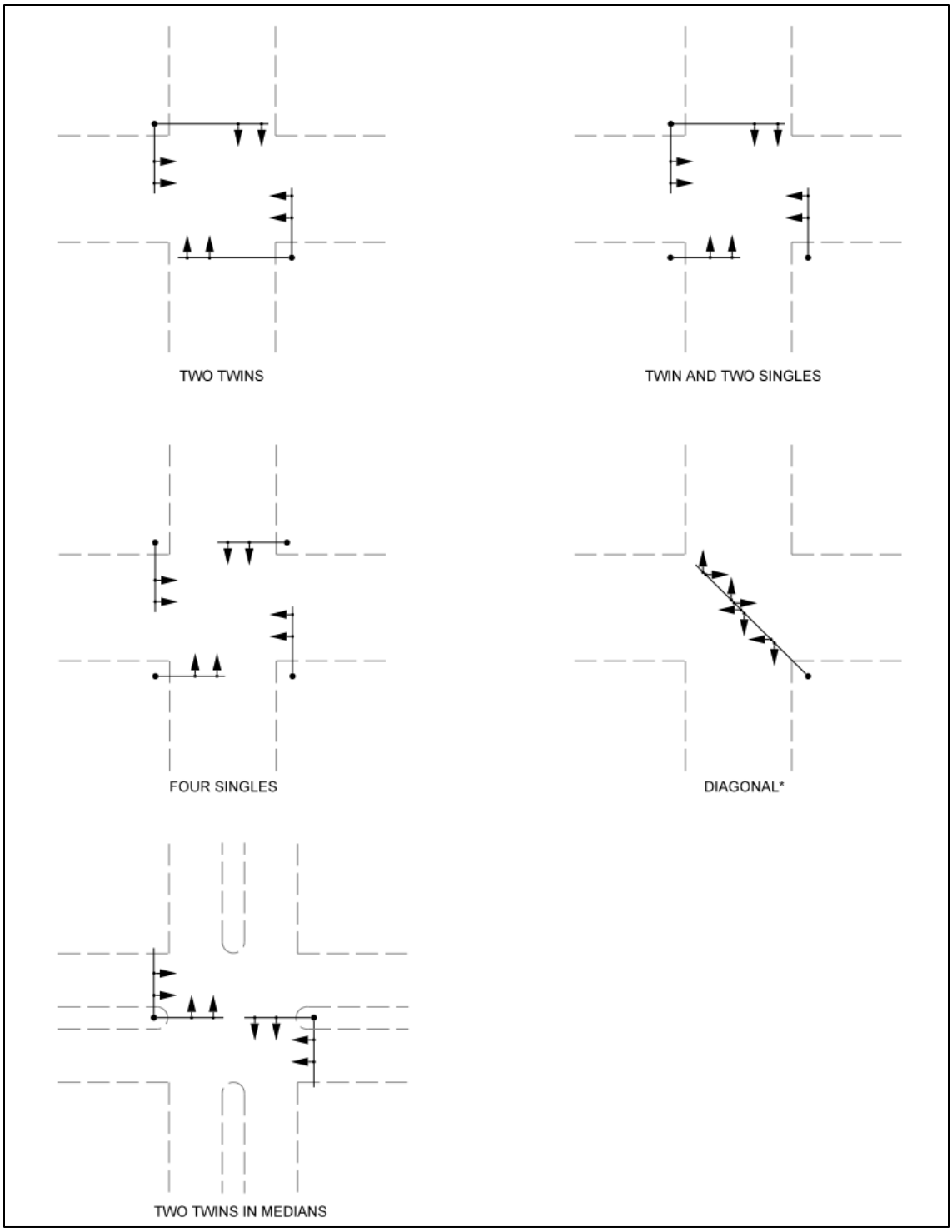


Figure SG. 7 - Mast Arm Signal Configuration

*Diagonals are not typically used because they do not provide an ideal signal head to the stop bar distance.

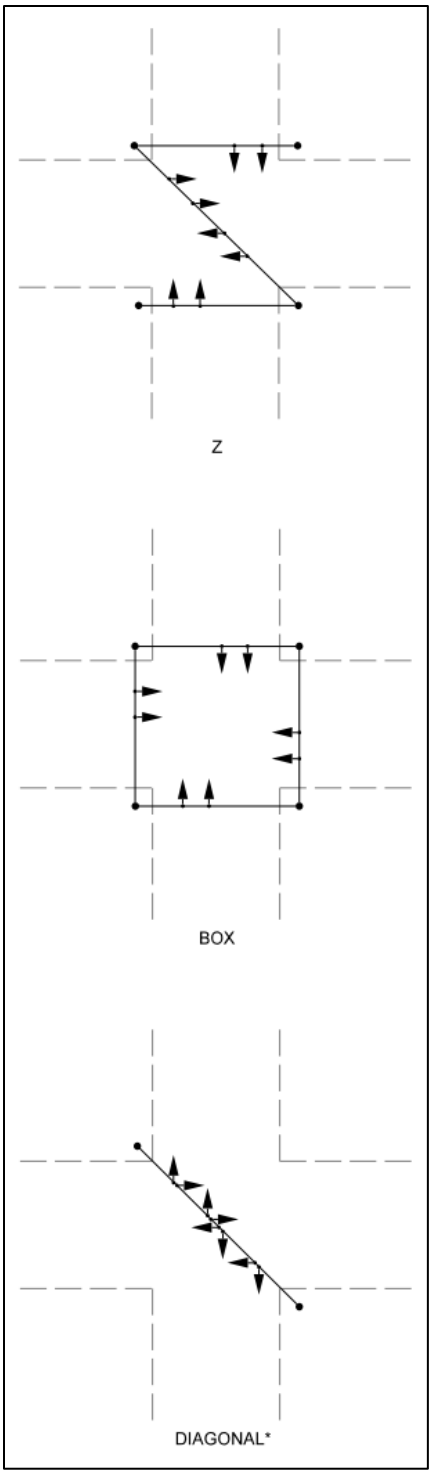


Figure SG. 8 - Span Wire Signal Configurations

*Diagonals are not typically used because they do not provide an ideal signal head to the stop bar distance.

Signal Structure Minimum Offsets and Placement

It is most desirable to locate signal structures as far off of the travel edge as possible/ practical, outside of the clear zone. Always use engineering judgment, as every situation is not the same. Refer to the AASHTO's Roadside Design Guide for further information. The following are some minimum guidelines for structure placement:

- Within MSHA ROW
- Meets ADA minimum clearance requirements
- Consider corner sight distance
- Minimum offsets and utility clearances based on Tables SG.3, SG.4 and SG.5

Wherever possible, the Designer should avoid placing non-breakaway signal supports in the median of approaches with speeds higher than 50 mph. When this is the only practical choice, the non-breakaway supports and any HIBs in advance of the intersection shall be shielded in accordance with AASHTO's Roadside Design Guide and MSHA's Guidelines for Traffic Barrier Placement and End Treatment Design. Further, breakaway bases are to be used for pedestal poles.

Table SG. 3 - Minimum Offsets for Signal Structures

Clearance Type	Min Offset Distance (ft)
Edge of shoulder to face of pole (open section)*	6
Back of w-beam to face of pole**	4.5
Face of curb to face of pole (closed section less than or equal to 50 mph). Non-breakaway poles should be avoided in medians.	2
Face of curb to face of pole (closed section greater than 50 mph)***	6
Face of pole to face of another pole	6
Between outside faces of pole foundations	4
Face of building / vertical obstruction to face of pole	6

***Signal Structures should be protected with traffic barrier or placed outside of the clear zone in open sections greater than 50 mph.**

****Offset to traffic control devices is greater than the 3' min offset to fixed objects as defined by the MSHA Traffic Barrier Guidelines**

*****Signal structures should be protected with traffic barrier or placed as far from the roadway as possible in closed sections greater than 50 mph.**

Utility Clearance

Utility clearance is the required distance between utilities such as power, cable, and telephone and signal equipment. The utility clearances also apply to signing and lighting. The utility clearance requirements may have an effect on the configuration of the signal structures and should be looked at from the very beginning.

The clearance distances from utility cables to signal structures and cables must comply with the latest requirements of the MD High Voltage Act, a pole owner (such as BGE) and National Electrical Safety Code (NESC) Sections 233 and 234. The most current version of NESC shall be followed.

Utility clearances apply to both overhead and underground utilities. The typical clearances can be found in the tables below. However, it should be noted that different utility companies may have different rules regarding clearances. Not only may the required clearances differ between companies, but some companies may require certain materials or types of conduit to be used within a certain radius of their utilities. When a structure must be placed close to a utility, the rules should be confirmed with the utility company and hand digging is recommended.

Table SG. 4 - Typical Overhead Utility Clearances

Cable Type	Horizontal Clearance (ft)	Vertical Clearance (ft)
Communication cables, guys, messengers	2	3
Secondary lines	5	5
Primary lines	10	10

Table SG. 5 - Typical Underground Utility Clearances

Utility	Clearance (ft)
Gas	5-10
Water	5-10
Sewer	5-10
Electric	3
Communications	2
Fiber	2
Storm Drain	2

Be aware of locations where field spun primary lines are installed, such as in Montgomery County. These are high voltage lines that are installed in the communication space and the 10 feet minimum clearance is still required. During the preliminary design of a signal, if equipment is being installed in close proximity to overhead utilities, it may be beneficial to prepare a utility sketch showing existing utility locations and the required clearances, as shown in Figure SG.9.

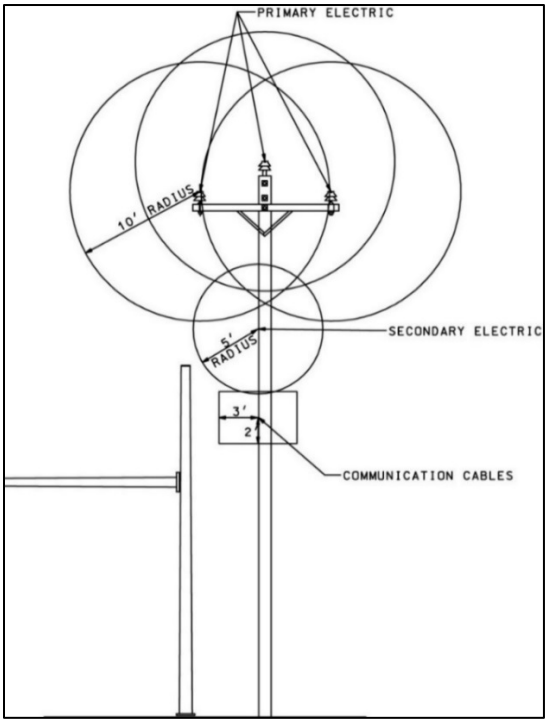


Figure SG. 9 - Overhead Utility Locations and Clearances

When signal equipment is proposed in close proximity to overhead utilities, existing utility heights should be shown on the signal plans. See Figure SG.10 below for an example.

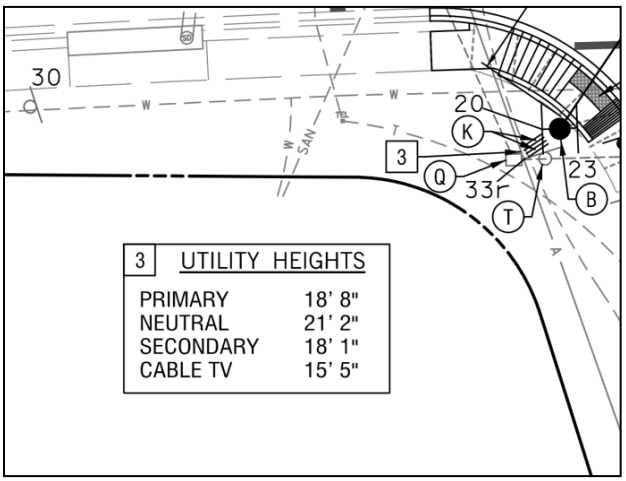


Figure SG. 10 - Plan Sheet Utility Heights

Designers should also consider clearance distances from utility cables to construction equipment when determining signal structure locations. The design must be constructible, however, in some situations the clearances can be met during construction by choosing alternate means and methods of construction. MSHA follows the power line safety regulations specified in Occupational Safety and Health Administration (OSHA) Standard 1926.1408 which contains a table with the required minimum clearance distances for corresponding voltages.

Special Design Considerations

Hazard Identification Beacon (HIB)

An HIB is a flashing yellow signal used to indicate a hazard or emphasize a regulation or warning sign. Some examples of HIB's may include:

- Warning of a signal ahead which does not meet visibility requirements
- Major horizontal or vertical alignment change
- Speed restrictions
- School zones
- Mid-block or advance pedestrian warning

HIBs can operate as either "Active" or "Passive". Active HIBs are connected to a controller and only flash when activated, such as when the signal is about to change from green to red to warn motorists that there is a "red signal ahead when flashing". Passive HIBs flash at all times.

Figure SG. 11 - Active HIB for School Zone

The identification for the need and function of an HIB should be determined during the DR preparation. Since an HIB is a signal, the type of structure, signal heads, detection, cabinet location, utility clearance, etc. should be done during the conceptual design phase. Frequently the HIB is a part of a full signal and is incorporated with the intersection signal. Other times the HIB is an independent element.

Figure SG. 12 - HIB Mounted within Sign Panel

When an HIB is mounted within a sign panel as show in the example above, the signal housing should be flush with the face of sign such that no light can be seen through the attachment. The signal heads should be mounted with brackets and/or straps and an installation detail should be provided on the plans. Special consideration should be given to HIBs that are integrated into a sign when breakaway steel sign supports are used. Flexible tubing/electrical conduit and breakaway couplings should be detailed on the plans to ensure that the power cable to the signal head is protected. As well, a handhole should be provided near the sign supports and signal cable should be spliced with connector kits before running back to the controller cabinet.

Other types of HIBs are used for Emergency Access Signals or Firehouse signals with preemption control as well as “Flag-in-the-air” intersection control devices. “Flag-in-the-air” HIBs provide a highly visible control for stopping vehicular traffic flow at school-entering and crossing points. These are used to compliment the presence of a crossing guard and potentially prevent them from having to stand in the roadway. Operating personnel will have access to a control button that is located inside the controller cabinet which is typically a pole mounted 24” x 24” cabinet.

Intersection Control Beacon (ICB)

An ICB is a combination of flashing yellow and red signal heads used to control an intersection. The ICB is used in addition to a stop sign control. The ICB is designed with the same elements as a full signal. Consideration should be given to the design wiring so the ICB may be converted to a full signal. ICBs are typically used in rural areas with lower volumes or in conjunction with Emergency Access Signals.

Flashing ICBs may operate in two modes:

- Yellow for major street and red for all other approaches or streets
- Red for all approaches

Signal Heads

Number of Signal Heads

A minimum of two signal heads shall be provided for each movement, including exclusive and exclusive/permissive left turns, to maintain visibility and ensure redundancy of the signal head display. Only one far side head is required for right turn overlaps; a near side head is only required if poor sight distance is present. A third signal head may be placed at multi-lane signalized intersections where:

- The mainline prevailing travel speed (85th percentile) is 45 mph or higher.

OR

- Engineering judgment determines that it is necessary to eliminate poor situations such as unusual highway geometrics, the surrounding area, line of sight and driver expectancy (for locations where the speed is less than 45 mph).

Additional guidance can be found in MSHA’s “Guideline for Placement of a Third Signal Indication” and the MdMUTCD.

Size of Signal Heads

Twelve-inch signal heads shall be used for all Traffic Control Device applications. Eight-inch signal heads are no longer used and any existing eight-inch signal heads should be upgraded during any signal upgrade project. In any situations where engineering judgment indicates that an eight-inch signal head may be preferred (emergency vehicle signals, Flag-In-The-Air (FITAs), pedestrian activated signals, bicycle signals, etc.), a waiver approved by the Director must be obtained prior to plan approval.

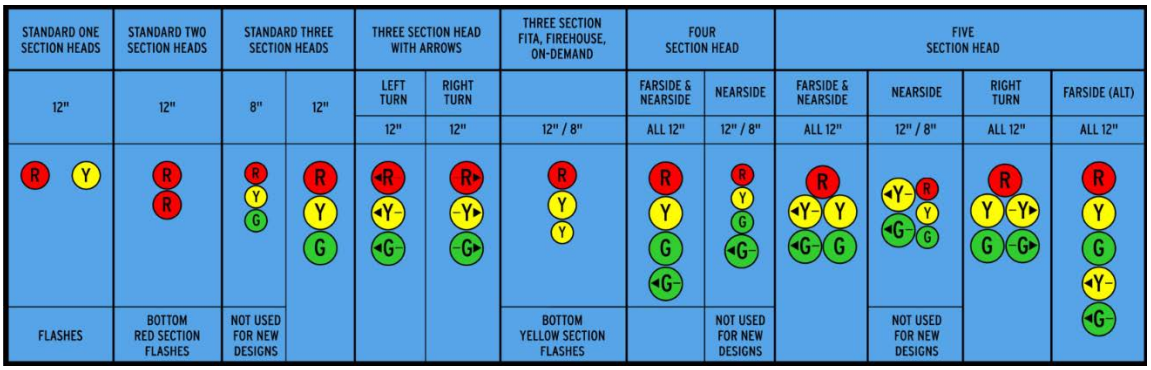


Figure SG. 13 - Signal Head Arrangements

Signal Head Sections / Arrangements

The most commonly used configuration for signal heads is a simple 3 section head with the "ball" display. Another option is the use of arrow displays.

There are several typical signal head arrangements as follows:

- Three section head with circular indications (twelve-inch): Permissive phasing and the second head for most other phasing such as exclusive/permissive and split phasing (to complement the 4 or 5 section head required).

- Five section cluster head (all twelve-inch): Signal head for exclusive/ permissive phasing (left arrows) and right-turn overlap (right arrows).

- Five section vertical head: Far-left turn signal head for exclusive/permissive phasing; this signal head can be used but is not the preferred option. The doghouse five section head is preferred. If this vertical five section head his used, it shall be side mounted on a 20 foot pedestal pole or installed on a shorter pedestal pole with a modified bracket due to its tendency to break under wind loading when attached on top of a pedestal pole with a typical bracket.

- Three section head with arrow indications: Exclusive phasing and flashing red arrow exclusive/permissive operation.

- Four section vertical head: Split-phasing.

Figure SG.13 shows diagrams of the different signal head configurations and sizes used for MSHA traffic control signals.

All projects shall require the installation of black-faced, LED signal heads unless otherwise specified.

For locations where crash data indicates that glare was a cause of crashes, the use of backplates, such as the ones shown in the figure below, may be considered. However, use of backplates should be limited and should primarily take place on roadways running in east-west directions. The installation of backplates must be approved by the Director. Backplates should not be installed on any signal structures that are older than 25 years. If a signal structure is 25 years old or less, they must be thoroughly inspected by the Administration to determine whether backplates may be installed.

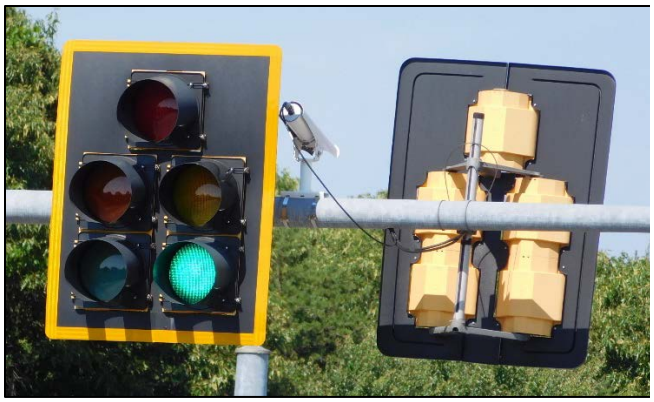


Figure SG. 14 - Signal Backplates

Signal Head Placement

The bottom of the traffic signal head housing (including backplates when applicable) on overhead signals should be at least 17 feet and not more than 19 feet above the high point of the roadway.

The horizontal placement may vary with the type of display on the approach. The primary concern when placing signal heads is visibility. Refer to the Traffic Control Signal Features section in the MdMUTCD for a complete discussion of this topic. A table in this section of the MdMUTCD provides minimum visibility distances for signal heads. The Designer should check the roadway horizontal alignment, vertical alignment on approaching roadways and any potential obstructions, such as buildings, walls, etc. when selecting the proper placement for traffic signal indications.

The MdMUTCD lists several criteria that should be considered when locating signal heads. Some of these guidelines that will determine the placement of the signal heads are as follows:

- A minimum of two signal heads shall be provided for each phase at an intersection.
- At least one, and preferably both, of the signal heads shall be placed within 20 degrees to the right or left of the center of the approach lanes for the through movement.
- At least one, and preferably both, of the signal heads should be placed between 40' and 120' from the stop line.
- A near-side signal head should be provided when the distance from the stop line to one or more far-side signal heads is more than 120'.
- A near-side signal head should be provided when there are unusual roadway geometrics, 3 or more through lanes, or when the horizontal or vertical alignment of the roadway limits the minimum visibility distance requirements.
- An exclusive movement, with a double left turn lane, shall have two far-side signal heads. A supplemental near-side signal head or far left signal head shall also be used.
- An exclusive or exclusive/permissive left-turn movement, with a single turn lane, requires a near-side and far-side signal head.
- A side street split phase requires a near-side signal.
- Far Left Turn Traffic Signals are generally used when the geometry of an intersection restricts view of far and/or near-side signal heads. This indication is in addition to the required number of signal indications as specified in the MdMUTCD and TEDD standards, and may eliminate the near-side exclusive/permissive and/or exclusive signal head.

If the minimum visibility requirements according to MdMUTCD Table Minimum Sight Distance for Signal Visibility (85th percentile) cannot be met, a Signal Ahead (symbol) sign and/or a hazard identification beacon shall be installed.

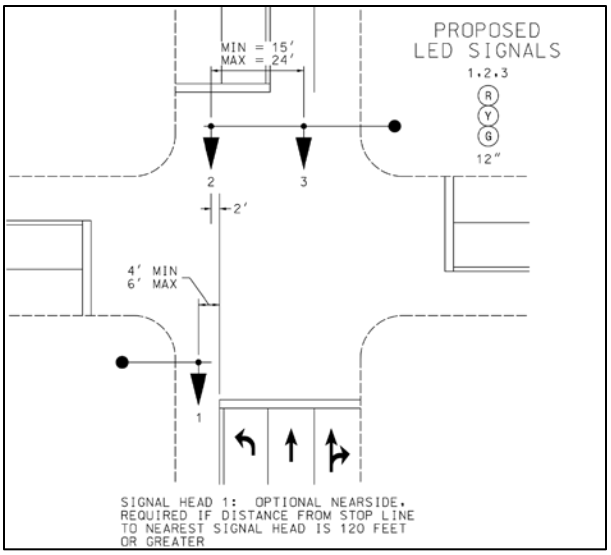


Figure SG. 15 - Signal Head Horizontal Placement – Preferred for two far side and one near side three-section standard heads

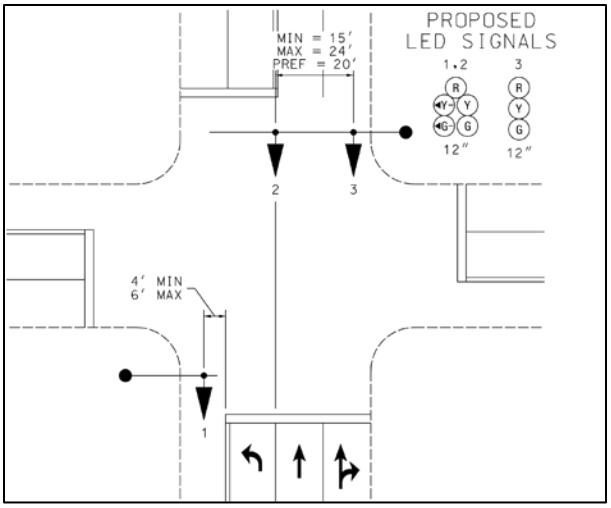


Figure SG. 16 - Signal Head Horizontal Placement – Typical Signal Head Placements for Exclusive/Permissive Left Turn

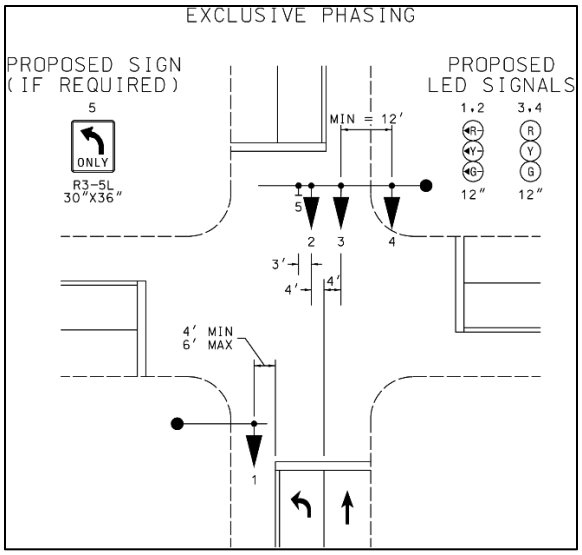


Figure SG. 17 - Preferred near and far side three section heads with arrows and two three-section standard heads

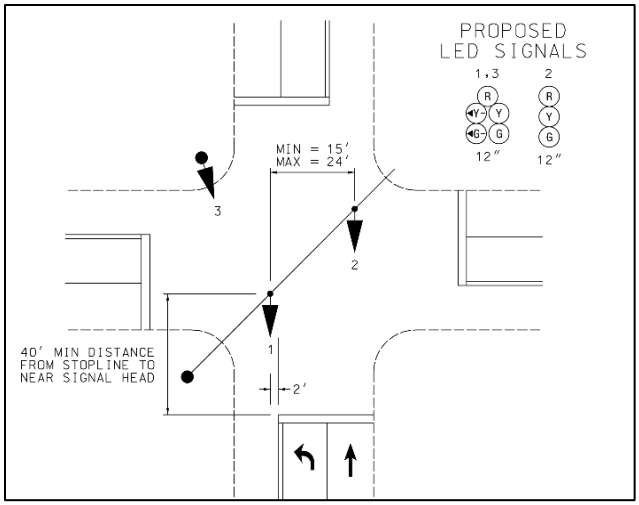


Figure SG. 18 - Typical Far Left Turn Traffic Signal Head Location*

*This configuration with diagonal should be used only when no other layouts are feasible

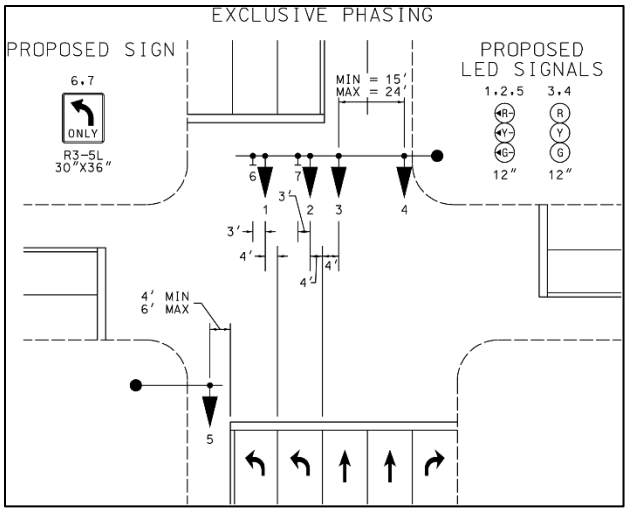


Figure SG. 19 - Typical Signal Head Placements for Exclusive Double Left Turn

Detection

Signal Detection Uses

Detection allows a signal controller to know when vehicles are at or approaching an intersection. Signal detection takes on three basic operational functions: presence, passage and sampling. These functions are either "locking" or "non-locking," but all have the ability to actuate a signal controller in one way or another. Most signals in Maryland are either fully or semi-actuated and will receive detection.

Presence detection calls or extends a phase when a vehicle is over the detection zone. Passage (or advanced) detection extends a phase when a vehicle passes over the detection zone. Sampling (or system) detection collects occupancy, queue, volume, and speed information to feed back to the controller.

"Locking" detectors indicate that a vehicle has gone through a detection zone and the memory of the vehicle is stored in the controller. Therefore, a "locking" detector call results in time being provided to a phase. Locking detection is typically used for mainline and side street passage. "Non-locking" detection means that the controller only knows if a vehicle is in the zone, once a vehicle leaves the detection zone the controller "forgets" it was ever there. Non-locking detection is typically used for side street and turn bay presence as well as queue detection.

Fully-actuated signals have a combination of presence detection for the side street and passage detection for the mainline. Fully actuated signals are mainly used for stand-alone signals (not part of a system) and may have presence detection for mainline left turns and passage detection on the side street as well.

Semi-actuated signals have presence detection for the side street but no passage detection on the mainline. Instead, they may have sampling detection on the mainline for signal systemization. Passage detection may be included for the side street based on higher speeds.

Signal Detection Methods

The Administration uses four types of detectors, two intrusive (inductive loops and magneto-inductive probes) and two non-intrusive (video detection and non-invasive probes). The Administration prefers the use of non-intrusive detection whenever possible.

Video Detection

This type of detection system uses a video camera to create an image of one or more detection zones.

The video imaging detection system includes a video detection camera and a 3 conductor #18 AWG cable as the lead-in that connects the camera to the cabinet. Included with the video detection camera is an integrated imaging CCD array with optics, image-processing hardware, and a general-purpose CPU bundled into a sealed enclosure. Video

detection should make use of the latest equipment approved by the MSHA Signal Shop.

When adding a new video detection camera at a location with existing video detection, the entire video detection system should be replaced, including the video interface equipment, if the existing detectors do not meet current standards. The compatibility of the new system should be verified before installation. The preferred camera for MSHA usage changes periodically, so it is important to verify that the latest approved equipment is used.

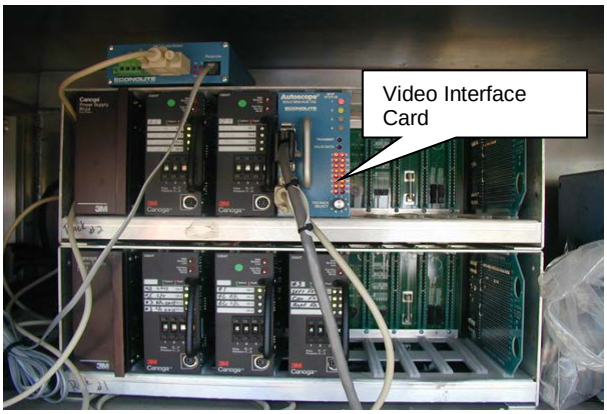


Figure SG. 21 - Rack Mounted Video Interface Card

Figure SG. 20 - Video Interface Card (Close Up)

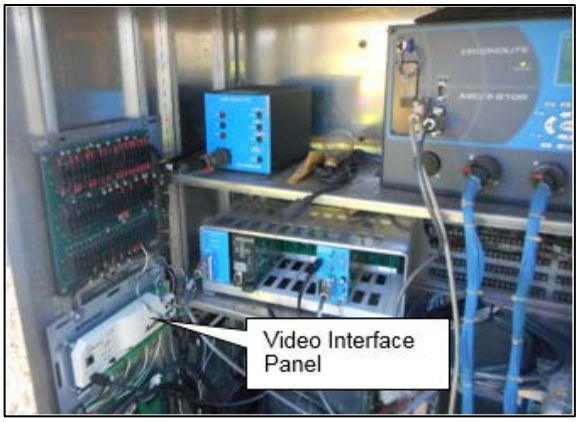


Figure SG. 22 - Video Interface Panel

For maximum performance, the Administration recommends attaching the video camera to a mast arm on the far side of the intersection centered above the lane of the detection zone. It may also be installed on a lighting bracket arm or video detection camera arm attached to the signal pole. An extension pole can be used to mount the camera an additional 5 feet above the mast arm in order to increase the field of view but prior approval from TEDD is needed before this is utilized. For every foot of sensor height, the camera can “see” about 10 feet. For locations with traffic signals on span wire, the video camera should be located to the left of the left-turn lane mounted on the signal pole. If possible, cameras should not be located to the right of the lane (this is to avoid detecting larger vehicles in adjacent lanes).

Camera location and mounting height are dependent on the geometry of the intersection and obtaining an unobstructed field of view. Video detection is not effective if poles are set back significantly from the roadway. Based on the location and distance of the camera from the desired detection area, the Field of View (FOV) can be calculated and the required lens can be determined. It should be noted that a single camera can be used for detection at both a left turn stop line and for system/sampling detection (other direction of travel) if the median is not very wide.

Where significant truck volumes are present, video detection cameras should be installed as high as possible to better aim the camera at the stop line. This will help reduce trucks from "lagging" in the detection zone and will avoid "sluggish" signal timing. It has been observed that video detection zones are being programmed to be much larger than your traditional in-pavement loop zone, so placement of the camera is extremely important. Signal technicians should find a balance between the size of video detection zones and allowable phase extension time when programming the controllers.

Some additional considerations in designing video detection are:

- Lighting brackets
- Obstructions such as overhead utilities, billboards, traffic signals, etc.
- Occlusion of the detection area by moving vehicles, both downlane and crosslane
- Shadow effects/horizon should not be visible in the field of view of camera
- Distance from camera to detection zone
- Select a location that minimizes vibration and motion
- Part time signals (school signal)

Magneto-inductive Vehicle Sensor

Magneto-inductive vehicle sensors are commonly known as microloop probes. A microloop probe is a small cylindrical, passive transducer, which transforms the earth's vertical magnetic field intensity into inductance. It transforms changes in magnetic field intensity into inductance changes that can be sensed by detector units. The microloop probes have the same application and placement as a 6'X6' small area inductive loop. However, a microloop probe acts more like a point detector and provides very good resistance to detecting vehicles in adjacent lanes.

Non-invasive microloop probes are installed in a seamless conduit under the roadway with handholes on each side of the road. The handholes for this type of probe are installed with the long dimension perpendicular to the edge of road to ease installation. The handhole symbol must be shown on the plans in that orientation.

This type of detection is not in the pavement and will not be affected with roadway milling. It is also ideal for high-speed / high-volume traffic conditions since it results in less traffic disruptions and conflicts during installation. Where resurfacing is anticipated in the near future and where lane patterns will shift, the probes can be slid horizontally as lane patterns change. Further, in the event they go bad, damaged probes can be pulled out and replaced with new ones in the same conduit.

The non-invasive microloop probe lead-in runs continuously from the probe devices to the controller. It is available in any length up to 1,000 feet.

Specific MSHA practice includes the following guidelines:

- Three probes per lane at 3' centers.
- Inserted into a three-inch non-ferrous Schedule 80 conduit.
- Conduit is installed 21 +/- 3 inches below the road surface using horizontal directional boring.
- Install one handhole on each side of the road perpendicular to the roadway (the short side of the handhole shall be parallel to the roadway).

Another method of installing microloop probes beneath the roadway surface is by drilling a 1-inch diameter hole (18-inch to 24-inch deep) in the pavement and inserting the probes. This method also has a greater service life over 6 feet x 6 feet inductive loops due to the reduced exposure to hazards such as road traffic, pavement movement, pavement deterioration, and roadwork but do not offer the same repair efficiency as the non-invasive microloop probes.

Microloop probes are not used in concrete pavements, in tunnels, around power lines or rail lines, or on existing bridge decks.

When installing microloop probes, a magnetic field analysis should be conducted prior to commencing boring and cutting of pavement. Refer to the MSHA *Book of Standards for Highways and Incidental Structures* for additional specific installation guidelines.

Inductive Loops

Inductive loop detectors are loops of wire placed and sealed in the surface of the roadway that create an electrical field at the surface of the roadway. Disturbances of the electrical field are observed and vehicles are detected. Typically the loops are carried into a handhole and spliced with an aluminum shielded wire that is carried back to the controller.

Inductive loops may be used as small area detectors. However, small area detectors are generally only used when retrofitting existing loops, if directed by TEDD. When used, MSHA designs these loops by placing one 6 foot X 6 foot loop per travel lane.

Inductive loops are also used as large area detectors, typically 6 feet x 30 feet quadrupole. Large area detectors that serve exclusive right-turn lanes that are signalized and exclusive left-turn lanes that have exclusive/permissive phasing are timed with a delay output feature. The delay output feature allows a detector call to be delayed or dropped by the amplifier should a right turning vehicle turn on red, or a left-turn vehicle turn during the permissive period. The delayed call timing is programmable in length of time by the amplifier.

Large area “quadrupole” type detectors require three sawcuts in the longitudinal direction and the loop wires are wrapped in a “figure 8” pattern. These are also placed as one loop per travel lane.

These loops are formed by sawcutting the roadway, placing a No. 14 AWG wire encased in flexible tubing (IMSA 51-5) in the sawcut and then sealing the sawcut. The required sawcut depth for concrete road surfaces is 2”, while a 4½” sawcut depth is required for asphalt road surfaces. The strength of vehicle input from the detection area depends on the number of turns of wire around the perimeters of the loop. This varies with the loop size. The following table shows the type of loops and the number of turns:

Table SG. 6 - Wire Turns for Loop Detectors

Detector Loop Size	No. of Wire Turns	Wire Length (FT)
6' x 6'	4	96
	3	72
6' x 30'	3-6-3	396
6' x 20'	3-6-3	286

In concrete pavement, 3/2-4-2 turns are used in lieu of 4/3-6-3 to avoid severing the concrete reinforcement with the loop sawcut. The 2-4-2 is also used in shallow asphalt areas. When possible, using inductive loops in concrete pavement should be avoided because the rebar can interfere with the magnetic field.

The loop wire connection from the handhole to the controller unit cabinet is carried via a two-conductor aluminum-shielded lead-in cable for each loop sensor. This is the only place where

a splice is allowed for signal cable except for ground mounted HIBs as discussed above. As such, the lead-in cable must be a continuous run of wires from the handhole adjacent to the loop location to the controller cabinet, as the splicing of lead-in wires is not allowed and a break in the loop run will cause the loop to fail. To ensure that the wire is protected from cracks in the roadway, all new loop wires should be placed in a 1" conduit from the travel way to the nearest handhole as described in the 'Conduit – General Uses' section herein.

Some additional considerations when designing loop detectors:

- Avoid surface features (drainage, manholes, gas valves, etc.)
- Avoid installing in deteriorated pavement (susceptible to failure)
- Avoid long lead-in cables (susceptible to failure)

Other Technologies

In addition to video imaging, inductive loops and microloop probes, several other technologies are available for signal detection. Although they are not regularly used within the state of Maryland, some of these technologies include:

- Microwave
- Magnetic
- Magnetometer
- Infrared
- Light Emission
- Sonic
- Radar

These are not typically used on MSHA projects unless special situations arise.

Types and Placement of Signal Detection

Presence Detection

Presence detection indicates that a vehicle is in the detection zone. Presence detection can be either "locking" or "non-locking" depending on the application. These detectors are typically used on side streets and left turn bays at the stop line when it is critical to know if a vehicle is waiting for green. It is important to add new presence detection in the appropriate (turn) lane when a permissive signal phase is replaced with an exclusive/permissive or exclusive signal phase. The preferred presence detection is video imaging detection; however, 6 feet x 30 feet inductive loops are common at existing signals, especially at span signals. Another use of presence detection is for queue detection. Due to the distance back from the signal, 6 feet x 20 feet inductive loops are typically used.

Location of Presence Detection

For presence detection, video detection cameras are generally placed on the far side of an intersection on the mast arm or a lighting bracket arm angled at the stop line of the movement being served. Ideally, the detection zones should be placed parallel to the lanes of traffic for optimal presence detection accuracy of moving or stopped vehicles. One camera is typically required for each approach for presence detection.

Figure SG. 23 - Typical Video Detection Location (Mast Arm Mount)

Figure SG. 24 - Typical Video Detection Location (Lighting Arm Mount)

Figure SG. 25 - Typical Video Detection Location (Extension Arm Mount)

When used, a 6'x30' inductive loop is installed at or near the stop line, commonly 12" behind the stop line. There are instances though when it may be deemed necessary to locate it in front of the stop line to account for cars that stop in front of the stop line. For installation of a 6'x20' inductive loop for queue detection, an Engineering study is needed to determine the appropriate set back from the signal. Figure SG.26 shows an example of detection locations at an intersection.

Passage Detection

Passage detection, also called point or pulse detection, identifies when a vehicle has passed through a detection zone and sends a message to the controller. Passage detection has a setting of "locking" in the controller and extends the green time for that movement. These detectors are typically used on mainlines. The preferred passage detection is non-invasive microloop probes. In areas that right-of-way, geometrics, or underground utilities restrict the use of non-invasive probes, microloop probes would be the next choice for passage detection. Another option is to use 6 feet x 6 feet inductive loop detectors or video imaging cameras for passage detection. When video imaging is used for passage detection, it is typically for side streets.

Location of Passage Detection

Passage detection is placed in relation to the stop line, based on the posted speed and a passage time of 5 seconds for the mainline. For side road passage detection, if the speed limit is 25mph or less no passage detection is used. For 30-40mph, a passage detector is placed 90' in advance of the stop line. For 45mph and above, a 3 second passage time is used for the placement of detection. Note: if both approaches have the same approach speed, a passage time of 5 seconds should be used for both approaches. Further, private entrances do not receive any passage detection. If passage detection cannot be physically installed at the designated setback distance due to utilities, entrances, etc., the preferred method is to move the detectors slightly further away from the signal rather than closer. However, if there are physical constraints requiring the detectors to be moved significantly further away from the signal, the option of moving them slightly closer to the signal may be considered. See Tables SG. 7 and SG.8 for detector setback information.

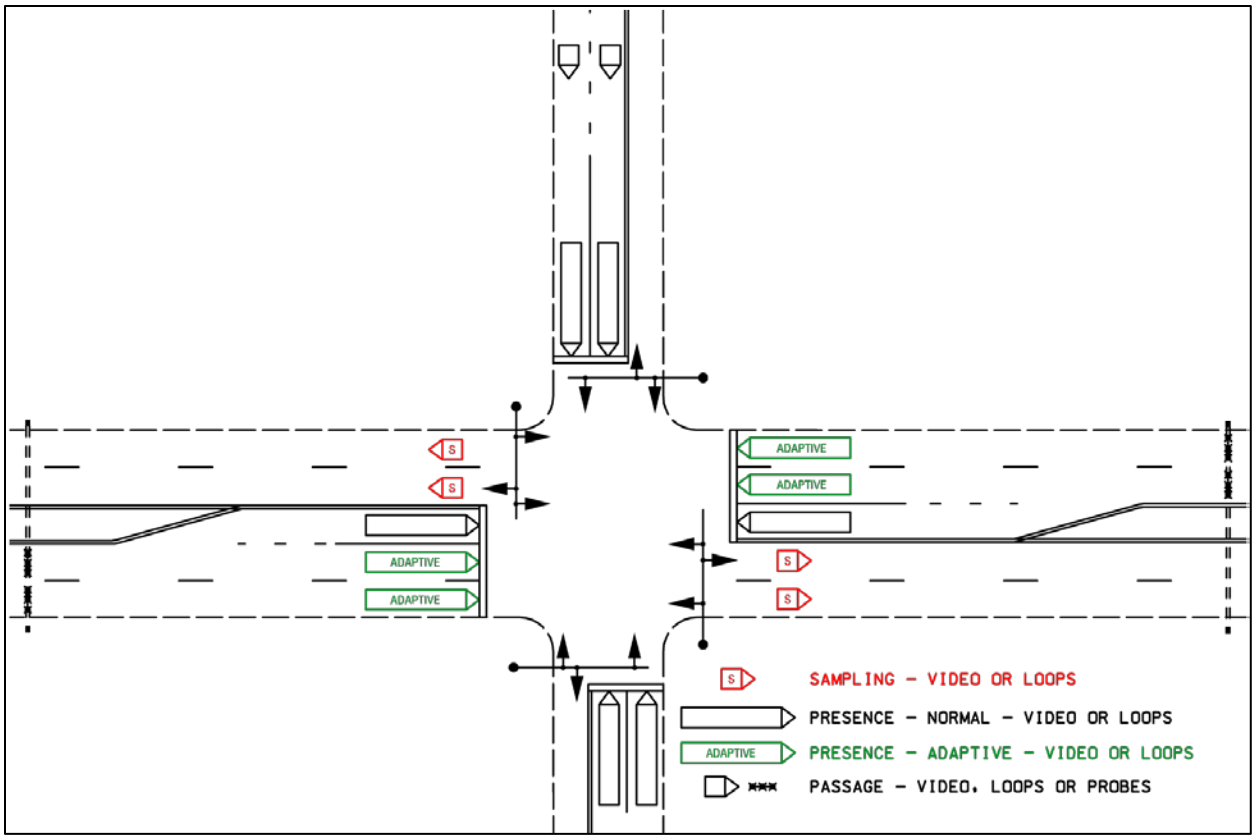


Figure SG. 26 - Detection Zone Types

Table SG. 7 - Detector Setback for Side Streets

Posted Approach Speed (mph)	Detector Setback Criteria
0-25	No Detection
30-40	90 feet
*45+	3 sec. Passage Time
Private Entrance	No Detection

*Side streets with the same approach speed as mainline should have a 5 second passage time

Table SG. 8 Detector Setback from Stop Line, in Feet

Posted Speed (mph)	Passage Time from Detector to Stop Line (sec)				
	1	2	3	4	5
20	29	58	87	116	145
25	36	78	108	144	180
30	44	88	132	176	220
35	51	102	153	204	255
40	59	118	177	236	295
45	66	132	198	264	330
50	73	146	219	292	365
55	81	162	243	324	405
60	88	176	264	352	440
65	95	190	285	380	475

Sampling Detection

The term "system loops" or "sampling detectors" refers to detection feeding information about a signal system back to the controller. The operation of system and sampling detection only uses passage detectors. This detection collects data such as occupancy, queues, volumes and speeds, and sends it back to the controller.

Sampling detection should be installed when entering a system and at major intersections as recommended by TDSD.

Video detection is typically used for new or replacement sampling detection. However, 6 feet x 6 feet inductive loops provide more accurate presence and occupancy readings and are still used in some jurisdictions.

Location of Sampling Detection

Sampling detection shall be placed downstream of an intersection in a location that represents free flow of traffic.

The placement of the system detection is designed differently than the placement of the individual intersection detection. The specific location of system detectors depends on the traffic patterns, direction of traffic, distribution of traffic, and location of heavily traveled intersections within the arterial system. The goal is to locate the detectors to collect data that is representative of the major traffic flow in the system. In most cases, system detectors are placed on the upstream and downstream ends of the arterial. One system detector per lane shall be installed.

Pedestrian Amenities

Pedestrian Crossings

Pedestrians play a critical role in signal design. During the conceptual phase, it should be determined if a pedestrian signal will be designed. Pedestrian Signals shall be stated in the DR and shall be installed per the following criteria:

- All crossings with medians regardless of width
- All crossings of 4 or more lanes
- Crossing width of 30 or more feet
- Wherever the ADE-T's determine such use is justified based upon factors such as: elderly pedestrians, school children, and unusual intersection geometrics.

If pedestrian phasing is included, then the inclusion of crosswalks, ramps compatible to ADA standards, pedestrian signals and poles shall be considered during the conceptual design. Crosswalks can be installed without pedestrian signals but pedestrian signals cannot be installed without crosswalks. All new pedestrian crossings shall be designed for either the present or future installation of accessible pedestrian signals (APS).

Countdown Pedestrian Signals (CPS)

All signalized pedestrian crossings shall have 16 inch LED countdown pedestrian signals, unless otherwise specified in the D.R. An example of a countdown pedestrian signal is shown below. Countdown pedestrian signals should be installed a maximum of 10' laterally offset from the crosswalk extended to ensure good visibility.

Figure SG. 27 - Countdown Pedestrian Signal

Note that when emergency vehicle preemption is present at the signalized intersection, the use of countdown pedestrian signals should be evaluated and reviewed prior to design. This is to prevent pedestrians from receiving a false impression that they have more time to cross the street than the signal allows once a preemption call is placed to the controller. When countdown pedestrian signals are used at signals with preemption, they are programmed such that the pedestrian clearance cannot be shortened.

Accessible Pedestrian Signals (APS)

An APS is a device that communicates information to a pedestrian about pedestrian timing in non-visual formats such as audible tones, verbal messages, and/or vibrating surfaces. This also includes detectable warning surfaces or truncated domes. During conceptual design it is necessary to identify the potential demand and/or request for accessible pedestrian signals. In the MSHA OHD Accessibility Policy & Guidelines for Pedestrian Facilities along State Highways, it states that "All projects, regardless of who is administering the contract, shall accommodate and provide accessibility for persons with disabilities where it is reasonable, feasible and appropriate to do so…..basically any time we do anything to the roadway that would or could improve pedestrian access." Further, ADA ramps shall be provided in accordance to the functionality and requirements of the APS.

APS can provide information to pedestrians about the existence and location of the pushbutton, beginning of the walk interval, direction of the crosswalk and location of the destination curb, intersection street names in Braille or with a speech message, intersection signalization with a speech message and intersection geometry through maps, diagrams, or speech messages.

APS stations include a tactile arrow and pushbutton attached to an informational sign with the intersection street name to be crossed in Braille. This station has capabilities of providing a vibrotactile walk indication (in addition to audible walk indication), a pushbutton locator tone, and automatic volume adjustment. A pedestrian education sign shall be mounted above the APS station that also includes the name of the street being crossed. This street name should be shown in the Construction details on the plan pertaining to the sign installation.

If the major street minimum green interval is sufficient for the required side street (WALK and flashing DON'T WALK/Countdown) pedestrian intervals, the APS pushbutton generally serves only to provide audible notice of when crossing is permitted rather than to trigger a pedestrian cycle. The pedestrian signal will automatically go to WALK every cycle but the audible/tactile message will not be activated unless the button is pushed. However, the pedestrian signals for crossing the mainline are generally alternate pedestrian phases which are pushbutton actuated, which means the button must be pressed in order to receive a WALK phase and audible/tactile message. This should be clarified on the General Information sheet under the 'Intersection Operation' section and reflected in the Phasing Diagram on the signal plan sheet.

Signal plans that include APS should contain verbal messages shown on the General Information sheet under the 'Special Notes' section. A typical verbal message is "Wait to cross Main at First. Wait." Note that the roadway designation of "street, road, avenue, etc." should not be included in the message. If an intersection contains a road that has two different names on two legs of the intersection or if an intersection contains a road on one leg and a ramp to a highway, freeway, or expressway on the opposite leg, both names should be included in the verbal messages. See the example below and the corresponding verbal messages.

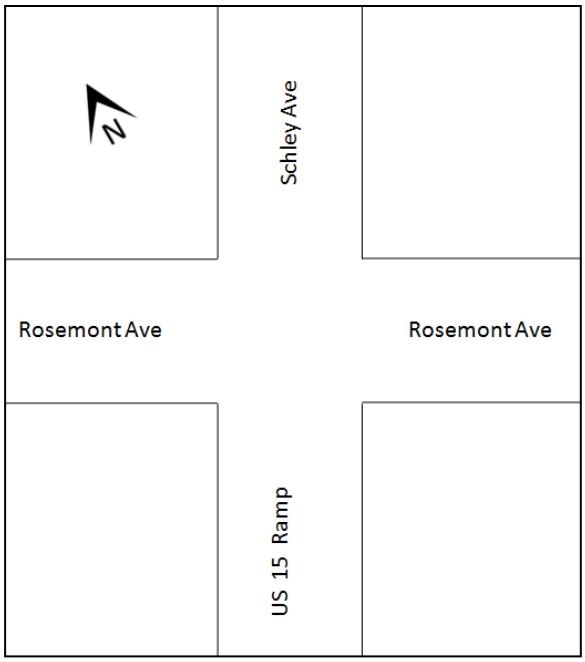


Figure SG. 28 - APS Message Sample Intersection

The messages would be as follows:

- To cross the North Leg: "Wait to cross Schley at Rosemont. Wait."
- To cross the South Leg: "Wait to cross US 15 Ramp at Rosemont. Wait."
- To cross the East Leg and West Leg: "Wait to cross Rosemont at Schley and US 15 Ramp. Wait."

If, despite design efforts, the crosswalk is slanted and shifts 10 feet or more laterally, then the following message should be added at the end of the crossing messages above, "Crosswalk angles right" or "left" depending on the situation.

APS pushbutton stations should typically be located based on the following guidelines. Designs that deviate from these guidelines require an APS waiver. Note that specified dimensions for pushbutton placement refer to the actual face of the button not center of pole.

Figure SG. 29 - APS Station and Pedestrian Education Sign (For Countdown Signals)

- Adjacent to a level all-weather surface to provide access from a wheelchair,
- On a wheelchair accessible route to the curb ramp
- Within 5 Ft (60 in) of the crosswalk line extended
- Maximum 10 Ft (120 in) and minimum 2.5 Ft (30 in) from the edge of the curb, shoulder, or pavement
- At least 10 Ft (120 in) from other APS pushbuttons located on the same corner
- Maximum 18 in reach to pushbutton from a 5' x 5' level landing area (preferred)
- From level landing area, height should be no more or less than 36"
- Tactile arrows on pushbuttons should be oriented parallel to the associated crosswalk and should have high visual contrast
- Pedestrian symbol on pushbutton to face crosswalk

- Minimum of 32” clearance (need ADA Waiver), 60” minimum preferred (without waiver)
- Pushbutton orientation shall face toward the intersection on the outside of the crosswalk.

An example of an acceptable placement of Accessible Pedestrian Signals can be seen in the Figures SG.30.

Alternatives to the above design criteria are available for the addition of APS to an existing intersection with existing pedestrian signals. When two pushbuttons must be installed on the same pole, speech walk messages and pushbutton information messages are needed. An APS waiver approved by the Director is required for this design.

Figure SG. 30 - Acceptable Placement of APS

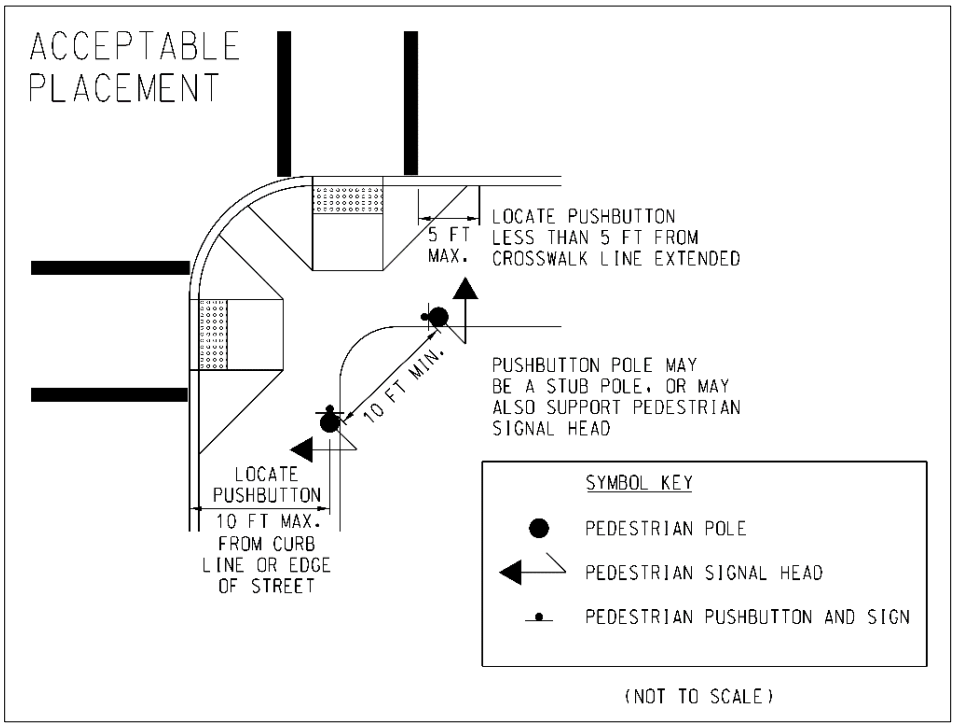


Figure SG. 31 - Acceptable Placement of APS

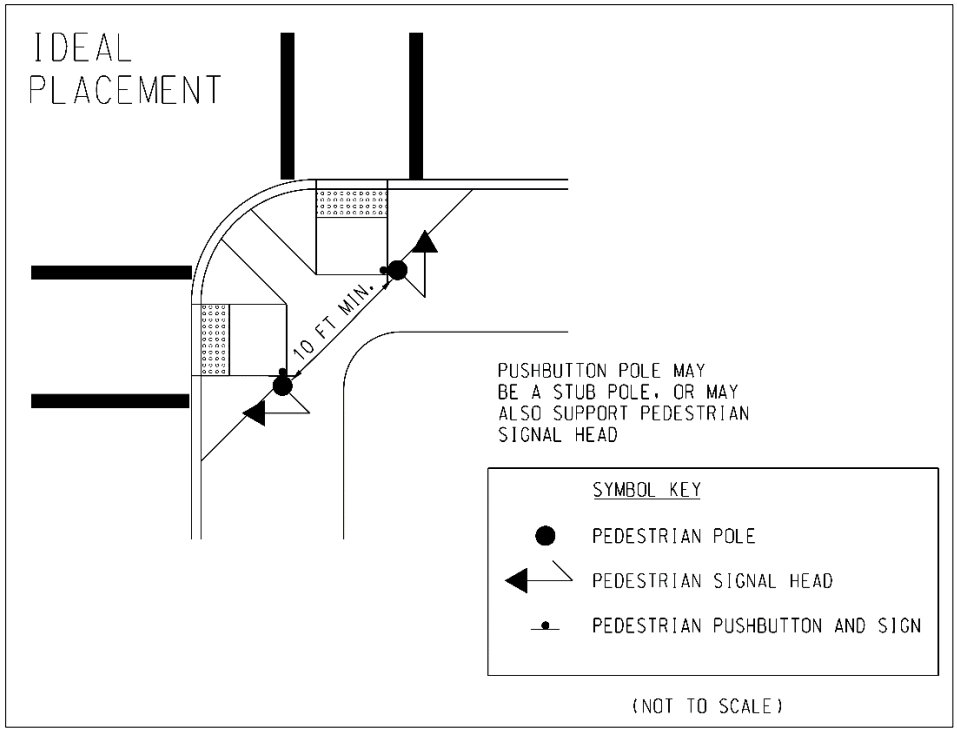


Figure SG. 32 - Ideal Placement of APS

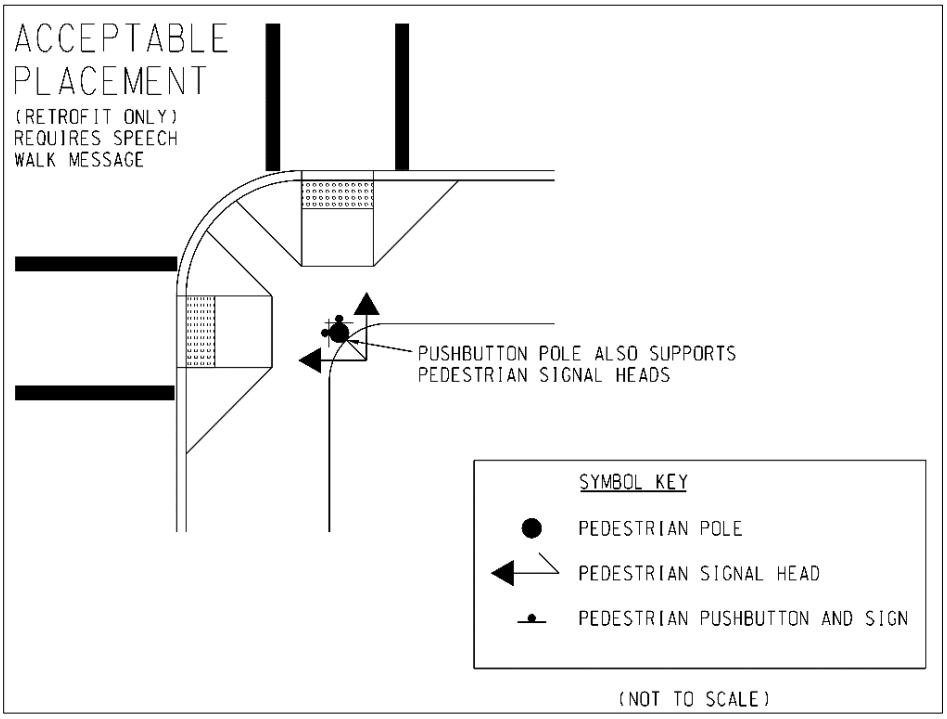


Figure SG. 33 - Retrofit Placement of APS

*Note that this configuration requires an APS waiver to be approved by the Director

ADA Requirements

The general ADA requirements for ramps, sidewalks and median cut-throughs can be found in the MSHA *Book of Standards* and the OHD Guidelines. However, it is important to recognize a few basic parameters to consider when designing for pedestrian crossings and APS devices. When ADA features are included in the design, blow-up details showing pertinent ramp, sidewalk and equipment locations and dimensions should be provided on the signal plan if space permits or more often as a separate detail sheet.

For sidewalk ramps, the maximum running slope is 12:1 (~8%) and must include or be adjacent to a flat landing area with maximum slope 48:1 (~2%). The preferred design for crosswalks is to have separate ramps for each crossing with a reasonable separation on each corner of an intersection. For locations where two crosswalks converge at a combination ramp (only 1 ramp is provided on the corner), there should be a 48” minimum clear space between the two crosswalks to ensure the detectable warning surface is within the crosswalk boundaries, as shown in the figure below.

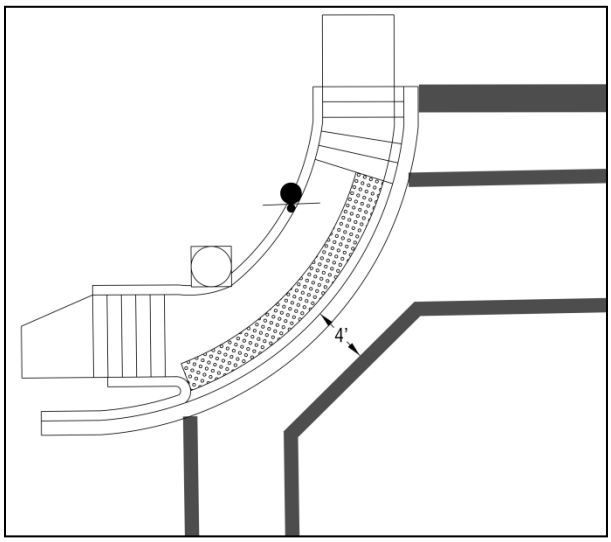


Figure SG. 34 - Crosswalks with Shared Ramp

Sidewalks should be 60” wide, not including the top of curb. Maximum cross slope is 48:1 (~2%). Minimum width at isolated pinch points is 32”, with max length 24” and will require ADA Waiver.

Median cut-through should be 60” minimum in length and 48” minimum in width. If it is less, the median nose should be pulled back to accommodate a full crosswalk. If the median cut-through is raised, the flat area should be 48” x 48” minimum. Crosswalk should be straight and not kinked at the median if possible. Pushbuttons in the median depend on the length of crossing, signal phasing, number of pedestrians width of median, and location specific considerations. Pushbuttons are particularly important for crossings that are part of an alternate pedestrian phase in which the crossing phases are only initiated by pressing a button. The list below contains guidelines indicating when pushbuttons are warranted in medians:

- Median width is greater than or equal to 10’
- Mainline width is 33’ or greater on one side of the median
- Mainline speeds are greater than or equal to 35 mph
- Two pushbuttons should be installed in the median when the width is greater than or equal to 20’
- Pedestrian accident history (particularly 3 or more in 5 years) may warrant median pushbuttons in locations not meeting the criteria above
- Median pushbuttons are NOT to be used for pedestrian phases which are on recall (typically 2 and 6)

The guidelines above are meant to aid designers. However, based on engineering judgement, design request, and district input about actual pedestrian volume and behavior at specific sites, design variations are possible.

Design Waivers

If the aforementioned design criteria cannot be met nor proper APS placement based on the ADA guidelines and MSHA *Book of Standards*, then a design waiver must be submitted. There are two types of waivers: ADA and APS. If ADA guidelines cannot be met, such as the lack of a 5 foot flat landing area, then an ADA waiver should be submitted to OHD for approval. If APS requirements cannot be met, such as placing a pushbutton more than 10 feet from the edge of curb, then an APS waiver should be submitted to the Director of OOTS for approval. A project should not be awarded to Construction until all necessary approved waivers have been received.

Signal Preemption

Signal preemption is used to implement a special sequence or phase of signal indications by responding to an external command. Some of these applications include a firehouse, emergency vehicles, railroad crossings, and transit signal priority. The most common application in Maryland is for firehouse preemption.

When or if signal preemption is required should be determined in the conceptual design. This shall be included on the Design Request. The type of preemption to be used should also be determined. Firehouse preemption is usually designed with hardwiring or the use of an optically activated priority control.

A general rule of thumb is that a pushbutton and hard-wire should be used if the firehouse is within 800' from the intersection, but coordination with the firehouse chief is needed on actuation method. Consideration should also be given to measures to clear queues on the mainline for emergency vehicles access.

Transit signal priority (TSP) is an operational strategy that is applied to reduce the delay transit vehicles experience at traffic signals. TSP involves communication between transit vehicles and signals. The reduction of delays is accomplished through extending greens, truncating reds, altering phase sequences, and including special phases. TSP typically does not interrupt coordination. TSP is initiated using an infrared detector eye and a GPS detector.

Optically Activated Priority Control System

An optically activated priority control system is a system with an emitter and detector used for preemption. The emergency vehicle has an emitter mounted to it that produces pulses of high intensity light that is received by a detector located at the signal. The detector is usually located on top of a signal mast arm. After the detector receives the emission, the message is sent back to the controller and the signal is preempted. This option is good for clear lines of visibility when the emergency vehicles travel a straight path to the signal. The optimal line of sight is 1,500 feet. This eliminates the need for extensive wiring to a firehouse.

Receivers should also be installed at other adjacent signals along the corridor, as well as key intersections within targeted areas to aid in vehicular progression during an emergency.

Hard Wire

Hard wiring is running a direct wire from the signal controller directly into the firehouse. The firehouse is equipped with a pushbutton that is used when signal preemption is needed. This option is good when the firehouse is in close proximity to the signal and visibility may be limited. This is also the common application for rail preemption. Right-of-Way and the potential requirement of easements must be considered for hard wiring firehouse preemption.

Phasing for Preemption

Signal phasing is generally set up one of two different ways for preemption depending on where the signal is located. For most cases, when the signal at or near a fire station is

preempted, the signal will cycle to an all red phase for traffic. Thus, emergency vehicles will be able to leave the station without conflict. The other typical scenario is for signals that are on the same corridor as the fire station. These signals will be preempted such that the mainline (or roadway of which the emergency vehicle will travel) will be phased to green so that cars are flushed through the corridor and the emergency vehicle will not experience delays.

Wiring and Grounding

Once the structures, signal heads and detectors are in place, then the wiring design may begin. The electrical wiring is a key element to proper operation of the signal. The wiring is represented on the wiring diagram included on the general information sheet.

Detectors

Video imaging cameras are wired using a 3 conductor #18 AWG cable that runs from the video detection camera to the controller. This cable is measured by linear feet and no longer comes in pre-manufactured lengths like previous models. The current MSHA approved equipment should be used and the contract items should be verified as the cable may be incidental.

Microloop probes are wired with a continuous run from the probe through the handhole back to the cabinet using a specific cable for the probe. (This is a 4 conductor No. 18 AWG shielded cable with a polyethylene jacket).

Inductive loop wires are formed using a No. 14 AWG wire incased in flexible tubing that is carried to the nearest handhole. From this point, a 2-conductor aluminum shielded (No. 14 AWG) cable is spliced to the inductive loop wire for each loop and is run continuously back to the cabinet.

Signal Heads

Signal heads are wired based on location and number of sections. A 7 conductor is used from the controller to the left most through signal on each approach. A separate 7 conductor is also used from the controller for all 4 or 5 section signal heads as well as all nearside heads. A 5 conductor jumper cable is used from the left most head to the adjacent signal head in the same phase. A 7 conductor cable is used for the 3-section arrows of an exclusive left-turn phase and in this case, a 5 conductor cable is used for the adjacent 3-section ball/permissive heads.

In special cases with 4 or more signal heads, additional cables may be required from the controller to signal heads to allow the signal heads to be monitored separately. As well, when a twin mast arm is installed in the median, the 7 conductor should be run from the upright to the left most signal head of each phase and a 5 conductor jumper can still be used as described above.

Lighting

When intersection lighting is used in conjunction with a signal it requires a 3-conductor No. 12 AWG tray cable. This cable should run directly from the metered service pedestal to each luminaire and should not run through the cabinet.

Signal Preemption

An optically activated priority control system requires the wiring of the optical detector back to the signal cabinet. This application also has a special cable that is a 4-conductor No. 20 AWG (7x28) stranded cable with No. 20 AWG stranded copper wire.

When using a hard wire and push button for signal preemption, a 5-conductor No. 14 AWG cable is used from inside the firehouse to the cabinet.

Pedestrian Signals and Pushbuttons

Pedestrian signal heads (Walk-Don't Walk/Countdown) are each wired using a 5-conductor No.14 AWG cable. The APS pedestrian pushbutton uses a 2-conductor No.

14 AWG cable. These are all run back to the cabinet.

Grounding

Grounding is the act of connecting an electrical circuit to the earth. It prevents the buildup of voltages. This is a key safety step in any design with electrical equipment. In order for mast arm signals and/or pedestal pole foundation(s) to be grounded, a continuous "homerun" ground wire is attached to the steel structure, run to the closest handhole where it is attached to a ground rod and then run back to the cabinet ground source. The handhole lid shall also be grounded where voltage is present.

For span wire designs, ground wire is necessary from each strain pole to a ground rod placed in a nearby handhole. The ground wire also continues from one of these handholes (typically near pole closest to the cabinet) to the cabinet ground source.

For all signals, the handhole closest to the cabinet requires one ground rod. For additional information on the number and location of ground rods at the cabinet and metered service pedestal, refer to the MSHA *Book of Standards for Highway and Incidental Structures*. See figure SG.35 for a grounding diagram.

Interconnect

When signals are interconnected together, either twisted pair or fiber optic cables are used to connect controllers. More details are provided in the Signal Systemization section of this Manual.

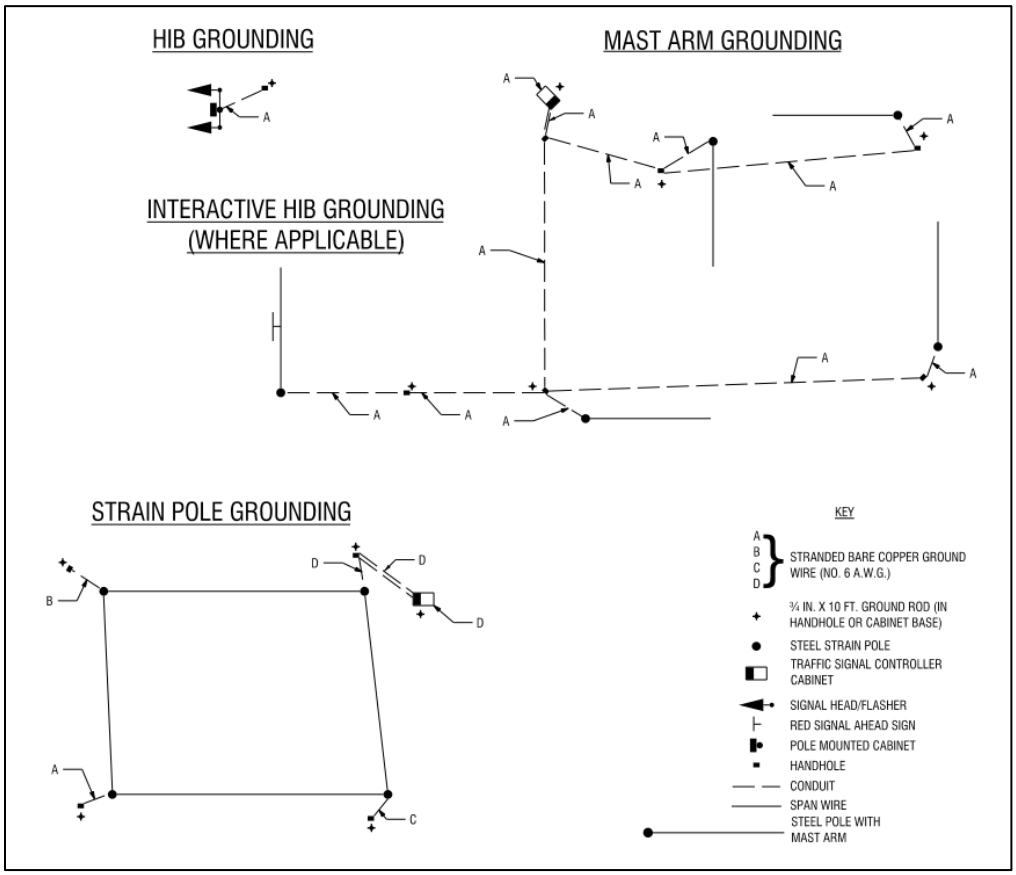


Figure SG. 35 - Grounding Diagram

Conduits and Handholes

Conduits

Conduit acts as duct for electrical cables to run between handholes, controller, pole bases and service equipment. They are also needed as detector sleeves from handhole to edge of travel lane. Conduits come in various materials and sizes. The most common materials are polyvinyl chloride (PVC) and galvanized steel. For most applications with signals, rigid PVC, schedule 80 is used. For applications with loops lead-ins, a non-metallic is used.

Conduit Installation

There are three methods of installing conduits:

1. Trench: Trenching is the most common and least expensive method. Its application is for alongside a roadway to place the conduit in a grassed or dirt area.
2. Slot: Slotting is used to place the conduit in the roadway. The roadway or driveway pavement is cut wide enough to lay the conduit and then the roadway is patched. This method is more expensive than both trenching and boring. It is used where conduit cannot be bored due to utilities or constructability.
3. Bore (directional-drilled): Boring is a method of placing the conduit under the roadway, driveway or other major feature without disturbance. It is typically more expensive then trenching, but less expensive than slotting and requires major equipment. Test pits are required if the bore crosses underground utilities.

Boring is preferred over slotting because interruption to traffic is minimized, damage to the roadway surface/structure is minimal, and the cost is slightly lower. When boring conduits, there must be sufficient room and right-of-way to place the machinery to perform the boring operation. Approximately 20 feet of space is needed in the direction of the conduit and 6 feet laterally. Slotting in pavement is generally acceptable to avoid conflicts with underground utilities.

Other things to consider when choosing the type of conduit installation include:

- Underground utilities (need to test pit)
- Slope (will hand digging be required)
- Sidewalk (need to repair due to trench or bore pit)
- Location of driveways
- Roadway resurfacing (recent or future)

Bends

Bends are used in the signal pole bases and in the base of the controller cabinet. A 3-inch minimum bend is installed in all pole bases, with exception to the pole base closest to the controller cabinet for an intersection with strain poles; one 2-inch and two 3-inch bends should be installed in this pole base. For all new mast arm pole bases, two (2) 3-inch bends should be installed to allow for spare capacity in the future. Conduit should be installed from the bends to the nearest handhole and any unused bends/conduit shall be capped in the handhole. Pedestal poles require a 2-inch minimum bend but a 3-inch bend is usually installed for standard foundations. When a modified pedestal pole foundation is used, a 2-inch bend should be used due to constraints of the breakaway couplings. The controller cabinet requires two (2) 4-inch and two (2) 2-inch bends. Additional conduit bends shall be added appropriately if conduit fill exceeds recommended capacity. Further, an additional 2-inch bend should be installed in the pole base if proposed overhead service is run to the signal pole.

Sizes

The Administration uses four electrical conduit sizes: 1”, 2”, 3” and 4”. The one-inch conduit used is either a liquid-tight flexible non-metallic electrical conduit or a rigid galvanized conduit.

The two, three and four-inch conduits used are all schedule 80 rigid PVC conduits. Determining conduit size is based on the conduit fill capacity and the general use of the conduit. Typically, 4" conduit is used between the handholes closest to the signal poles to "box in" the intersection to allow for future improvements and conduit fill.

Conduit Fill Capacity

The determination of the conduit size should first be based on the capacity of the conduit. The capacity is based on the cross-sectional area of the conduit and the desired percentage of fill. As a general rule of thumb, when designing a new signal it is better to design conservatively to allow for future modifications. Using 25% of the cross-sectional area of the conduit is the desirable maximum for new signals, and 40% is the maximum for rebuilds/modifications. Remember that different conduits have different capacities. For example, the 40% capacity of a 2" schedule 80 rigid PVC conduit is 1.150 sq. in. The most current version of the National Electrical Code should always be followed for determining the fill capacity. Upon request, the designer will provide conduit fill computations.

General Uses

After determining the required capacity of the conduit, some of these general guidelines may be used for deciding on conduit size. Always check the conduit capacity and use it as the final design decision.

- One-inch conduit is used as a detector wire sleeve for the loop wires between the edge of travel lanes and the nearest handhole. A one-inch liquid-tight flexible non-metallic electrical conduit is used for lengths shorter than 6 feet. For longer lengths, a one-inch rigid galvanized conduit should be used. One sleeve is provided for each detector.
- A two-inch conduit is used at pedestal poles with modified breakaway foundations, between the cabinet and metered service pedestal, between the metered service pedestal and closest handhole for lighting cable, and between the cabinet and closest strain pole.
- Three-inch conduit is used between the signal/pedestal pole and handhole as well as between handholes to transport detector lead-in wires and signal cables. For intersections with strain poles and span wire, the Administration requires a minimum of two three-inch conduits to the pole that is closest to the controller cabinet. When video detection is added, there should be one four-inch and one three-inch conduit to the pole closest to the controller cabinet. Similarly, for intersections with mast arms which have a significant amount of equipment installed on the pole/arms (typically for twins) such as multiple heads, lighting, pedestrian signals, video detection, etc., a four-inch conduit should be used instead of one of the three-inch conduits based on fill capacity calculations. Three-inch conduits are also used for interconnection, under driveways and non-invasive microloop probes.
- Two four-inch conduits shall be installed between the controller cabinet and the closest handhole. A four inch conduit is also used from the metered service pedestal to the power source; size of conduits for service is dictated by the power companies, and for all underground road crossings (slot or bore). When an intersection is "boxed in," often to provide additional capacity for future use, four inch conduit should be used. Some jurisdictions may request that two four-inch conduits are used in this case such as in Montgomery County. If this request is made, discuss with TEDD Project Manager before incorporating into the design.

Handholes

Handholes, also known as junction boxes, are small concrete boxes placed underground with a steel lid. They are used as a point for cable to enter where it may be spliced or change direction. The only splice points are when loop wire is spliced to the home run cable and for ground mounted HIBs. The use of handholes with signal design is critical. Handholes should be placed near each signal pole, at the cabinet, where a change in direction is necessary for the cable and at a point where the detector wire can easily be installed. New signal designs should use the MSHA standard for an oversized handhole closest to the cabinet. On long conduit runs the maximum distance between handholes is 200 feet to accommodate the pulling of underground cables. However, if HDPE Roll Pipe is used instead of PVC conduit (with approval from TEDD), the spacing between handholes can be increased to 500'. Handholes should be placed on both sides of a bore or slot and should not be placed at a low point where they could collect water.

During field inspections, existing handholes should be inspected and a determination should be made, whether or not it can be reused. A maximum of eight conduits total (max. of four 4" conduits) can enter a standard handhole, so the number and size of existing conduits in the handhole should be observed as well as the condition of the foundation, presence of water, and amount of cables present.

Cabinet and Controller

Type of Cabinet

The signal cabinet is the housing for the controller. The location and type should be determined during the early stages of design once the pole layout has been developed and the power source has been identified. There are two major types of signal controller cabinets: pole mount and base mount. Pole mounted cabinets are attached to the signal structure, either a strain pole or mast arm pole, and are smaller in size. The base mounted cabinet is located on the ground with a concrete foundation and concrete pad in front of it. The preferred cabinet is a base mount, although insufficient space, topography or other extenuating circumstances may dictate the choice. The table below outlines the types of cabinets and their applications. The type of cabinet to be used should be determined at the conceptual design stage.

Table SG. 9 - Types of Cabinets and Their Uses

Type of Cabinet	Pole vs. Base Mounted	Uses/Notes
G Cabinet	Pole	Used for HIBs (passive and active); only allows 2 phase outputs from controller but no load switches. Phase outputs can be used to activate flashers.
NEMA Size 5	Pole	Temporary signals; signals where space is restricted
	Base	Signals where space is restricted
NEMA Size 6	Base	No longer used for new signals.
Type S	Base	Preferred for all new signals and should be installed with extension base and concrete pad in front and rear.

Location of Cabinet

It is most desirable to locate the cabinet as far off the travel edge as possible, outside the clear zone. The same considerations from the AASHTO's Roadside Design Guide apply to locating the cabinet as with the signal structures. Some further factors to consider when selecting the location of the cabinet include:

- Does the location permit safe access by maintenance?
- Does the maintenance personnel have a clear view of the intersection when facing the cabinet?
- Is the cabinet conveniently located near a power source?
- Is the cabinet out of the path of errant vehicles? Does it need to be protected?
- Are two conflicting signal indications visible from the cabinet location?
- Is the cabinet restricting driver visibility? (Corner sight distance, for traffic using the intersection)
- Sufficient right-of-way to permit ready access.
- Avoid susceptibility to run-off-the-road accidents.
- Proximity to interconnect conduit system.
- Avoid blocking ADA path.

Controller

The signal controller is the heart of the signal. It controls, monitors and operates the signal. MSHA uses only sixteen-phase, fully actuated controller units. The controller unit is composed of several elements for optimal performance. MSHA uses NEMA TS-2 standards for its controllers and components. The latest MSHA approved controller model should be used in all new cabinets.

Figure SG. 36 - Signal Controller

Figure SG. 37 - Typical Signal Cabinet (Size 'S')

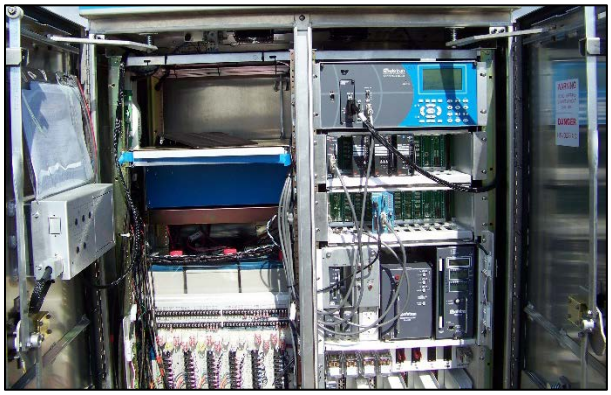


Figure SG. 38 - Typical Signal Cabinet (Size 'S')

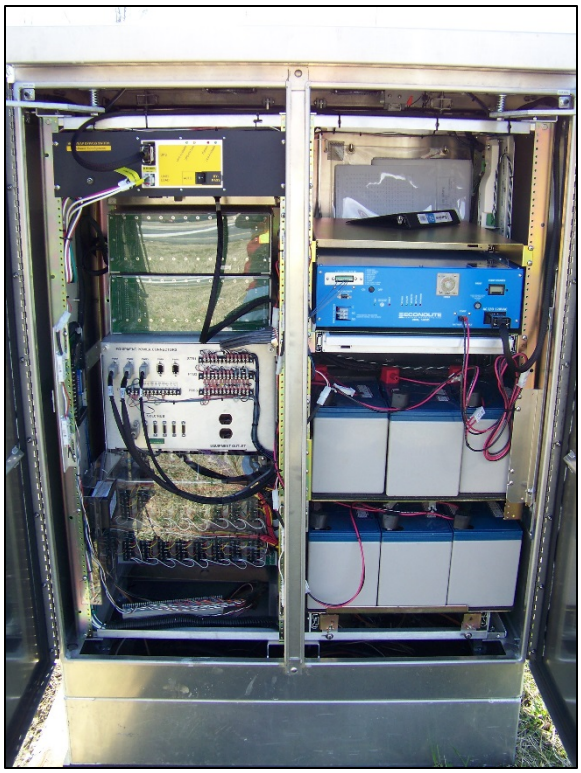


Figure SG. 39 - Typical Signal Cabinet with UPS (Size 'S')

Auxiliary Equipment

Every controller cabinet is equipped with auxiliary elements in addition to the main controller such as the conflict monitor. Additional auxiliary elements that MSHA uses on an as needed basis are also listed below.

1. Malfunction Management Unit (MMU): The MMU is also known as a conflict monitor. A MMU is designed to detect and respond to improper and/or conflicting signal operation and improper operating voltages. This includes such things as power failures, flashing operation failure, controller timing, detector status, alarms, cycle failure and voltage. MSHA includes an MMU with battery back-up for most of their projects. Some of these units are now incorporated into the main controller.

2. Detector amplifier: The detector amplifier is used to pass information from the detector to the controller. It indicates things such as passage versus presence and the condition of the detector. The detector amplifiers may also be used for counting. MSHA typically uses 4-channel, rack-mounted amplifiers. Each detector is represented by one channel, for example, if there is a signalized intersection with 8 different inductive loops and/or microloop probes (passage and presence) then this controller would need two 4-channel amplifiers.

3. Video Detection Interface Equipment: The video detection interface equipment works with the video detection cameras and the signal controller to relay information and call and/or extend phases as needed based on the detection.

4. 2-Wire APS Central Control Unit: The APS Central Control Unit controls the pedestrian phases and is connected to the pushbuttons and pedestrian signal heads. Each Central Control Unit can accommodate four channels or phases. Each channel can have a maximum of four pushbuttons, meaning that each Central Control Unit can accommodate a maximum of 16 pushbuttons.

Figure SG. 40 - 4-Channel Vehicle Detector Amplifiers

Special Notes

Maryland SHA furnishes all of the cabinets and controllers for their signalized intersections, except in the case of a developer/other funded project in which they are supplied by the

contractor and wired by the shop. Other special cases are as follows:

- Cabinets for Montgomery County are to be sent to the Montgomery County Signal Shop, not MSHA, for wiring and testing.
- Special relay packages are used for two signals that are interconnected as a master/slave operation (with TEDD approval).

Power and Communication

Power Service

Like any other computer or system, the signal controller needs power. A location for a power feed should have been identified during the field work. The requirements for connecting electrical power from the local utility lines to signal equipment may vary among utility companies. Service connections normally consist of a single-phase circuit of 120/240 volts, 60 Hz and 60-200 ampere (30 ampere for HIB) service (depending on the utility company) connected to the nearest source of power. The power source location shall be confirmed with the power company during design by means of a Power Location form letter with copies of the plan attached and power feed location highlighted. However, some power companies, such as BGE and Potomac Edison, require applications to be completed. The final request for service is done during construction. If an existing power feed is being removed, the meter number should also be provided to the power company with the service request.

The service point may be from either an overhead or underground power line. Power may be pulled from base mounted transformers or pole mounted transformers. The method required by BGE and preferred by some power companies is to use a 200 Amp metered service pedestal with underground service between the power source and the cabinet for new power drops. However, other companies, such as PEPCO still use 100 amps in some situations to avoid having to furnish 250 kcmil cables. Service equipment (meter socket and disconnect switch) on older signals is mounted on the back of the cabinet, but this is not preferred on new installations. Also, service equipment is sometimes mounted on the pole for overhead service.

The Table SG.10 shows the specific equipment requirements necessary for power service feeds for each power company.

Table SG. 10 - Power Service Requirements by Utility Company

Utility Company	Size of Conduit from MSP to Utility Pole	Cable Notes	Notes
Pepco	4"	3 - 1 Conductor (250 kcmil) for 200 amp service No. 2 AWG Copper or 2/0 Aluminum for 100 amp service	Install 35' slack (each cable) coiled at base of utility pole. A 'work with' is necessary with Pepco for installation to prevent theft or damage of the cable. However, Pepco will install the cable when the source is a base mounted transformer.
BGE	4"	Power Company to Install	Schedule 40 conduit with pull string to be used from the MSP to the Utility Pole. Any handholes or manholes between the utility pole and the MSP must be BGE approved pullboxes.
Potomac Edison	3"	Power Company to Install	Install conduit with pull string
Delmarva	3"	Power Company to Install	Install conduit with pull string
Choptank		Power Company to Install	Install conduit with pull string, verify conduit with power company
SMECO	3"	Power Company to Install	Install conduit with pull string
Conowingo	3"	Power Company to Install	Install conduit with pull string

Uninterrupted Power Supply (UPS)

To prevent down time (or unnecessary activation of flash mode) at signals in the event of a power outage, MSHA is installing UPSs, also known as battery backups, at targeted intersections. The UPS will allow the signal to remain operational for a short period of time until maintenance crews are able to restore power. UPSs shall be installed at locations fitting the following criteria:

- Railroad pre-emption
- Airport obstruction lights (aircraft warning beacons)
- Military base entrances
- Interstate, US route, and State route ramps
- Multi-intersection controller units
- Single point control intersections
- TSSM Hubbette
- System master controllers
- Interactive advance warning beacons (i.e. HIB for red signal warning)
- Multiple left or right turn lanes in same direction
- Unusual geometrics
- Other Agency/Local Jurisdiction Initiatives

Communication

Maryland SHA uses cellular modems to provide wireless, high speed data communications to maintain and operate the signals. MSHA uses the Centracs central management system software in order to monitor and manage traffic signal assets. Centracs allows the use of an Adaptive traffic signal timing module in locations warranted by MSHA and also allows a nearly unlimited number of traffic signals to be coordinated. All new signals should use wireless communications and any modifications or reconstructions of existing signals should implement wireless communications if they do not already exist at the location. However, it should be noted that signals that are managed or maintained by local jurisdictions rather than MSHA, may use other communication sources and methods.

Wireless communications should be considered during the design phase of a project. The location of the cellular antenna should be carefully considered and shown on the signal plans. The antenna should be located in the area with the best possible cellular signal strength. Some preferred antenna locations include areas with higher elevation, close proximity to interstate roadways, and areas away from any buildings or structures that may block signals. Typically, the antenna should be installed on a mast arm pole or strain pole in the same quadrant of the intersection as the cabinet.

The design should also include cellular antenna lead-in cable and conduit. The preferred maximum length for the lead-in cable is 125 feet using a 400 series coax cable. This maximum length also includes the height of the pole or structure on which it is mounted. When designing the lead-in cable and conduit, the capacity of the conduit must be confirmed. The 400 series coax cable has a diameter of approximately 0.53 inches. If an antenna location cannot be found to meet the maximum length of 125 feet, a larger coax cable may be required. However, this should be brought to the attention of the TEDD project manager and discussed as early in the design process as possible. At signal locations where cellular strength is poor and no other options exist for antenna placement, larger antennas may be considered and should be discussed with the TEDD project manager and with the Office of Information Technology (OIT).

During the construction of a project involving the installation of wireless communications, MSHA will furnish the cellular antenna and the cellular antenna lead-in cable to be installed by the contractor. MSHA will furnish and install the cellular modems and Ethernet switches. As wireless communications are implemented, TOD will request the disconnection of existing phone drop communication service.

The use of Centracs for interconnected signals is described in the following systemization section. Further information about Centracs can be found in the MSHA memo titled "Centracs Advanced Transportation Management System (ATMS) Implementation and Design Guidance for Traffic Signals."

SIGNAL SYSTEMIZATION

A signal system is interconnecting two or more signals along a roadway or network of roadways. There are two basic types of signal systems, open-loop system and closed-loop system.

An open-loop system operates the intersection controller, but does not receive feedback status. It may operate with a master controller that supervises the cycle length, offsets and splits for each signal or it may operate without a master controller as a coordinated system of intersections. An example of this is where GPS time receivers are installed in each cabinet of their 'system' without hardwire interconnect. The coordination is maintained using Time of Day coordination plans and syncing the clocks using the GPS receivers. This is done in areas where it is not physically possible to run hardwire interconnect.

A closed-loop system provides two-way communication between the intersection controller and the signal shop via the cellular modem and wireless antenna dedicated to the system. This communication used to be performed by an on-street master controller. With a closed-loop system, the traffic signal central management software at the signal shop will receive and respond to diagnostic information such as speed, density, volume and capacity.

If existing hardwired interconnect is present at an intersection/along a corridor that is being modified or reconstructed, the entire system of interconnected signals should be upgraded to implement wireless communications. When existing interconnect is present, the proposed design should be constructed without causing any down time to the existing system. In some cases, temporary interconnect may be required for this to be achieved.

A signal system has three major components in the design process:

1. Controller (as described in prior sections of this manual)
2. Communication Links
3. System Detection (as described in prior sections of this manual)

Wireless Communications

A cellular modem, antenna, and lead-in cable is required at one signal within an interconnected system. The antenna and lead-in cable design for this signal should be the same as described in the communication section above. The location can be anywhere within the system that would provide the best possible cellular signal strength. For all interconnected systems that have not been upgraded to wireless communications, the first project to occur at a signal within the system must convert all locations within the system to be compatible with the traffic signal central management software (Centracs). The on-street master controller will no longer be used with Centracs and should be called for removal by MSHA as part of the Centracs conversion.

Signals within a system that do not have a cellular modem and antenna must have an Ethernet switch installed in the cabinet to

connect to the fiber or twisted pair copper cable. In locations where two interconnected systems cross, the cabinet must include two Ethernet switches.

Communication Links

In order to implement a signal system, the local intersection controllers must be interconnected via communication links. Communication links may be designed using several different techniques. Some of these may include:

- Cable
- Wireless
- Leased CATV Cable Channels
- Switched Telecommunication Service

Wiring

While Maryland now uses wireless communications to connect to the signal shop, cable is used for its communication links. Two common types of cable are twisted pair and fiber optic. Cable may be run overhead or underground.

Interconnect cables are generally 12-pair jelly-filled, No. 19 A.W.G., for underground installations and/or 12-pair self-supporting, No. 19 A.W.G., for overhead installations. The decision to install interconnect cables underground versus overhead should be based on cost and constructability. If both underground and overhead installation is necessary, a 12-pair self-supporting cable is used throughout the entire run. Other types and sizes of interconnect cable may be requested by a local jurisdiction such as 50-pair cable in Montgomery County. Interconnect cable is not typically spliced, with the exception of Montgomery County where interconnect may be spliced with splice kits (rather than splice boxes) with approval from the Administration and the County.

Underground

When the design incorporates underground communication links, PVC conduit is used as with signalized intersections

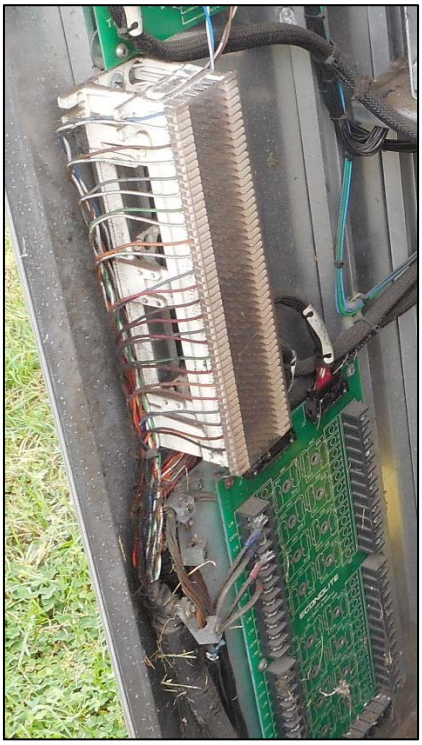


Figure SG. 41 - 12-Pair Interconnect Cables

Overhead

An overhead utility company attachment agreement is required if interconnect cables are to be placed on telephone, electric company or joint use poles.

Overhead attachment details should be shown on the plan to indicate how the interconnect cables should be installed, e.g., face of pole, height, support and clearance from other utilities and overhead clearances over driveway entrances. This element of the design can be the most critical aspect of the project. The Designer is responsible for the coordination of the overhead attachment agreement and any adjustments required with the owners of the overhead utilities. Where cable transitions from overhead to a pole mounted cabinet or to underground conduits, a

riser should be installed on the utility pole in accordance with owner requirements.

SIGNS

A signal plan may include some signing when designed independent of a signing and marking plan. The types of signing to be installed will be as indicated in the Design Request, and/or as required for proper operation of the intersection. The placement of the sign should take into consideration the size of the sign, position over travel lanes and offset from the nearest signal head to the edge of the sign plate. When installing a sign on the mast arm (overhead), the designer should maintain a 17' clearance from the bottom of the sign to the roadway. Associated signs may include:

- Overhead Street Name Signs – D-3(1) signs are typically installed on all legs of an intersection. They are mounted near left and far right, dual-faced. When the intersecting street has different names on either side of the intersection, the left side street name is shown on the left sign, and the right side street name on the right sign. Street name signs should have a maximum height of 20" on span wires, be installed back to back on mast arms if height is over 20" and dual faced if height is 16" or 20".

- Route Marker Assemblies – At intersections along numbered routes, an associated shield assembly is mounted near right and far left facing the minor street traffic. Preferably, the assembly should be mounted on the signal support upright, installed parallel to the main road. When this is not feasible, the assembly (on one sheet aluminum panel with a black background) is mounted on wood sign supports instead, as shown in Figure SG. 42 - Route Marker Assemblies at Signalized Intersections. Based on dimensions in the MSHA Sign Standard Book, a standard sized associated shield assembly should be used for nearside (right arrow) signs and oversized signs should be used for far side (left arrow) signs.

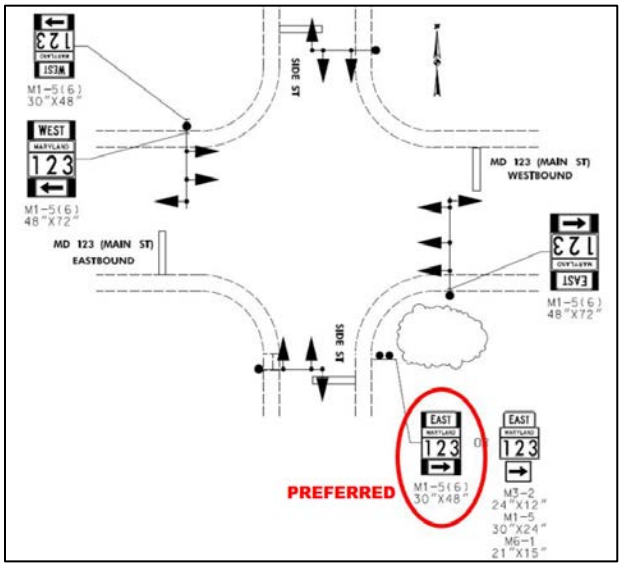


Figure SG. 42 - Route Marker Assemblies at Signalized Intersections

- Signal Warning Signs – Signal ahead symbol (W3-3) sign(s) shall be installed on the approach to an intersection when the signal visibility requirements listed in the MdMUTCD cannot be met and for all new signals. A single sign will be used on two-lane, two way and multilane, undivided roadways. Two side-by-side signs, one on the outside and one in the median, will be used on divided highways. The sign(s) shall be located in accordance with the latest approved version of the MdMUTCD. For advance placement of warning signs, use the 85th percentile speed.

  For new signals, a W16-14(1) "NEW" panel should be mounted above the W3-3 sign panel with two flags mounted midway along the top sides of the sign panel on both mainline approaches. These signs are also required on side road approaches with speeds over 35 MPH. The flags and new panel will remain in place for a period of 90 days at which time MSHA District Forces

will remove them. If the W3-3 sign is not warranted, the District should remove it as well.

- Advanced street name signs should be installed on all approaches where a State route intersects another State route, whether signalized or not. They should also be installed along the State route in advance of a signalized intersection between a State route and a local road. Advanced street name signs should be white on green, except where a W3-3 sign is permanently required. In this case the sign should be black on yellow and installed on the same supports as the W3-3 sign.
- Lane Use Control Signs – R3-5 through R3-8, when used shall be placed on the far side of the intersection, centered over the center of the lane(s) or a projection of the lane(s) to which it applies, according to MdMUTCD guidance.
- Other Signs – Additional regulatory and warning signs should be installed, as appropriate, for control of the intersection. Such signs include “no turn on red” and pedestrian warning signs. The sign(s) shall be located in accordance with the pertinent section of the MdMUTCD.

When a STOP controlled intersection is being converted to signalized control, the contractor shall be instructed, through the Construction Details, to remove the STOP signs immediately after the signal becomes operational.

PAVEMENT MARKINGS

A signal plan may also include some pavement marking design when designed independent of signing and marking plans. The types of pavement markings to be installed will be indicated in the Design Request. They may include crosswalks, stop lines, message/arrow markings, lane lines, channelizing lines, edge lines, and the removal of existing markings. The Designer is responsible for detailing new pavement markings to a point where they can be transitioned into the existing markings.

LIGHTING

Lighting as part of a signal design is termed intersection lighting. All signal designs should include intersection lighting. This is lighting typically attached to the signal poles via a bracket arm. Available luminaire arm lengths are 10 feet, 15 feet, and 20 feet. The lighting is wired directly to the luminaire from the metered service pedestal and bypasses the cabinet. In other cases, intersection lighting may be accomplished by leased lighting in situations where adequate space on a signal pole is not available or where overhead utilities would conflict. All new luminaires shall be LED and all existing non-standard lighting should be upgraded to LED luminaries as part of a signal modification. . Refer to the MSHA Lighting Guidelines for more information on adding lights to signal poles.

PLAN PREPARATION

Developing a Concept Layout

A conceptual layout or preliminary design is developed before the final signal plan is designed. A concept shall be developed for both individual signalized intersections and signal systems. Based on discussions at the field PI meeting, the designer will develop what he feels is the desired layout prior to completing a design. This conceptual design sets the foundation for the signal design. Although conceptual layouts are typically not submitted to TEDD for distribution, the designer can seek input from the parties involved including the project manager, team leader and district traffic office as a confirmation of decisions made in the field.

The goal of the conceptual layout is to put on paper what the designer feels is the desired configuration of the major signal components including the poles, cabinet and signal heads.

The focus should be on the type, configuration and placement of signal structures to be used, type of controller cabinet, which quadrant will best suit the cabinet, how the signal heads should be configured, what type of detection should be used and are there any special design considerations such as a hazard identification beacon (HIB), intersection control beacon (ICB), signal preemption, etc. It is also important to ensure that an existing signal will remain operational during all proposed construction.

Reviewing the Preliminary Design

Whether the conceptual layout is submitted to TEDD for review or not, the designer should resolve any conflicts or issues at this point to eliminate the need for change after final design. Typically, designs are not submitted to TEDD for review until Final Review, however, for more complex designs, the TEDD Project Manager may want to review a preliminary layout.

The following items should be considered when reviewing a conceptual signal layout:

1. Check that the signal meets the requirements of the Design Request.
2. Check that the signal is not in conflict with any utilities and within Right-of-Way.
3. Check for the power feed source.
4. Check for any special design considerations such as HIBs, pedestrians and ADA requirements, bikers, preemption or interconnection.
5. Check that the signal will work as a system with the roadway, signing and marking.
6. Check for overall concurrence with Federal, MDMUTCD and MSHA standards.

After the conceptual layout has been reviewed, the design then moves to final design. Final design is the core of the project. This involves finalizing layout, operation, quantities, specifications, and estimate, and developing a Final Review plan set to be submitted to TEDD for review and distribution. Once comments are received on the Final Review plan set, a PS+E package is prepared for OOTS approval.

Signal Plan Sheet

Signal Plan Sheet Elements

The plan sheet consists of the following:

- North Arrow and North Arrow Note
- Sign Displays
- Non-standard sign details
- Signal Displays
- NEMA Phasing Diagram
- Construction Details
- General Notes
- APS Notes (Where Applicable or within General Notes) A 10 scale blow up should be provided for any corners requiring APS/CPS and ADA changes. The blow up should contain all ramp details. If there is not enough room on the sheet to show the required blow ups of the corners, an additional sheet should be provided.

See sample plans for examples and the TEDD design Checklists for additional plan attributes.

North arrow is typically oriented above the horizontal axis, and the assumed direction of the major street is generally based on the MSHA Highway Location Reference. It is important to verify this at the very beginning of design since the signal head numbering and signal phasing are both dependent on the plan orientation.

Signal head numbering on plan sheets should follow the following criteria:

- Mainline signals are numbered first starting with either signal heads facing northbound traffic or eastbound traffic
- Minor roads are numbered after mainline roads following the same rules (starting with northbound or eastbound traffic)
- Signal heads are numbered in increasing order from left to right
- Near side signal heads are numbered first on each approach
- Pedestrian heads and signs are numbered last using the same rules

Construction Details

These notes are used to convey information about how the signal equipment is to be installed or removed. They are identified in alphabetic order starting with "A." If there are more than 26 notes, use AA, BB, etc. Construction details have associated callouts on the plan that consists of an arrow pointing to the specific area of work and includes the corresponding letter inside a shape, such as a circle around them. The shape used for callouts should match the shape used around the revision letter in the title block. The same letter may appear in more than one callout. For example, the letter for "Install handhole" will appear as many times as there are new handholes. If there is insufficient space on the plan sheet for the Construction Details, they may be shown on the General Information Sheet.

NEMA Phasing

Phasing is assigning the Right-of-Way and combination of one or more movements that can occur concurrently during a cycle. MSHA uses the standard National Electrical Manufacturers Association (NEMA) phasing for signal operation.

The phase numbering and sequencing are shown diagrammatically in the upper right-hand corner of the plan sheet. It allows the designer, contractor and MSHA to know the operation of the signal. Some of this information is obtained from the DR. The DR usually indicates if there are any exclusive or exclusive permissive movements or any special phasing. This can be used as the starting point for designing the phasing. Below is the standard convention used to determine phase numbering as adopted by MSHA. Additional examples of NEMA phasing diagrams based on different orientations of the north arrow can be obtained by request from TEDD. Phases associated by a dashed line may operate concurrently. Phases associated by a solid line will not operate concurrently. Further, the arrow heads should be solid if there is a proposed change to that phase and should be hollow if no change is being proposed to an individual phase. If the signal has lead/lag phasing for turning movements, the appropriate phase number should be identified as being either "LEAD" or "LAG", and the lead/lag phasing should be noted in the phasing notes under the phasing diagram by stating "Phase X will lag behind Phase Y".

A split phase is the operation of opposing movements at separate times. For example, the northbound and southbound traffic move simultaneously, then the eastbound traffic proceeds and last is the westbound traffic. The eastbound/westbound traffic is considered a split phase. If the side street phasing is split, the side streets use Phases 3 and 4 only. The side street approach movement with the heavier volume should be designated as Phase 4. Further, at a 'T' intersection, the side street is always Phase 4 as well.

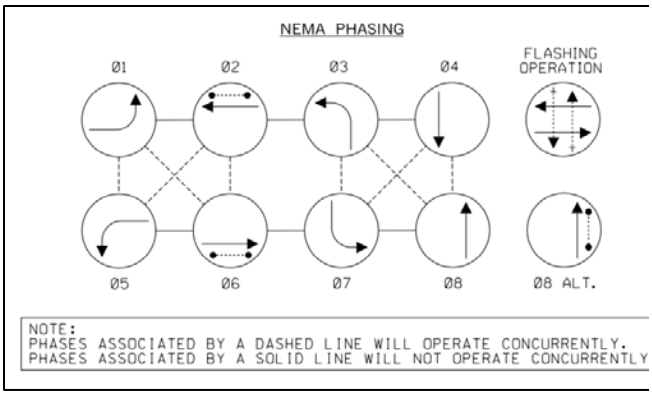


Figure SG. 43 - NEMA Phasing

Use the following NEMA Phasing Number Convention unless otherwise instructed by the TEDD PM:

- Major street
  - Left turn signals (phases 1 and 5)
  - Thru signals (phases 2 and 6)
- Minor street
  - Left turn signals (phases 3 and 7)
  - Thru signals (phases 4 and 8)

General Information (GI) Sheet

Project Description

This section is used on all projects to describe the type of work that is planned, interconnect and other special design considerations, the location, directional assumptions, intersection operation, APS operation and notes, controller requirements, and the need to arrange for cellular communication installations.

Project Contacts

The names and titles of Administration and non-Administration personnel with phone numbers and addresses are provided, as appropriate. At a minimum, the following personnel are identified:

- Assistant District Engineer – Traffic
- Assistant District Engineer – Maintenance
- Assistant District Engineer – Utilities
- Chief, Traffic Operations Division
- Chief, Signal Operations Section
- Chief, Sign Operations Section
- Utility Company Representative (with utility work order number)

Phasing Chart

The phasing chart identifies the status (whether the green, yellow or red is visible) of each signal head for each phase. Symbols for movements should be shown as filled for proposed or unfilled for existing, unchanged movements/phases in the right most column of the phasing chart. An example of a phasing chart is shown on the following page.

Wiring Diagram

The wiring diagram shows electrical cable routing for proposed and existing signal heads, luminaries, detectors, pushbuttons, power, communications/interconnect, ground wire and controller cabinet. See wiring section for specific details. A north arrow should always be shown with the wiring diagram and with the phasing chart.

APS Special Notes

The APS special notes and messages should be included on the GI Sheet. If they are not included on the GI sheet, they can be included on the Detail Sheet instead if provided.

Equipment List

Equipment to be furnished, installed and salvaged are broken down into three lists:

- Equipment List A - supplied by the Administration. These include but are not limited to detector amplifiers, controller, cabinet, video detection interface, intersection monitor and sheet aluminum signs (including

hardware). For developer, design-build and local/state agency signal projects, it is the applicant's responsibility to furnish and install all materials for traffic signal work. Catalog cuts must be submitted and accepted for all materials prior to their installation. All new controllers and cabinets shall be delivered to the Chief Signal Operations Section a minimum of 21 days prior to their installation for wiring and testing.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
PHASE 1 + 5	←G—	←G—	←G—	R	R	←G—	←G—	R	R	R	R	R	R	R	R	R	R	R	DW	DW	DW	DW	DW	DW	DW	DW
1 + 5 CHANGE TO PHASE 1 + 6, PHASE 2 + 5, OR PHASE 2 + 6																										
PHASE 1 + 6	←G—	←G—	←G—	G	G	R	R	R	R	R	R	R	R	R	R	R	R	R	DW	WK	WK	DW	DW	DW	DW	DW
1 + 6 CHANGE	←Y—	←Y—	←Y—	G	G	R	R	R	R	R	R	R	R	R	R	R	R	R	DW	WK	WK	DW	DW	DW	DW	DW
PHASE 2 + 5	R	R	R	R	R	←G—	←G—	G	G	R	R	R	R	R	R	R	R	R	WK	DW	DW	WK	DW	DW	DW	DW
2 + 5 CHANGE	R	R	R	R	R	←Y—	←Y—	G	G	R	R	R	R	R	R	R	R	R	WK	DW	DW	WK	DW	DW	DW	DW
PHASE 2 + 6	R	R	R	G	G	←R—	←R—	G	G	R	R	R	R	R	R	R	R	R	WK	WK	WK	WK	DW	DW	DW	DW
PED. CLEARANCE	R	R	R	G	G	←R—	←R—	G	G	R	R	R	R	R	R	R	R	R	FL/DW	FL/DW	FL/DW	FL/DW	DW	DW	DW	DW
PHASE 3 + 7	R	R	R	R	R	←R—	←R—	R	R	←G—	←G—	R	R	←G—	←G—	←G—	R	R	DW	DW	DW	DW	DW	DW	DW	DW
3 + 7 CHANGE TO PHASE 3 + 8, PHASE 4 + 7, PHASE 4 + 8, PHASE 3 + 8 ALT, PHASE 4 ALT + 7 OR PHASE 4 ALT + 8 ALT																										
PHASE 3 + 8	R	R	R	R	R	←R—	←R—	R	R	R	R	R	R	←G—	←G—	←G—	G	G	DW	DW	DW	DW	DW	DW	DW	DW
3 + 8 CHANGE	R	R	R	R	R	←R—	←R—	R	R	R	R	R	R	←Y—	←Y—	←Y—	G	G	DW	DW	DW	DW	DW	DW	DW	DW
PHASE 4 + 7	R	R	R	R	R	←R—	←R—	R	R	←G—	←G—	G	G	R	R	R	R	R	DW	DW	DW	DW	DW	DW	DW	DW
4 + 7 CHANGE	R	R	R	R	R	←R—	←R—	R	R	←Y—	←Y—	G	G	R	R	R	R	R	DW	DW	DW	DW	DW	DW	DW	DW
PHASE 4 + 8	R	R	R	R	R	←R—	←R—	R	R	R	R	G	G	R	R	R	G	G	DW	DW	DW	DW	DW	DW	DW	DW
4 + 8 CHANGE	R	R	R	R	R	←R—	←R—	R	R	R	R	Y	Y	R	R	R	Y	Y	DW	DW	DW	DW	DW	DW	DW	DW
PHASE 3 + 8 ALT	R	R	R	R	R	←R—	←R—	R	R	R	R	R	R	←G—	←G—	←G—	G	G	DW	DW	DW	WK	WK	DW	WK	WK
3 + 8 ALT CHANGE	R	R	R	R	R	←R—	←R—	R	R	R	R	R	R	←Y—	←Y—	←Y—	G	G	DW	DW	DW	WK	WK	DW	WK	WK
PHASE 4 ALT + 7	R	R	R	R	R	←R—	←R—	R	R	←G—	←G—	G	G	R	R	R	R	R	DW	DW	DW	DW	DW	WK	DW	DW
4 ALT + 7 CHANGE	R	R	R	R	R	←R—	←R—	R	R	←Y—	←Y—	G	G	R	R	R	R	R	DW	DW	DW	DW	DW	WK	WK	DW
PHASE 4 ALT + 8 ALT	R	R	R	R	R	←R—	←R—	R	R	R	R	G	G	R	R	R	G	G	DW	DW	DW	DW	WK	WK	WK	WK
PED. CLEARANCE	R	R	R	R	R	←R—	←R—	R	R	R	R	G	G	R	R	R	G	G	DW	DW	DW	FL/DW	FL/DW	FL/DW	FL/DW	FL/DW
4 ALT + 8 ALT CHANGE	R	R	R	R	R	←R—	←R—	R	R	R	R	Y	Y	R	R	R	Y	Y	DW	DW	DW	DW	DW	DW	DW	DW
FLASHING OPERATION	FL←R-	FL←R-	FL←R-	FL/Y	FL/Y	FL←R-	FL←R-	FL/Y	FL/Y	FL←R-	FL←R-	FL/R	FL/R	FL←R-	FL←R-	FL←R-	FL/R	FL/R	DARK	DARK	DARK	DARK	DARK	DARK	DARK	DARK

Figure SG. 44 - Sample Phasing Chart

- Equipment List B – furnished and/or installed by the Contractor. Construction items are obtained by reviewing the construction details and wiring diagram and making sure all materials and equipment are included. Their formats may vary by contract type, as some items are incidental to other items especially in Areawide projects. Additional items must be included but do not appear elsewhere in the construction details or on the wiring diagram. They may include test pit excavation and maintenance of traffic.
- Equipment List C – to be removed by the Contractor and delivered to MSHA. If the existing controller equipment is being replaced, the existing controller and auxiliary equipment are to be returned to OOTS. If the signal is maintained by Montgomery County, it shall be returned to the Montgomery County Signal Shop. All other equipment shall become the property of the Contractor.

PREPARATION OF AS-BUILTS

As-Built traffic signal plans document the operational and physical conditions of newly constructed traffic signals. As-Built plans are required for all construction activities that change the functional operation of the intersection.

The physical and operational elements of an As-Built plan should include accurate field verification of the following:

- Location of traffic signal equipment (poles, handholes, cabinet and conduits).
- Location of detectors and lead-in cables.
- Location and type of pavement markings.
- Location of signal heads on mast arms or span wires.
- Location of intersection signing and lighting.
- Clearances to overhead utilities.

With As-Built plans, the Construction Details from the original signal plan sheet should be updated to be labels rather than action items. For example, if the symbol (E) on the original plans said “Install Handhole”, the symbol (E) on the As-Built plan would simply say “Handhole”.

An As-Built plan consists of a single plan sheet and contains the following information:

- NEMA phasing chart.
- Existing signs and signals.
- Wiring diagram and a wiring key (placed on the right-hand side above the title block).
- Legend of geometrics and utilities.

For developer, design-build and local/state agency signal projects, it is the applicant’s responsibility to furnish the Project Manager with an electronic copy of the as-built plans, documenting any significant changes from the approved design, in the latest MicroStation format approved by MSHA.

LIGHTING DESIGN

LIGHTING DESIGN

DATA COLLECTION

Office data collection is the first step in designing lighting. Collecting data, base mapping (obtaining or developing a base plan) and field review apply to any type of lighting. This is the time when the designer gathers information, collects existing data from outside sources, visits the project site and looks at potential design options.

Office Data Collection and Preparation

Before preparing a design, the Designer should collect preliminary data and research existing records to develop the base plan and subsequently proceed with a conceptual design. For example, the Designer can research MSHA files for as-built plans, highway design plans, right-of-way plats and utility plans. Although all of the as-built information may not be available or completely accurate, the Designer should do this research to gain information on the history of the location. The designer could also check with the District for existing plans.

The District office should initiate the Design Request (DR) for lighting design projects, and thus may have some background information on the project. Again, although this information is shown in the DR, the Designer can gain insight on the location, history, problems and recommendations by contacting the preparer of the DR.

Another element for collecting office data is any proposed work being done. If the project is an insert job to a highway project, then the proposed geometrics and area improvements should be obtained. This may be acquired through the MSHA lead division or a local authority.

Base Plan

The base plan is a key to the field work and design of lighting. It must be accurate and able to be used as a base for construction. In order to properly design the lighting, the designer needs a base plan showing existing topography, roadway geometrics, utilities, etc. The base plan should be in electronic format. One place to start is with the TEDD Archives. Often there may be an existing electronic file with this information that can then be field verified. The designer should verify within TEDD that the obtained plan is the latest version. For an insert job the electronic base plan may be obtained from the lead division, usually Highway Division. Other options may include a professional survey or extensive field work to obtain all of the mapping information.

Photometric Concept Layout

Preliminary photometric calculations should be performed taking into account the existing conditions, base plan and design criteria as specified in the DR. The photometric calculations should be used to develop a preliminary concept layout with proposed pole locations and luminaire types. This concept will not typically be submitted to TEDD but will be brought to the field PI for discussion and verification.

Information to Collect in the Field

Initial Site Visit

Most of the necessary information should be obtained during the initial site visit. This is the time to collect new information, verify existing information and prepare for the proposed and/or modified lighting design.

1. Collect existing information. This should include at a minimum:

    - Existing lighting – If there is any existing lighting then the control equipment,

pole layout, pole types, luminaire types and sizes, etc. should all be gathered to be included with the plans. Determine what may be reused and what needs to be replaced.

NEMA identification decals are placed on the outside of the ballast housing of each roadway luminaire. The color indicates the type of light source and the number indicates the lamp wattage:

- Yellow = High Pressure Sodium
- Red = Metal Halide
- Light Blue = Mercury Vapor, this lamp type is no longer used in new installations due to environmental reasons.
- Green = Light Emitting Diode (LED)
- The number multiplied by 10 designates the wattage. For example, a black on yellow “25” = 250 Watts HPS

- Road geometrics (including diverging lanes, converging lanes, interchanges, intersections, structures, lane widths, etc.)
- Drainage elements (structures and ditches)
- Roadway alignment, vertical and horizontal
- Light level readings of existing lighting system and/or ambient levels to gauge offsite issues or future light trespass concerns.
- Driveways and entrances
- Utilities, overhead and underground
- Trees and vegetation
- Existing power service (location and size)
- Existing manholes, junction boxes, cable, and connector kits

2. Verify the proposed pole locations from the approved photometric concept plan. Decide what areas will and will not be lit. Locate potential power feeds for service. Identify if there are any constraints to be considered for planning conduit and manhole locations.
3. Confirm existing circuitry where needed.
4. Locate and measure the heights of overhead utilities, particularly at potential conflict locations. This will allow for meeting the NESC requirements of utility clearance and avoiding any conflicts between the proposed lighting and existing utilities. These measurements shall be documented.
5. Transmission line should be reviewed by the power company for required clearances/easements.
6. Always take photographs while in the field. This may save another trip to the site.

Subsequent Site Visits

For most projects it will be necessary to do at least one subsequent site visit. This should include the verification of all proposed work. Things may change frequently in the field without prior notice so it is important to verify that the design is constructible and optimal for the given location under current conditions.

Field Data Collection Methods

The limits of the site review are usually determined by the limits of roadway or sign lighting. The methods used to collect field information may vary from a professional survey to simple tape and wheel techniques. The method will also vary dependent of the information required. Some or the following methodologies are explained further.

- Professional Survey – A professional survey is the hiring of an outside company or MSHA survey forces to collect the field information and mapping. A professional topographically survey may be needed on a case-by-case basis. This is the most accurate, all-encompassing method to collect field data, but is typically the most expensive.

- Tape and Wheel – The designer or designated person does a tape and wheel survey. This is the simple method of visiting the project site and using tape measures, wheels or other measuring devices to collect critical information. Using this method information may be collected on lane widths, distance between existing light poles, pole size, etc. All data collected shall be documented.

- Utility Heights – Measuring overhead utility heights is a critical element in the site visit, but it is also the most hazardous. Measuring the height of utilities is commonly done using an overhead cable measuring rod made of fiberglass. The rod is then used to measure the height of the different overhead utilities from the ground. DO NOT measure the primary electric lines with the rod due to hazardous high voltage. Further, do not attempt to measure any lines with the rod unless with someone who is trained and experienced.

- Photographs – Although photographs are not necessarily a formal method of collecting data, a picture can say a thousand words. Taking photographs will put the project site at arm's length once back in the office. Photos can be used to check lighting equipment locations, signal configurations, signs, intersection layout, roadside features, potential conflicts, etc.

- Notes – Taking good field notes is key when at the site. There are many things that a tape and wheel cannot measure. Taking notes to describe what is at the site is an excellent method of data collection. For example it is necessary to know the utility pole number for a potential power drop service, taking note of this number is the best way to communicate this information with the utility company to request location of a power source.

LIGHTING CONCEPT

Developing a Concept

The conceptual plan is developed before the final lighting plan is designed. It is the first milestone in which input is received from the parties involved including the designer, project manager, team leader and district traffic office at a minimum.

Prior to the conceptual plan being developed, the base mapping should have been obtained and verified in the field. All field information should be shown on the base mapping including utilities, intersection geometrics, pavement markings, etc.

The conceptual lighting design process can be broken down into several steps as follows:

1. Determine Function of Lighting

2. Determine Classification of Roadway

3. Select Luminaire and Light Source
4. Select Structure
5. Preliminary Calculations
6. Define Design Criteria
7. Develop a Preliminary Layout

This is sometimes referred to as a post-it plan for lighting. The key is selecting the hardware, defining design criteria and developing a preliminary layout. Each of these steps will be discussed further in depth.

Function of Lighting

Lighting for MSHA projects serves several different functions. At the beginning of the project the function of the lighting should be defined and agreed upon by all parties. On any given project there may be more than one function and all of these should be identified.

The most common application is roadway lighting. Other lighting functions include pedestrian/bicyclist lighting, sign lighting, and parking lot lighting. These four functions have similar design methods, but vary with criteria and function. Defining the function of the lighting allows the designer to determine the criteria to use for design. For example, lighting a freeway will have different criteria than parking lot lighting.

Roadway Lighting

The purpose of roadway lighting is to promote safety at night by providing illumination of the highway, vehicles, pedestrians and roadside objects.

Interchange Lighting

It is current MSHA policy that all new projects which require lighting implement partial interchange lighting per the MSHA Lighting Guidelines. Full interchange lighting does also exist in some locations throughout Maryland and is described below for specific situations.

Partial Interchange

Partial interchange lighting involves lighting the conflict point(s) of an interchange, i.e. merge-diverge areas of ramp connections, ramp splits/ramp merges, intersections and critical roadway features such as sharp curves, reverse curves etc., and when the following is true:

- Generally works well for interchanges that can be readily visualized by motorists by viewing the critical decision points.
- Additional lights other than those minimally required shall be considered per the MSHA Lighting Guideline or at the discretion of the Administration.

Full Interchange

Full interchange lighting is the lighting of all roadways and ramps within an interchange and the following:

- Generally supplements continuous lighting along the mainline roadway.
- Also applied where substantial lighted commercial or industrial developments are located in the immediate vicinity of the interchange and where the crossroad is lit for at least ½ mile on each side of the interchange.

MSHA does not install full interchange lighting.

Intersection Lighting

Intersection lighting involves lighting only an intersection. It is Administration policy to light all signalized or ICB controlled intersections. Other intersections may be lit after an

engineering study warrants it due to safety concerns, high crash history, complex geometrics, etc.

Continuous Lighting

Continuous lighting illuminates a straight stretch of roadway between interchanges and/or intersections.

Per the MSHA Lighting Guidelines, continuous roadway lighting shall not be installed along any state highway unless justified by an engineering study AND approved in advance by the Director of the Office of Traffic and Safety.

In general the Administration's practice is not to light continuous sections of the highway. However, sections of highways may be lit where combinations of sight distance, horizontal or vertical curvature, channelization or other factors contributing to a confusing or unsatisfactory condition exists.

Roundabout Lighting

It is the Administration's policy to light all roundabouts. See the MSHA *Lighting Guidelines* for more information. Lighting a roundabout follows the same process as lighting a roadway.

Tunnel Lighting

Tunnel lighting shall be considered where normal daytime illumination of a roadway section is restricted such that the driver's visibility is substantially diminished. Tunnel lighting shall be designed in accordance with the most recent version of the Illuminating Engineering Society RP-22, American National Standard of Tunnel Lighting.

Underpass Lighting

Underpass lighting can be considered critical during the daytime or nighttime to mitigate "dark spots". Underpass lighting during the daytime is considered where sidewalks are present. For nighttime it can be considered for pedestrian safety and to supplement for dark spots created by a structure's obstruction of light emitted by the adjacent light pole(s). Underpass lighting shall be designed per the MSHA Lighting Guideline and when length to height ratios of the structure exceed 10:1.

Transition Lighting

Transition lighting gradually takes a driver from a high level of lighting to little or no roadway lighting. Generally, MSHA doesn't use transition lighting for nighttime use, but uses transition lighting as needed for daytime use when entering and exit tunnels or underpasses.

Pedestrian Lighting

The Maryland Department of Transportation is committed to planning and constructing alternate forms of transportation i.e. walking and bicycle paths. Sidewalks that are located adjacent to the lighted roadways often do not have separate lighting provided for the safety and comfortable use by pedestrians and bicyclists. The incidental house side distribution of roadside luminaires is the only lighting afforded for the comfort of the pedestrian. Where a better quality of lighting for pedestrians is desired, the illumination design for the roadway can be modified to correct any deficiencies or supplemental lighting can be provided. The MSHA Pedestrian Lighting Policy as outlined in the MSHA Lighting Guidelines should be used for specifics on criteria for eligibility, financial responsibility and design standards.

When specific lighting is provided for pedestrians, the quality of lighting provided is dependent on whether the lighting is installed for illuminating the sidewalk or walkway, or if there is an additional requirement for special pedestrian security. Lighting for security purposes has an additional requirement for providing the specified vertical illumination 5'

above the walkway to allow pedestrian identification at a distance.

Pedestrian characteristics are usually classified into three levels: high, medium and low.

- High: This is high nighttime pedestrian volume, over 100 pedestrians per hour, with expected crosswalks and sidewalks such as downtown retail areas, near theaters, stadiums, transit terminals, etc.

- Medium: This is a lower nighttime pedestrian volume, 11 to 100 pedestrians per hour, such as near office buildings, libraries, apartments, industry, etc.

- Low: This is a very low nighttime pedestrian volume, fewer than 10 pedestrians per hour, such as rural areas, low density residential areas, etc.

Sign Lighting

Refer to the Sign Lighting Section of the Maryland MSHA Lighting Guidelines, 2017 for information regarding locations that require sign lighting. When sign lighting is required, LED light sources shall be used.

If a signing upgrade project is upgrading a sign that has sign lighting because it is not Type XI sheeting, the new sign should be made of Type XI sheeting and sign lighting should be eliminated where possible. When sign lighting is required, individual luminaires and supports should be used.

Sign lighting is usually accomplished by lighting the signs from the bottom for the following reasons:

- By having the lights pointed in an upward direction, any light which misses the sign, tends to shine into the sky and not provide a severe glare source for the drivers.

- Having the light point up tends to reduce the amount of light shining on adjacent properties and reduces the light trespass; although control of the light spilling upwards should still be considered to minimize sky glow.

Parking Lot Lighting

Typically any given parking lot will be lit. For MSHA the most common application will be for Park & Ride facilities. Lighting for a parking lot will utilize different criteria for illuminance, but the design process is the same.

Aesthetic Lighting

Aesthetic lighting is lighting designed to enhance existing or proposed surrounding features such as buildings, landscaping, structures, community signs etc. This is becoming more common with streetscape projects. For a typical roadway, aesthetic lighting will not be used.

Classification of Roadway

The roadway classification will help determine the photometrics required for lighting as well as assist in selecting the proper lighting. These are basically the same as any other roadway classification for highway projects. The classifications are defined in the *MSHA Lighting Guidelines.*

Luminaire and Light Source

The luminaire is the housing unit for the light source, along with the distribution and power elements such as reflectors, refractors, drivers, socket, wiring terminals, etc. Selecting a luminaire and light source is a key element in the illumination design of lighting.

There are several variables within the luminaire to be determined: shape, distribution, light source, ballast and depreciation.

Distribution

Roadway luminaires are classified by the way they transmit and distribute light. The use of various types of reflectors and refractors permits the lighting designer to produce an efficient and aesthetic design. Luminaire classifications are defined in terms of vertical light distribution, lateral light distribution, and the control of distribution above nadir, known as cutoff.

Vertical Distribution

The vertical distribution of light is divided into three categories; short, medium and long. Vertical distributions are classified by the candlepower along the transverse roadway lines (TRL) measured in lengths of the pole mounting height (MH). A shorter vertical distribution will reduce glare, but will require a tighter spacing to maintain uniformity. A longer vertical distribution will increase glare, but increase spacing. MSHA commonly uses a medium vertical distribution.

Horizontal/Lateral Distribution

The lateral distribution of lighting is essentially the shape that the luminaire distributes on the pavement. There are five basic types of horizontal distribution, Type I through Type V. Types I and II have two subgroups for two-way and four-way distribution. Figure LT.1 illustrates Types I-IV. MSHA typically uses Type III distribution.

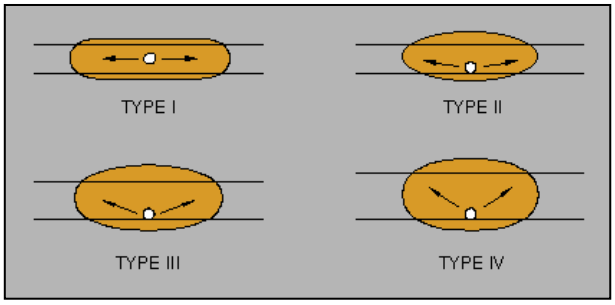


Figure LT.1 - Horizontal Distribution

Control of Distribution above Nadir

The control of lighting distribution above nadir is known as cutoff. (The nadir is a reference of point in the line of the pole.) Lighting 90° above nadir leads to “sky glow,” glare and often an overflow of light where no light is needed.

Full Cutoff

A full cutoff luminaire allows no light above an angle 90° above nadir. For an angle 80° above nadir, the intensity can be no more than 10% of the total lumens. It has become common practice on highway projects to use the full cutoff luminaries.

Cutoff

A cutoff luminaire allows less than 2.5% of the total lumens above an angle 90° above nadir. For an angle 80° above nadir, the intensity can be no more than 10% of the total lumens.

Semicutoff

A semicutoff luminaire allows less than 5% of the total lumens above an angle 90° above nadir. For an angle 80° above nadir, the intensity can be no more than 20% of the total lumens.

Noncutoff

A noncutoff roadway fixture, as pictured below, typically has a dropped lens (a refractor). This allows the light to be easily distributed from the fixture to an area larger

than the section being lighted. This type of fixture may be appropriate for area lighting such as wide intersections along divided highways, at grade railroad crossings, parking lots, maintenance yards, and urban streets where some house-side lighting is desirable for pedestrians. There are no intensity limits for a noncutoff luminaire. The Administration typically does not use these types of luminaries.

Figure LT.2 - Noncutoff Roadway Lighting Fixture

Backlight, Uplight, and Glare (BUG) Ratings

Addendum A for IESNA TM-15-07 contains tables that list BUG ratings that may be used to evaluate luminaire optical performance related to light trespass, sky glow, and high angle brightness control.

Roadway lighting systems are under increasing scrutiny from various sectors of the public. While the general public is not usually aware of specific design requirements of roadway lighting systems, glare, sky-glow, and aesthetic elements are widely perceived and open to criticism. The lighting designer should become familiar with these issues and be prepared to design a lighting system that meets the needs of the owner. An increasing number of communities are adopting lighting ordinances meant to reduce sky-glow.

Light Sources

The light source is housed inside the luminaire and is the artificial source of light. There are many different types of light sources. Light sources may be selected based on their efficiency, depreciation, color, life, cost and/or restrike time. There are three basic categories for light sources, low pressure sodium lamps, high intensity discharge lamps, and LEDs. These may be found in existing conditions, but the only category that is currently used by MSHA is LEDs.

Low Pressure Sodium

Low pressure sodium (LPS) lamps are monochromatic and have no color rendition. They have good initial efficiency, however the efficiency decreases and the current draw increases with aging. The lamps also tend to be much larger and require larger fixtures making them prohibitive for roadway lighting applications. LPS lamps are not used on MSHA projects.

High Intensity Discharge

High pressure sodium (HPS) lamps were the standard light source for the Administration's roadway lighting. HPS was used because they give the optimum mix of a long life and low maintenance with a high efficiency (lumen output per watt). The primary draw- backs are that it has a pinkish orange color, which some people find objectionable and tends to mute some colors.

Mercury Vapor

Mercury vapor lamps have formerly been used in sign lighting and may still be in use, but they are no longer used for new installations.

Metal Halide

Metal halide lamps have a blue-white color that provides a very good color rendition. They have a good energy efficiency, however also have a relatively shorter service life.

They are primarily used for old high mast lighting applications and by local jurisdictions that need a better color rendition with their pedestrian or roadway lighting. All new metal halide lamps are Pulse Start. Pulse Start metal halide lamps have a longer lamp life, are more efficient, and have a quicker start up.

LED

LED is the standard light source for MSHA for all lighting except for high mast. An LED light source is a semiconductor diode. It consists of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction. When connected to power source, current flows from the p-side or anode to the n-side, or cathode, but not in the reverse direction. Charge-carriers (electrons and electron holes) flow into the junction from electrodes. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon (light).

LED light sources are available in a variety of colors. They are very energy efficient and have a long service life. The LED technology continues to develop making the light source more efficient, have a longer life, and cheaper.

Inductive

Inductive lamps are light sources in which the power required to generate light is transferred from outside the lamp envelope to inside via electromagnetic fields. This differs from a typical electrical lamp that uses electrical connections through the lamp envelope to transfer power.

Inductive lamps are amongst the most efficient light sources. They offer energy savings, long life spans, high scotopic output and high color rendering index. The inductive lighting technology continues to develop making the light source more efficient and have a longer life.

Ballasts

Ballasts are used for high intensity discharge light sources. The ballast is an interface between the electric current and the light source. It allows the light source to obtain the necessary circuit conditions for starting and operating. For application with MSHA projects, a high power factor ballast is housed in the luminaire.

Drivers

Drivers are used for LED light sources. The driver converts line power to the appropriate voltage (typically between 2 and 4 volts DC for high-brightness LEDs) and current (generally 200-1000 milliamps or mA), and may also include dimming and/or color correction controls.

Depreciation

Another factor in the selection of a luminaire and light source is depreciation. The depreciation of the luminaire and light source directly affect the illuminance calculations. Depreciation is measured as a light loss factor and is a combination of several factors. The two main factors are maintenance and equipment. Both of these elements combine to form a total light loss factor. Depreciation is defined by a percentage of loss. The factor will vary greatly depending on the elements discussed below.

Light Loss Factor

In most cases, measured values are less than the calculated values of the new, clean lamp and luminaire. Any lighting parameter, including luminance and veiling luminance, can be calculated in terms of either an initial or a maintained value. Any compensation for system aging is part of the “light loss factor” (LLF). LLF is the overall factor used to link calculated to measured levels. LLF must be incorporated into lighting design calculations. A LLF of 0.64 should be used for all MSHA lighting projects, but designers should confirm

the current LLF with TEDD before establishing design parameters.

Equipment Factor

Equipment factors are not time dependent, but are related to the specific equipment in use. These include ambient temperature, voltage, ballast and lamp factor, luminaire component depreciation and change in physical surroundings.

Lighting Structures

The light structure is the support of the luminaire. Most commonly the luminaire is attached to a bracket arm in turn connected to a pole that sits on a base. Luminaires can also be attached to walls and bridges. It includes the pole, base and typically the bracket arm.

Pole Assembly

Low Level Lighting

Low level lighting is most commonly used in Maryland. It refers to poles that are 50' and lower in height.

Bracket Arm

The bracket arm connects the pole to the luminaire. The arm may range in size from none to 35'. The bracket arm length is dependent on the offset of the pole from the edgeline, with the luminaire preferably installed over the edge of travelway.

Bases

The first element to define for the base is the use of a breakaway base versus an anchor base. A breakaway base is a safety feature that breaks the pole from its foundation when impacted. An anchor base does not offer this safety feature and can be a hazard if not protected. Breakaway bases should be used when the structure is not protected from errant vehicles such as with w-beam traffic barrier or barrier wall.

High Mast Lighting

High mast lighting is typically installed at large complex interchanges within predominantly business or industrial areas. It is associated with mounting heights that require special lowering gears to maintain the lights. The lights typically require higher wattage lamps to produce the desired illumination levels on the pavement. The light output usually provides an improved visual field negating the tunnel effect usually associated with low-level lighting, improved uniformity and reduced veiling glare. The poles can be placed further away from the travel lanes, which decrease the possibility of off-the-road crashes. Light trespass into surrounding neighborhoods however, is a usual source of complaints associated with high mast lighting. High mast lighting will not be installed along state roadways unless required lighting levels cannot be achieved with low level lighting and justified by an engineering study, per the MSHA Lighting Guideline.

Underpass Lighting

Underpass lighting is installed for tunnel and underpass lighting applications. MSHA prefers that underpass lighting be mounted on the substructure. The method of strapping on metal plates to the pier caps is the most common method of mounting underpass lights to existing piers.

Roadside Placement

During the conceptual plan it may not be necessary to finalize an offset location of the lighting structures, but it should be considered. Lighting structures are like any other roadside hazard and should be placed based on AASHTO's Roadside Design Guide. Look for obstacles that may limit placement such as bridges, signs, signals, utilities, etc.

Some of these elements may help to define where poles may or may not be placed.

Other Structures

In addition to simple pole structures, luminaries may be attached to walls, bridges, or other special features. These often require a special design.

Preliminary Calculations

After selecting the luminaire, light source and structure to be used, the process of designing the layout begins. Placing the lights is an iterative process that depends heavily on several factors such as roadway geometrics, roadway classification, and pavement surface. Some of the other factors that are considered when determining the design are traffic crash history, severe grades and curves, type and location of high use driveways, underpasses, overpasses, trees and zoning of surrounding areas.

The prevailing photometric design criteria for highway lighting can be found in the latest approved version of the *MSHA Lighting Guidelines*. Currently the Administration design practice utilizes illuminance for roadway lighting and veiling luminance for glare reduction. The calculations involve an iterative process for predicting the quality of lighting and are usually performed using commercially available software.

Design Software and Establishing Lighting Criteria

There are numerous design software programs available to use when calculating lighting photometrics. They allow for ease and efficiency of computations. Most software packages require several inputs from the user. This may vary with the software, but below is a general list of inputs that should be established during preliminary design:

- Roadway geometrics
- Luminaire selected
- Light Source
- Depreciation factors
- Orientation
- Distribution
- Mounting height
- Bracket arm length
- Pavement classification

It is required that the consulting engineer complete lighting calculations, not the manufacturer.

Illuminance

Illuminance is generally described as the amount of light falling on a surface or as “incident light” and is measured in footcandles (fc) (or lux (lx) in the metric system). This method is the simplest to calculate using an integration of all the light falling on a spot on the pavement surface from all adjacent light point sources. An additional calculation is done to determine the uniformity of lighting based on the ratio of the average and minimum illumination.

The recommended values of illuminance and veiling luminance (described below) for various roadway classifications and pedestrian classifications are found in the *MSHA Lighting Guidelines*.

Luminance

Luminance is a method of predicting effective brightness of an object that a driver sees based on light, which is reflected back to the eye after having struck the surface. The

luminance of the object depends on its material characteristic and reflectance. Luminance is usually expressed in candelas per square meter (cd/m2). Additional calculations are done to determine the uniformity of lighting and the veiling luminance (glare) to determine the comforting level of lighting.

Veiling Luminance

Also known as disability glare, veiling luminance is a stray light that is produced within the eye. The veiling luminance ratio is the ratio of the maximum veiling luminance from a system divided by the average pavement luminance.

Pavement Classification

Pavement classifications for the purpose of pavement luminance and lighting design are classified as follows (Source is the *Roadway Lighting Design Guide* by AASHTO):

- R1: Portland cement concrete road surface. Asphalt road surface with minimum of 12 percent of the aggregates composed of artificial brightener aggregates.
- R2: Asphalt road surface with an aggregate composed of a minimum 60 percent gravel. Asphalt road surface with 10 to 15 percent artificial brightener in aggregate mix.
- R3: Asphalt road surface with dark aggregates; rough texture after some months of use.
- R4: Asphalt road surface with very smooth texture.

MSHA uses the R3 classification for all roads.

Defining the Design Criteria

Defining the design criteria is the most critical step in the design process for lighting. During this step it is essential to put in writing each piece of the design. This should include at a minimum:

- Lighting Function
- Classification of Roadway/Ped Conflict
- Luminaire
- Lens
- Vertical Distribution
- Lateral Distribution
- Cut-Off
- Light Source Type
- Light Source Wattage
- Mounting Height
- Bracket Arm Type
- Type of Pole
- Pole Base
- Average Maintained Illuminance
- Uniformity Ratio
- Veiling Luminance
- Operating Voltage
- BUG Rating

Figure LT.3 shows an example of a list of design criteria definitions.

Preliminary Layout

The preliminary layout is the first opportunity to start to layout structure locations. This may be based on:

- Preliminary analysis with design software
- Previous experiences
- Engineering judgment

Many software programs for lighting design incorporate a "pre" program to allow for preliminary layout. Software programs which aid in photometric analysis are useful for developing initial light structure locations.

Previous experience can also aid in preliminary layout design. If using the same luminaire, light source, mounting height, and design criteria it may be possible to use previous experience to assist in layout design. Experience also allows the designer to be familiar with certain types of luminaire distribution and the designer becomes familiar with specific capabilities.

Engineering judgment and studies is a last way to develop a preliminary layout of luminaires. The preliminary layout will determine if luminaries will be placed on one side of the road, both sides of the road, in the median, or staggered. This layout should also define a preliminary spacing of the luminaries.

Reviewing the Concept

The conceptual plan is the time for all interested parties to agree and finalize the major decision making components of the lighting design. It is recommended to prepare a memorandum to accompany the concept plans. The memorandum should summarize the lighting analysis and concept design and should document all criteria and assumptions used to create the preliminary layout and concept. At this point the designer should receive input from the Project Manager and the Team Leader. This conceptual plan will govern the other elements of design to follow. Resolving any conflicts or issues at this point will eliminate the need for change after final design.

A reviewer should consider the following items when viewing a conceptual lighting plan:

1. Check that the lighting meets the requirements of the Design Request.
2. Check for any special design considerations such as underpasses, roundabouts, signing, and pedestrians.
3. Check that the design criteria is well defined and that the criteria is met within the design.
4. Check for overall concurrence with Federal and MSHA standards.

Design Criteria for Lighting

US 29 / MD 216

Highway Lighting Assumptions and Conditions

Lighting Function
- Partial interchange lighting
- Lighting for both roundabouts
- Add lighting to expanded Park & Ride
- Complete lighting of loop ramps

Luminaire and Light Source
- High pressure sodium lamps
- Flat glass lens
- Full cut off
- Medium vertical distribution
  Type III lateral distribution
  Light loss factor = 0.64
  HPF rector or lag ballast
  GE luminaire (M250A2)

Lighting Structure
- 40 Ft poles
- Galvanized steel poles
- Galvanized steel bracket arm
- Breakaway transformer base

Illuminance
- Uniformity ratio (avg:min): 3:1
- Minimum maintained illuminance: > 0.2 fc
- US 29, Freeway classification; average maintained illumination between 0.6 fc and 0.8 fc
- MD 216, Expressway classification; average maintained illumination between 0.8 fc and 1.2 fc
- Use AGI software to calculate illumination

Electrical
- 277/480 operating voltage
- Three phase, four wire
- Duct cable

Sign Lighting Assumptions and Conditions
- All overhead signs will be lighted
- LED luminaires
- Die-cast aluminum housing
- Standard light mounting with individual I-beam supports

Figure LT.3 - Example of Design Criteria

ROADWAY LIGHTING DESIGN

Once the lighting concept plan has been developed, reviewed, and approved the next step is to formally evaluate the photometrics and finalize the layout. By now all criteria to be used, pole selection, luminaire and lamp selection and a preliminary layout have been determined.

Lighting Calculations

A lighting calculation is a complex process. Most designers use computer software to evaluate the photometrics and design the lighting layout. This is typically the most efficient and effective method of computation. The lighting calculations should be prepared as part of the conceptual plan. For roadway lighting, the average maintained illuminance, uniformity, and veiling luminance should be computed.

Using Design Software

At this time, MSHA doesn't require a specific type of software. Since most manufacturers of luminaries and lamps have their own design software, the results of any given software will vary. For this reason, the software used should be specified to allow for quality review and comparison to other software applications.

Some applications will only consider straight line roadways and the designer will need to apply general engineering practices to account for special geometrics such as curves. Other applications have preliminary calculations, which allow the user to develop a preliminary spacing.

The approved roadway LED luminaires and lamps can be found on the MSHA list of qualified products. IES files shall be obtained from the various luminaire manufacturers.

Interchanges

Partial interchange lighting is the illumination of only the parts of the interchange that are most critical to the night driver, which are the merge-diverge areas of the ramp connections, intersections, and other critical roadway features.

Partial interchange/ramp intersection required lighting analysis areas include:

- Acceleration and deceleration lanes
- Ramp terminals
- Intersections

Partial interchange/intersection additional lighting areas beyond the analysis areas include:

- Horizontal curves
- Crest Curves
- Other areas of geometric and traffic complexity
- Crossroads at frontage road or ramp intersections
- Other areas of nighttime hazard.

The following guidance is provided for locating lighting poles. Diagrams are provided in the MSHA Lighting Guideline to indicate the typical configuration for partial interchange lighting through diagrammatic scenarios. The exact locations of lighting poles should be adjusted to avoid obstructions and must provide adequate lighting levels per the MSHA Lighting Guideline and the photometric results.

Refer to the *MSHA Lighting Guidelines* for information regarding the lighting of ramps and acceleration and deceleration lanes.

Where there is a split in the ramp lighting shall be provided. Intersections at the end of a ramp shall be lit based on intersection warranting conditions prescribed in the IESNA RP-8 Roadway Lighting Manual.

Transition Lighting is a technique intended to provide the driver with a gradual reduction in lighting levels and glare when leaving a lighting system. Some factors that may influence the justification for a transition lighting area are:

- Radical reduction in roadway cross section
- Severe horizontal or vertical curvature of the roadway.
- Change from a very high lighting level.

Transition Lighting is recommended at the option of the designer after a study of the conditions at a specific location.

Aesthetically pleasing lighting structures and pole colors may be required under some projects to coordinate with existing structures or other special design applications. Usually, these requirements are defined by MSHA and are documented in the Design Request.

Intersections

There are three types of at grade intersections: unrestricted traffic flow on both roadways, restriction by means of stop signs on one or both of the roadways, and control by traffic signals. Some are complicated by pedestrian activities as well as vehicular traffic. The lighting task on all of these, however, is fundamentally the same. The luminance level in these areas should generally be higher than the level of either intersecting road.

Luminaires should be located so that lighting will be provided on vehicles and pedestrians in the intersection area, on the pedestrian walkways, and on the adjacent roadway areas. Of particular importance is the amount of light falling on the vertical surfaces of such objects that differentiate them from the pavement background they are seen against.

With channelized intersections, the Designer should examine the frequency and location of nighttime crashes so that an adequate design can be prepared to address the problem.

Underpasses vs. Tunnels

Structures considered to be underpasses are those in which the length and physical configuration of the structure do not substantially limit the drivers' ability to see objects ahead.

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. Tunnel lighting may be considered where an underpass exceeds 80 ft in length and has a length to height ratio of up to 10:1. Tunnel lighting shall be considered when the portal to portal length is greater than the minimum wet pavement stopping distance.

Underpass lighting shall be designed for "nighttime" hours. The need for "daytime" lighting shall be based on an engineering study. Typically, MSHA installs underpass lighting for walkway and bikeway safety or vehicular safety. Underpass lighting may also be installed as a part of partial interchange lighting where the acceleration/deceleration lane limits extend underneath of a structure. See the MSHA Lighting Guidelines for details.

Underpasses of multiple highway structures, where the space between these structures permits good penetration of daylight on the underpass roadways, will normally be treated separately, rather than as one single,

composite length. Where direct daylight reaches the roadway beneath the overhead structure of considerable length, on one or more sides, daytime lighting may not be required.

When the length of an underpass exceeds 80ft, it is necessary to analyze the specific geometry and roadway conditions, including vehicular and pedestrian activity, to determine the need for daytime lighting or tunnel lighting.

Long underpasses, where adequate lighting from the street luminaires cannot be accomplished, require special treatment. Long underpasses also greatly reduce the entrance of daylight and, therefore, may warrant lighting during the daytime.

For nighttime lighting, luminaires on the lower roadway should be positioned so that there are not large dark spots in the pavement lighting from that on either side of the overpass. These luminaires should also provide adequate vertical illumination on the supporting structures.

A roadway which is not continuously lighted may warrant underpass lighting in areas having frequent nighttime pedestrian traffic through the underpass, or where unusual or critical roadway geometry occurs under or adjacent to the underpass area.

Roadways having continuous lighting will generally warrant the use of underpass illumination. Favorable positioning of luminaires adjacent to the underpass can often provide adequate lighting of relatively short underpass areas without the need for supplemental lighting.

Underpass lighting levels and uniformities should duplicate, to the extent practical, the lighting values on the adjacent roadways. Because of luminaire mounting height and spacing limitations in an underpass, it may be necessary to provide somewhat higher levels of lighting in the underpass to achieve the required underpass uniformity values. Such increased levels should not exceed approximately twice that of the roadways adjacent to the underpass.

For further information of tunnels and underpasses lighting see IES's *RP-22 American National Standard for Tunnel Lighting*. Design approach based on photometric calculations and required lighting limits should be approved by MSHA before advancing the concept to detailed design.

Special Geometrics

Depending on the software used to complete the lighting calculations, special consideration may need to be given to some situations. For example, a horizontal curve may need the spacing of the poles tightened to compensate for the effect that the curve has on the illumination.

Horizontal Curves

The visual problems of driving increase on horizontal curves. In general, gradual, large radius curves and gently sloping grades when lighted, are treated as straight level roadway surfaces. Sharper radius curves require closer spacing of luminaires in order to provide higher pavement luminance and improved uniformities. The spacing ratio between poles may vary from 0.55 to 0.90 to provide adequate and uniform levels of lighting. Spacing shall be appropriate for site conditions in addition to recommended illuminance requirements.

The geometry of abrupt horizontal curves, such as those found at interchanges and many roadway areas, also requires special consideration. Headlighting is not as effective in these situations and silhouette seeing cannot be provided in some instances.

Luminaires should be located to provide light on vehicles, road, curbs, traffic barriers and other fixed objects. It is generally found in national guidelines that poles are more likely to be involved in fixed object type crashes if placed on the outside of curves. Many vehicle operators may be unfamiliar with these areas and lighting the surroundings greatly helps their discernment of the roadway path.

Proper horizontal orientation of luminaire supports and poles on curves is important to assure balanced distribution of the light flux on the pavement. Furthermore, when luminaires are located on steep grades, it is desirable to orient the luminaire so that the light beams reach the pavement equidistant from the luminaire. This assures maximum uniformity of light distribution and keeps glare to a minimum.

Acceleration and Deceleration Lanes

Acceleration lanes refer to entrance ramps and frequently have all the challenges of abrupt curves. Light from vehicle head lights in acceleration lanes may be ineffective. It is thus desirable to provide good direct side lighting on the vehicles entering the main traffic lanes. Generally, lighting is provided starting within 100 feet prior to the physical gore along the ramp, and ending at a point where the full width acceleration lane begins to taper.

Deceleration lanes warrant careful consideration because these are areas where motorists are reducing speeds and looking for exit/turn information. Luminaires should be placed to provide illumination on curbs, abutments, traffic barriers and vehicles in the area of traffic divergence. Poles should be located based on the Roadside Design Guide best practices to protect against vehicles that may cross the gore area. Install partial lighting in the deceleration zone. Starting at the full width lane and ending approximately 100 feet past the gore area, i.e. the safety clearance.

Roundabouts

When illuminating roundabouts, MSHA's Roundabout Design Guidelines (also found in the MSHA Lighting Guideline) should be used as a reference. This guide emphasizes the following recommendations:

- Lights should be located so that they provide good illumination on the approach nose of splitter islands, the conflict area where traffic enters the circulating stream and at places where traffic streams separate at points of exit.

- Particular attention should be given to the lighting of the pedestrian crossing areas at sites where the pedestrian/bicycle/vehicle conflicts are likely to be significant.

- Poles should not be placed within splitter islands, on the central island directly opposite an entry roadway, or on the left-hand perimeter immediately downstream of an entry point.

Lighting of roundabouts in local streets should be individually designed to suit site considerations. Aesthetic lighting may be a consideration for the type and placement of poles in roundabouts. As a general guide MSHA lights each leg of a roundabout.

The risk of an errant vehicle colliding with a pole should always be considered when designing the lighting system, and the use of breakaway type poles should be encouraged.

Final Pole Layout

After the photometric computations have been completed the final layout should be designed. Using the results of the photometrics as well as good engineering judgment the poles should be located in their final location.

Placement of Poles

The horizontal placement of the pole is the placement in relation to the roadway. Most horizontal placements are defined by an offset distance from the baseline, face of curb or edge of pavement. Lighting structures should be placed based on AASHTO's Roadside Design Guide.

The physical roadside conditions may restrict the placement of lighting poles. Therefore, it is important that the Designer consider limitations in the design to provide for constructability. Sign structures, overpasses, traffic barriers, roadway curvature, roadside slopes, gore clearances and lighting equipment limitations are factors which must be taken into account during design. The Designer must evaluate all judgment factors including safety, aesthetics, economics and environmental impact while accounting for the physical limitations.

Some safety considerations for lighting pole locations include the following:

- It is desirable to place poles outside the roadside clear zone, but this isn't often possible in order to meet the photometric needs. When placed inside the clear zone, breakaway bases should be used.

- Pole locations should consider the hazards and convenience in servicing the lighting equipment.

- Poles should be located to provide adequate safety clearance in the gore areas of exit and entrance ramps. For exit ramps it shall be at least 100' from the physical gore.

- Breakaway bases can only be used for forty and fifty foot poles with certain arm lengths. Forty foot poles with arm lengths of up to 25 feet may be installed on a breakaway transformer base. Fifty foot poles with arm lengths up to 15 feet may be installed on a breakaway transformer base. Any forty or fifty foot poles with greater arm lengths must be protected or placed beyond the clear zone.

- Poles should not be placed within 50 feet of an overhead sign. Violating this could cast distracting shadows on the roadway surface at night and/or wash out the message on the sign.

- Poles on the inside radius of superelevated roadways should have sufficient clearance to avoid susceptibility of being struck by trucks.

- Poles should not be placed on the traffic side of traffic barrier or any natural or man-made deflecting barrier without permission

- Where poles are located in exposed areas, they should be designed to have a suitable breakaway or yielding feature. The safety feature shall comply with all applicable AASHTO requirements for structural supports.

- Poles behind traffic barriers should be so located to provide the necessary clear distance for the railing or barrier deflection as defined in the MSHA *Book of Standards for Highway and Incidental Structures* and the MSHA *Guidelines for Traffic Barrier Placement and End Treatment Design*.

- Poles should be placed to avoid conflict with utilities, inlets and other underground or overhead items that must be cleared. Any pole placement near overhead transmission lines requires the power company's approval.

- Median pole locations should be considered where the width is appropriate on open roadways or median barriers are to be used. Median pole locations provide several lighting and economic advantages. The number of poles necessary may be reduced to approximately one-half, the amount of cable may be reduced, the house side lighting could be utilized, and the visibility on the high speed lanes also may be improved.

- Other design considerations also include:

- Provisions for present or future lighting may be included with the roadway and structural work. Such provisions include under pavement conduit, junction boxes and conduit, and pole anchorage in structures.

- Annual cost of energy and maintenance, maintenance capability, and responsibility for the maintenance of the lighting system are some of the items, which should be considered as part of the system design. All items should be weighed for their importance on any specific design.

SPECIAL LIGHTING DESIGN

Rest Areas

Rest areas incorporate both vehicular and pedestrian usage, and constitute an important highway feature to the traveling public. They are available for use at night as well as by day, and their general appearance should generate a feeling of safety and security. This condition can exist only if the facility is adequately lit for nighttime use. According to AASHTO, any rest area offering complete rest facilities should be lit.

Properly designed lighting, conventional or high mast, will enhance the architectural and landscape features of the facility, promote safety by easing the task of policing, and contribute to the rest and relaxation of the motorist by completely delineating the driving, parking and walking areas of the facility.

One of the prime concerns in consideration of rest area lighting is that the motorists traveling along an unlighted main highway do not have their vision adversely affected by glare or by spill light from luminaires placed adjacent to the roadway within the rest area. Adverse glare within all interior areas should also be given consideration. As the motorist on the main roadway traverses the entire length of the adjacent rest area, the motorist should be able to discern any vehicle leaving the rest area, as well as the traffic traveling along the main roadway.

The overall design of the lighting is divided into four general areas as follows:

- Entrance and exit

- Interior roadways

- Parking areas

- Activity areas

Parking Facilities

Parking facility lighting is vital for traffic safety, for protection against assault, theft and vandalism, and for convenience and comfort to the user. Typical parking facilities include park-n-ride lots, train stations, building parking lots and other types of commuter lots.

The illumination requirements of an open parking facility depend on the amount of usage it receives. According to the IES three levels of activity have been established and are designated as *high, medium* and *low*. For MSHA projects, the design of lighting for parking lots is for transportation parking such as airports, commuter lots, train station lots, etc. This is considered a medium activity. The *IESNA Lighting Handbook* and *RP-20 Lighting for Parking Facilities* should be used as a guide for the photometric design of these facilities.

If the level of nighttime activity involves a large number of vehicles, then the designation of the specific facility, like the ones mentioned above, for low and medium activity properly belongs in the next higher level.

In open parking facilities, a general parking and pedestrian area is defined as one where pedestrian conflicts with vehicles are likely to occur. A vehicular use area (only) is defined as one where conflicts with pedestrians are not likely to occur. These are areas such as service areas or access roads.

Special consideration should be given to lighting of access roads to all types of parking facilities and lighting levels should match the local highway lighting, as much as possible. The average maintained illuminance should be compatible with local conditions. Refer to the *MSHA Lighting Guidelines* for the average-to-minimum uniformity ratio requirements. In all parking facilities, consideration should be given to color rendition, uniformity of lighting and minimizing glare. Users sometimes have trouble identifying their cars under light sources with poor color rendering characteristics. Uniformities less than recommended can detract from safety and security. Glare can affect the ability to perceive objects or obstructions clearly.

Vandalism is an important consideration with open parking facilities. Damage can generally be reduced by mounting luminaires at least 3 m (10 ft) above grade. However, greater mounting heights are recommended and MSHA typically uses 40’ poles.

Pedestrian Lighting

When properly designed and installed, pedestrian lighting has benefits that include enhancing revitalization projects, increasing nighttime pedestrian use and commerce, increasing safety and security, improving aesthetics, and adding to the sense of pride of a community. In some instances, it may be preferable not to install pedestrian lighting due to environmental, financial, or other considerations including glare, light trespass, increased energy consumption and sky glow.

Maryland SHA’s Pedestrian Lighting Policy provides the following specific criteria for eligibility:

- Within ½ mile of a transit center or ¼ mile of a major transit stop or along connection between two or more transit centers
- Within a designated urban revitalization area
- Within ½ mile of an educational or similar facility that generates significant pedestrian traffic during hours of darkness
- High volume of pedestrians and/or bicyclists within any one-hour period of darkness
- Within a commercial area with significant nighttime activity
- Pedestrian safety and security issues

See the MSHA Pedestrian Lighting Policy for specifics on warranting, funding, design,

construction, and maintenance of pedestrian lighting systems in which the Administration will be involved.

Sign Lighting

Motorists may stop or reduce their speed at roadway signs that are difficult to read, and thus create a hazardous condition. Proper sign visibility, including sign lighting, can aid rapid and accurate recognition of the sign shape, color and message. To determine which signs require lighting, refer to the Maryland SHA Lighting Guidelines, 2017.

Lighting for roadway signs becomes more significant as the volume of traffic increases, the complexity of highway design increases, the likelihood of adverse weather increases, and the ambient luminance increases.

The background luminance against which a motorist will view a sign is called its ambient luminance. Three categories of ambient luminance (high, medium and low) can be identified:

- High: Areas with high street lighting levels and brightly lighted advertising signs
- Medium: Areas with small commercial developments and lighted roadways and interchanges
- Low: Rural areas without lighting or areas with very low levels of lighting

MSHA illuminates overhead signs from the bottom of the sign rather than the top due to provide easier maintenance and better uniformity of lighting.

MSHA only uses LED sign lighting on all new installations, however older sign lighting typically consists of mercury vapor.

There are three types of lighted signs: externally lighted signs, internally lighted signs, and luminous source message signs (where the message is formed by lamps).

High Mast Lighting

High mast lighting is only considered when photometrics cannot be met with 40’ or 50’ poles and employs an area type of lighting with groups of luminaires mounted on free standing poles or towers, at mounting heights varying from approximately 80 feet to 180 feet or more. At these mounting heights, several high output luminaires develop a highly uniform light distribution. High mast lighting is used principally on interchange lighting, lighting of toll plazas, rest areas and parking areas, general area lighting and for continuous lighting on highways having wide cross sections and a large number of traffic lanes, such as Interstate 95.

The principal benefits of high mast lighting applications are the ability to provide excellent uniformity of illumination and reduce glare with a substantially smaller number of pole locations. This is especially true in interchange and other complex road areas.

While utilization efficiency is low on individual roadways, several roadways can usually be illuminated from the luminaires on a single pole. The off-road surrounding areas receive sufficient illumination to provide the motorist with an exceptionally wide illuminated field of vision compared to the “tunnel of light” effect provided by the conventional system. Performance of the system under adverse weather conditions such as rain, fog, etc., is good.

High mast lighting generally provides its own adaptation (transition) lighting to and from unlighted roadways.

High mast lighting makes a contribution to safety and aesthetics by reducing the number of poles that would be required for a conventional system and through locating poles out of the recovery area adjacent to the driving lanes. Also, their remote location eliminates the need for maintenance vehicles obstructing traffic on the roadway, or the requirement for maintenance personnel to be near the high speed traffic lanes.

While there are many benefits of high mast lighting, there are also several cons. High mast lighting can often lead to light trespass of non-roadway areas. It may also require access roads to reach pole locations further off the road. The lowering systems for high mast light poles also require maintenance. Additionally, high mast lighting may have higher costs. These factors should be considered when planning for high mast lighting on a project.

The design and installation of high mast lighting equipment is more complex than conventional lighting. Poles or towers, with lowering devices or other methods of luminaire servicing, require special design and maintenance considerations.

The most common type of luminaire used in high mast lighting is the area type, which is usually offered having symmetric or asymmetric distribution. Both types of distribution are frequently used to adequately fit the area to be lighted, and to minimize spill light.

Due to the lack of satisfactory experience in designing high mast installations to the luminance system, use of the luminance system is not encouraged when designing a high mast installation. Higher levels of illuminance on the roadway may be required after consideration of such factors as the complexity of the interchange, the existence of high brightness from competing light sources near the roadway, and the prevailing level of lighting on connecting roadways. In addition to the level of light on the roadway, the Designer must also consider objectionable spill light and discomfort glare beyond the right of way and the visibility of vertical surfaces of the roadway system, i.e., traffic barriers, bridge columns, abutments, drainage headwalls, and the like.

For the design of a high mast installation it may be assumed that all symmetric distribution luminaires on a given mast form a point source and have the same orientation and photometric display. All asymmetric distribution luminaires are usually oriented in groups with the principal axis of each luminaire in the group having the same orientation and having the same photometric pattern. Two methods available for formulating a design for high mast lighting are:

1. Utilized Lumens Method (Templates): By use of isofootcandle curve transparencies overlaid on drawings of the area to be lighting, pole locations are established and design values are then computed from standard utilized lumens formula. This method can also be accomplished by using direct calculations made from the coefficient of utilization charts.

2. Average Point Method: Readings are determined at points designated in an established grid pattern on the roadway and then averaged. Pole spacing, size of luminaire, and mounting height are usually determined by the Designer based on economics, illumination levels, and lighting area. Typically, the size of a luminaire may vary from 600W HPS to 1000W HPS and spacing of poles also may range from 400 to 600 feet.

LIGHTING ELECTRICAL SYSTEM

This section presents guidelines and procedures that may assist the Designer in selecting the type and size of an electrical service for a lighting system. It also presents guidelines for sizing Traffic Control Device Cabinets and equipment (as described in Maryland SHA's *Standard Specifications for Construction and Materials*), determining the size of lighting cables, determining the voltage drop on lighting circuits, and determining the type and number of connector kits used.

The electrical system for lighting is designed after the lighting is fully designed. The luminaires are selected and the poles have been laid out in their final locations. Following is a list of the basic steps to follow when designing the electrical system for lighting:

1. Determine Power Source
    a. Location
    b. Size
2. Define Lighting Cabinet
    a. Location
    b. Size
3. Define Luminaire Electrical Requirements
4. Circuit Layout, Wire Size and Voltage Drop
5. Connector Kits

Power Source

Power source refers to the power company's standard supply of electricity at secondary distribution systems, i.e. the system voltage supplied by the power company. Generally, a lighting system for an isolated intersection requires a single phase, 120/240 volts, 3-wire service. The first number, 120V, refers to the phase to neutral voltage in the transformer. The second number, 240 volts, refers to the phase-to-phase voltage. MSHA prefers to use the 120/240 volt service.

For larger projects such as interchanges and continuous roadway lighting, electrical services may be via either a single phase, 120/240 volts, 3-wire service or a 3-phase, 120/208 volts or 277/480 volts, 4-wire service. Three-phase circuits are composed of three single-phase circuits where the source voltages for each phase are 120° apart. MSHA prefers to split interchanges into smaller systems and use multiple 120/240 volts service if possible. Generally, interchanges are split in half preferably using the mainline roadway as the dividing line.

For information on the existing service, the Designer could obtain data on the service type, circuits, and cable sizes either from as-built plans, the MSHA District Office for Maintenance, or by coordinating a field visit to the electrical distribution cabinet.

Selecting Power

Selecting the electrical service size and type is the responsibility of the Designer. Generally, a higher operating voltage will allow the design of a more efficient and cost effective system, but for simplicity and consistency MSHA's preference is to use the 120/240 voltage service with a 100 or 200 amp cabinet dictated by need.

Luminaires are generally supplied in two types: a multitap which can operate on 120, 208, 240, or 277 voltage systems and secondly a 480 volt luminaire. Most old systems operate at 277/480 volt. If a 480 volt luminaire is used in an area that historically uses a lower voltage, then maintenance personnel must have a larger inventory of

spare parts, or may accidentally install an inappropriate luminaire. Historically, 480 volts luminaires have typically been used along I-495, while the rest of the State operates at a lower voltage, such as 120/240 volts. The Designer should always verify that a multitap luminaire is specified in order to avoid problems with wrong luminaires installed in wrong systems.

A Pepco 120/208 volt or 277/480 volt (used by most old services) 3-phase supply is generally considered an industrial service, and may not be available in a rural or suburban area. In these areas 120/240 volts, which is the standard for new systems, may be the only option.

Lighting associated with traffic signals is wired at 120 volts.

For servicing non-signalized intersections, an underground 120/240 volts, 3-wire, single phase service should be selected. An embedded metered service pedestal is normally specified for a project with less than 8 luminaires. This requires each luminaire to have its own photocell. However, there are exceptions to the use of an embedded metered service pedestal for projects with less than 8 luminaires which may be discussed and become apparent during the project review process.

A pole mounted lighting control cabinet with photocell, using a single phase 120/240 volts electrical service, is used where eight or more luminaires are installed and there is already existing service. The pole mounted lighting control cabinet has a 3-circuit panel and should be powered by a base mounted metered service pedestal with a photocell if there is no existing service. Separate photocells on each luminaire are not required with this type of control and distribution. When base mounted cabinets are used, the size of service should be dictated by the total load.

Selecting the Service Connection

The Designer is responsible for the coordination with the power company on the availability of service within the proximity of the proposed installation location. Coordination with the power company should begin in the preliminary stages and should continue throughout the project. The Designer should initiate the coordination activity with a telephone call and a follow-up letter with a preliminary concept layout of the lighting design. Service must be confirmed prior to wiring circuits. It should be noted that coordination requirements may vary depending on the power company. Some companies, such as BGE, require an application to be completed and submitted by MSHA. All correspondence should be documented and kept for reference throughout the project.

Determining Service Load

The electrical service required is dependent on several things, but the key item is the current required for the luminaires to operate. Each type of luminaire for each wattage size requires a different operating current at any given operating voltage. For example, a 250 watt high pressure sodium luminaire with a line voltage of 277 operates at a current of 1.2 amps.

Table LT.1 shows the operating currents at some of the standard operating voltages of commonly used luminaries in Maryland.

Table LT.1 - Typical Operating Current for Common Lamps and Ballasts

Type of Lamp	Bulb Watts	Current (amp)				Line Watts
		120 V	240 V	277 V	480 V	
HPS	100	1.2	0.6	0.5	0.3	127
HPS	150	1.6	0.9	0.7	0.5	189
HPS	200	2.1	1.0	0.9	0.8	253
HPS	250	2.6	1.3	1.2	0.7	312
HPS	400	3.9	2.0	1.7	1.0	475
*LED	96	0.8	0.4	0.4	0.2	
*LED	275	2.3	1.2	1.0	0.58	
*LED	280	2.4	1.17	1.0	0.6	

*The wattage of LED luminaires varies among manufacturers, and there are no standard values. The load information an LED luminaire must be obtained from the manufacturer.

In order to determine the required load of a proposed system, the Designer may follow two steps:

1. Identify the total number of luminaires and the types of lamp such as 250 High Pressure Sodium or LED. Include any luminaire within the system, signing and roadway.

2. Calculate the total load of the lighting system, based on the desired line voltage and operating current data as shown in Table LT.1. The total amperage may be determined as follows:

Equation LT. 1 - Minimum Total Amperage

$$\sum \left({}^{\#lamps}\!/_{type} \right) \times (current)$$

Given:

Operating Voltage: 277 V

Roadway Lighting Lamps: 12 luminaires with 250 Watt High Pressure Sodium Lamps

Sign Lighting: 4 luminaires with 100 Watt, LED Lamps

Based on the above given information the results are shown in Table LT.2**.**

Table LT.2 - Example of Calculating Total Load of a Lighting System

No of Luminaires	Type of Lamp	Lamp Power (watts)	Operating Current (amp)	Total Load (amp)
12	HPS	250	1.2	14.4
4	LED	100	0.5	2.0
TOTAL				**16.4**

This example results in a total minimum load required of 16.4 amps. Under these circumstances, the Designer could either request a 60 amp service from the power company, or may consider future expansion of the lighting system and request either a 100 amp or 200 amp service.

In general, the MSHA uses a minimum of 100 amp service for a typical application of 15 to 20 lighting standards. A 277/480V service will be more expensive to provide than a 120/240V service.

Another consideration in selecting the power source and size is the voltage drop on the circuits. A typical circuit would have less of a voltage drop with the same number of lighting standards under a 277/480 volts service than with a 120/240 volts system because of the higher operating voltage with a 277/480 volt system.

Base Mounted Lighting Control Cabinet

The lighting control cabinet is Base Mounted and refers to the control cabinet itself and the equipment within the cabinet including the meter socket, external disconnect switch and circuits panel. Control equipment is usually housed in an aluminum cabinet enclosure and is installed on the side of the road where it can be easily accessed for maintenance. It performs the following functions:

1. Distributes electrical energy (current) to individual luminaires via lighting circuits.

2. Powers on and powers off the lighting system via switching equipment such as photoelectric cells.

The number of circuits on a panel should not exceed 42 two pole circuits.

Circuit Layout, Wire Size and Voltage Drop

After determining the service to be used for the lighting system, the next step is to layout the circuits, determine wire to be used, and calculate voltage drops. These three items are dependent upon each other, meaning that this process is an iterative process to achieve an optimal system. There are also several methodologies to determine the same results. This section is directed toward the NEC equations and applications of calculations.

Circuit Layout

Circuits are run from the control and distribution equipment to the lights. Each circuit has a unique number in that panel. Following are some general guideline for laying out circuits in a lighting system:

- Odd circuit numbers run together and even circuit numbers run together.

- For a 120/240V single phase, 3 wire system circuits are run together in groups of two circuits (e.g. circuits 1 and 3 will run together or 2 and 4 will run together) See Figure LT.4.

- For a 277/480 V three phase, 4 wire system circuits are run together in groups of three circuits (e.g. circuits 1, 3, 5 will run together or 2, 4, 6 will run together) See Figure LT.4.

- Luminaires should always have alternating circuits so that if one circuit goes out, the one next to it will still be operating.

- For sign lighting, run dedicated circuits for only the sign lighting.

The maximum number of luminaires allowed per circuit is a function of the line voltage, voltage drop, operating current of luminaire, circuit breaker trip size, and the length of the circuit run. All of these variables are interrelated to each other.

As a matter of safety, the number of luminaires per circuit can preliminarily be determined such that the circuit should not be loaded to more than 80 percent of its capacity.

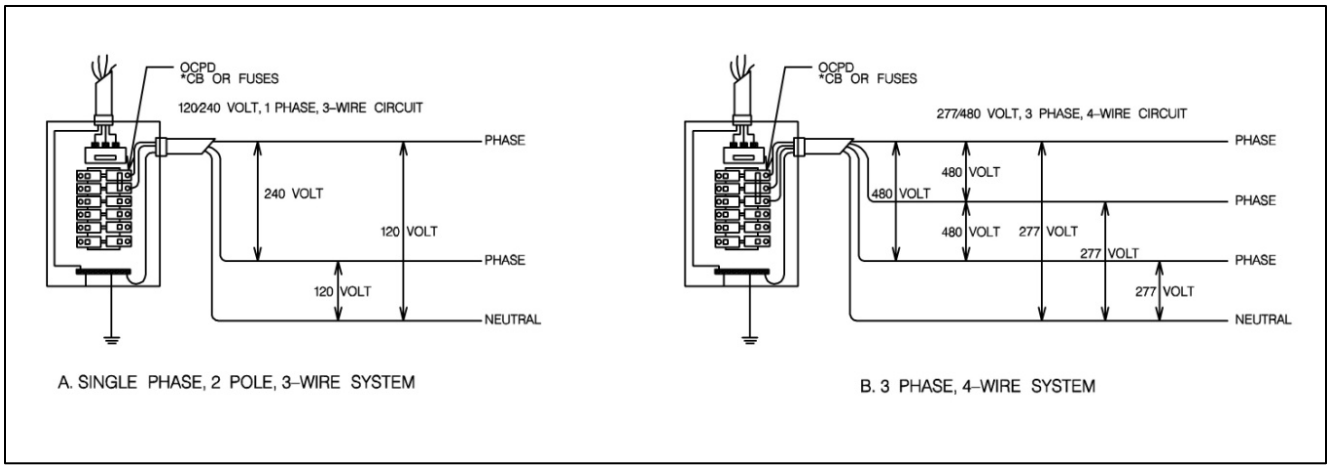


Figure LT.4 - Wiring Schematic

Optimal Cable Size

Generally, underground wiring for lighting is either #6 AWG or #4 AWG. Number 4 AWG cables are used for larger installations with longer circuit runs that may have higher voltage drop. The resistance of a larger size cable is lower than the resistance of a smaller size cable and, therefore, will have a lower voltage drop.

Number 12 AWG cables are used for luminaires in conjunction with traffic signals. For intersections where few lights are anticipated and there is a potential for the intersection to be signalized, a #12 AWG cable may be used to ensure expandability for a future signal. Smaller size cables are more susceptible to damage during construction, and are more susceptible to damage from environmental causes when buried.

Generally only one size cable should be used on a project. Requiring multiple cable sizes leads to constructability problems and increases the potential for error. If a project requires #8 AWG cables in one area and #4 AWG cables in another area, then it is possible for the contractor to install the #8 cables where the #4 cables are required. This will cause improper system operation, and may lead to critical failures. The exception is when #4 cables are used underground and #6 cables are used in bridges and walls. The NEC has different requirements for cables that are #4 AWG or larger than it does for cables that are #6 AWG or smaller. Generally, #4 AWG cables should not be run through bridges or in barrier walls. In these applications, only #6 AWG cables should be used.

Theoretically, determining the optimum cable size depends largely on the luminaire operating secondary voltages and the anticipated load of the luminaires. Some things to remember when selecting the wiring:

- Use multiple 2 conductor duct cables instead of 4 or 6 conductor duct cables. This allows for circuits not being used in a given pole to bypass the pole underground instead of running into the pole with connector kits.

- For sign lighting, use the 4 or 6 conductor duct cable since sign lighting uses more than one circuit and it isn't possible to fit 2 duct cables into the 4 inch conduit in the sign foundation.

- For cable runs in bridges and/or parapets, the designer typically must use #6 AWG wiring. However, a larger cable may be able to be used dependent upon the size of the junction boxes. Refer to NEC 314.28 for more information.

- Ensure that all plans are clearly marked to the size of wiring, number of conductors, duct cable and/or conduit.

Voltage Drop Calculations

In order to assure that the luminaires on the lighting system have the proper operating current delivered to them it is critical to determine the voltage drop on each circuit including all branches. A branch circuit is any subsection of a circuit that may be diverged in a non-linear path to service other lighting devices on the same circuit. Branch circuits begin at the splice point in electrical manholes.

Voltage drops should be computed at each lighting pole or sign luminaire in an incremental order. For planning, however, the Designer may also check the voltage drop at the last pole with the longest circuit run with the assumption that all loads occur at the last pole location. This procedure is only used for a quick checking of the most critical voltage drop on a circuit. MSHA requires pole-by-pole voltage drop computations on each of the lighting circuits, for all roadway and interchange projects. The maximum allowed voltage drop for any given circuit should not exceed 5 percent of the operating voltage.

The procedure to determine the voltage drop is as follows:

1. Layout the preliminary circuits.

2. Define a preliminary wire size.

3. For each circuit, determine the length of a circuit run between the electrical source and the load, i.e. the lighting standard or overhead sign.

4. Compute the voltage drop for each circuit based on the following equations:

The following equations can be used to calculate voltage drop:

Equation LT. 2 - Resistive Method

$$VD = \frac{P \times L \times R \times I}{1000}$$

Equation LT. 3 - Circular-mil Method

$$VD = \frac{P \times L \times k \times I}{CM}$$

Where,

P = 2 for single phase

L = One way length of circuit (feet)

k = Use values of 11.2 for copper for the circular-mil method.

R = Use resistance value from chapter 9, table 8 of the NEC for the resistive method.

I = load current (amps)

CM = area of the wire being used (circular mils)

Although both methods are acceptable and used by the NEC, equation 3 (CM) method is the common and preferred method used by MSHA.

Once the preliminary run of the voltage drop is computed, if the drop is unacceptable, then it is necessary to rerun this process again with either a new circuit layout, a different wire size or possibly both until an acceptable efficient system is reached.

Table LT.3 provides a side-by-side comparison of the relationship that conductor size has with equations 2 and 3. Table LT.4 also shows the comparison of conductor size with equations 2 and 3 but shows converted Conductor Resistance values that are based on a temperature of 40°C rather than 75°C.

The difference in results between the NEC equations and the MSHA equation is based on the relationship between resistance and temperature as follows:

- Resistance increases as conductor temperature increases.

The NEC voltage drop equation is based on a conductor temperature of 75°C while the MSHA assumes a conductor temperature of 40°C based on their experience. Since resistance will increase with a temperature increase, the NEC equation will produce a higher, more conservative voltage drop. MSHA follows the NEC, however, is not bound.

Voltage Drop Example 1 shows the calculation of the voltage for a single phase, 120 volt circuit with 3 luminaires, and Voltage Drop Example 2 shows the calculation of the voltage for a single phase, 240 volt circuit with 3 luminaires.

Table LT.3 - Comparison of Conductor Size and Voltage Drop Equations

Conductor Size (AWG)	Conductor Resistance* (ohm/kFT)	Area (Circular mils)	NEC Method R/1000**	MSHA Method 11.2/CM**	Difference
18	7.95	1620	0.00795	0.00691	0.00104
16	4.99	2580	0.00499	0.00434	0.00065
14	3.14	4110	0.00314	0.00272	0.00042
12	1.98	6530	0.00198	0.00171	0.00027
10	1.24	10380	0.00124	0.00107	0.00017
8	0.778	16510	0.000778	0.000678	0.0001
6	0.491	26240	0.000491	0.000427	0.000064
4	0.308	41740	0.000308	0.000268	0.00004
3	0.245	52620	0.000245	0.000212	0.000033
2	0.194	66360	0.000194	0.000169	0.000025
1	0.154	83690	0.000154	0.000134	0.00002

*Conductor Resistance is based on Direct-Current Resistance at 75°C (167°F). This example uses Uncoated Copper conductors with 7 strands for all conductor sizes except 1 AWG; 19 strands were used for this example.

**Values for R/1000 and 11.2/CM represent the conductor properties related components in the Voltage Drop Equations and are considered in this comparison.

Table LT.4 - Comparison of Conductor Size with Converted Temperatures and Voltage Drop Equations

Conductor Size (AWG)	Converted Conductor Resistance* (ohm/kFT)	Area (Circular mils)	NEC Method R/1000**	MSHA method 11.2/CM**	Difference
18	7.05	1620	0.00705	0.00691	0.000141
16	4.43	2580	0.00443	0.00434	0.000085
14	2.79	4110	0.00279	0.00272	0.000065
12	1.76	6530	0.00176	0.00171	0.000046
10	1.10	10380	0.00110	0.00107	0.000029
8	0.690	16510	0.000690	0.000678	0.000012
6	0.435	26240	0.000435	0.000427	0.0000085
4	0.273	41740	0.000273	0.000268	0.0000052
3	0.217	52620	0.000217	0.000212	0.0000053
2	0.172	66360	0.000172	0.000169	0.0000031
1	0.137	83690	0.000137	0.000134	0.0000026

*Conductor Resistance is based on Direct-Current Resistance at 40°C (104°F). This example uses Uncoated Copper conductors with 7 strands for all conductor sizes except 1 AWG; 19 strands were used for this example.

**Values for R/1000 and 11.2/CM represent the conductor properties related components in the Voltage Drop Equations and are considered in this comparison.

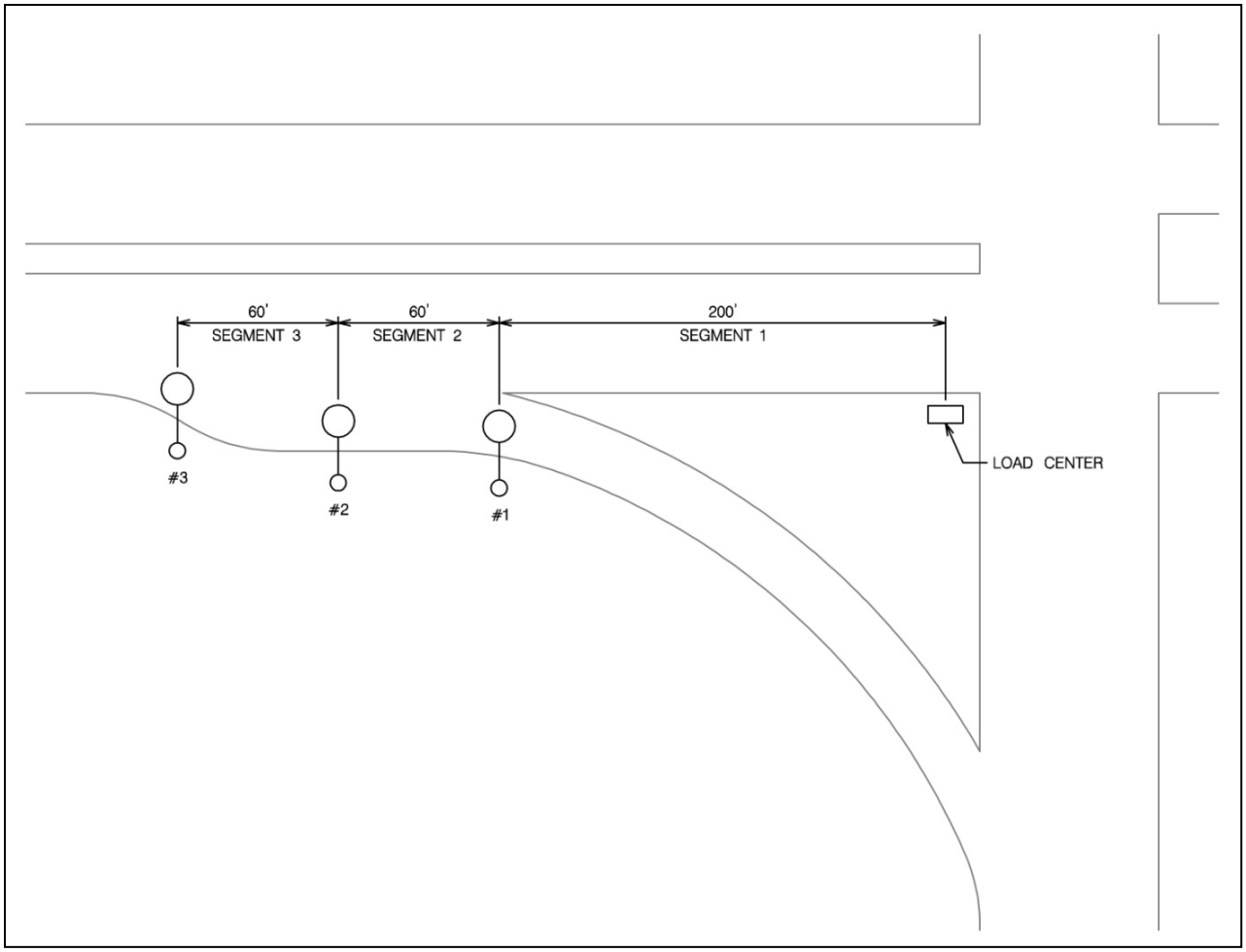


Figure LT.5 - Sample Plan for Voltage Drop Calculation

Voltage Drop Example 1:

Calculate the voltage drop for the lighting layout shown in Figure LT.5. Assume that the circuit is 120 volt, single phase and each luminaire draws 2 amps. Use #6 AWG for circuit conductors.

$$VD = \frac{2 \times L \times k \times I}{CM}$$

%VD = VD / V

Segment 1

$$VD1 = \frac{2 \times 200 \times 11.2 \times 6}{26{,}240}$$

VD1 = 1.02 V

Segment 2

$$VD2 = \frac{2 \times 60 \times 11.2 \times 4}{26{,}240}$$

VD2 = 0.21 V

Segment 3

$$VD3 = \frac{2 \times 60 \times 11.2 \times 2}{26{,}240}$$

VD3 = 0.11 V

VD = VD1+VD2+VD3

VD = 1.02+0.21+0.11 = 1.34 V

%VD = 1.34 / 120 * 100

%VD = 1.12%

Voltage Drop Example 2:

Calculate the voltage drop for the lighting layout shown in Figure LT.5. Assume that the circuit is 240 volt, single phase. Assuming that the luminaires are the same as used in Example 1, each will draw 1 amp at 240 volts. Use #6 AWG for circuit conductors.

$$VD = \frac{2 \times L \times k \times I}{CM}$$

%VD = VD / V

Segment 1

$$VD1 = \frac{2 \times 200 \times 11.2 \times 3}{26{,}240}$$

VD1 = 0.51V

Segment 2

$$VD2 = \frac{2 \times 60 \times 11.2 \times 2}{26{,}240}$$

VD2 = 0.11 V

Segment 3

$$VD3 = \frac{2 \times 60 \times 11.2 \times 1}{26{,}240}$$

VD3 = 0.05 V

VD = VD1+VD2+VD3

VD = 0.51+0.11+0.05 = 0.67 V

%VD = 0.67 / 120 * 100

%VD = 0.56%

Control Panel

The Lighting Control Cabinet and associated equipment is determined based on the combined load on all circuits.

Connected Load

The connected load refers to the total current and power in each circuit. It is defined by power (kilowatts KW) and current (amps).

The power is determined by summing the line wattage of each luminaire on the circuit.

Poles

Poles are the number of electrical connection points of the circuit breaker. A two-pole 240V connection system is normally used on all MSHA lighting projects for 120V/240V. A single pole 277V connection is used for 277V/480V systems.

Frame Size

The frame size refers to the amperage size of the main circuit breaker. A frame size of 100 or 200 amps is normally used on highway lighting projects.

Trip Size

The trip size refers to the amperage size of each branch circuit breaker. It is primarily used to safely disconnect the circuit in the event of an overload on the circuit breaker. For lighting, the normal operating load shall not exceed 80% of the trip size. A trip size of 20 ampere is normally used on MSHA lighting projects.

Connector Kits

Connector kits serve two purposes in a typical lighting design. First, connector kits are used for making a serviceable waterproof splice connection of lighting cables for each conductor or duct cable in electrical junction devices such as electrical manholes. Secondly, connector kits are used to connect branch circuit conductors to the luminaire (ballast circuit) conductors in the handhole or transformer base of lighting and sign structures.

There are four types of connector kits; Types I, II, III and IV. Some of the connector kits are used for fused or unfused applications. Fused connectors provide safety measures against knockdown of lighting poles, which causes the cables in the splice box to be disconnected without exposing any of the internal cable wiring.

Fused vs. Unfused

When a branch circuit conductor must be connected to the luminaire a *fused* connector shall be used. If a branch circuit conductor is being spliced in a junction device, (such as in a manhole or a handhole) an unfused connector should be selected. Neutrals are never fused.

In-line vs. “Y” Connection

In-line connector kits are used in manholes for continuous runs of duct cables. In-line connectors may be unfused when used in underground handholes and fused when used in pole bases. “Y” connector kits are used in handholes where a single duct cable must be spliced and branched in multiple directions. Figure LT.6 and Figure LT.7 show photographs of splices.

The applications for each connector kit are shown in Table LT.5:

Table LT.5 - Connector Kits

Application →	Unfused In-line	Fused In-Line	Fused Y	Unfused Y
Connector Type →	I	II	III	IV

Figure LT.6 - Example Inline Connector Kit (Unassembled)

Figure LT.7 - Example Y Connector Kit (Unassembled)

Number of Connector Kits

Typically, each conductor cable requires a connector kit. Determining the total number of connector kits needed for connection in a lighting system design is based on two factors:

1. The type of service being used (single or three phase system), and

2. The pattern of splices in a junction point either at the pole base or in a manhole/handhole.

The MSHA Book of Standards shows a typical schematic for using all four types of connector kits, under a 120/240 volt lighting system for 240-volt luminaire connections. Likewise, the Book of Standards shows a schematic for typical pole connections under a 277/480 volt system, with 277-volt luminaire connections.

Lighting Legend

The lighting legend includes symbols and detail callouts that provide the following information for each proposed pole and luminaire: type of luminaire and mounting detail, type and size of cable or wires required, the number and type of connector kits, the station number and offset, the pole number, the mounting height and mast arm length, and the circuit number. A detail callout is also provided for each handhole which provides: the handhole ID number, the handhole ID tag, the number of inline splices – type 1, and the number of 'Y' splices – type 4. For some projects, such as underpass lighting, a modified detail callout for handholes may be used that shows the number of each of the four (4) types of connector kits. Figure LT.8 and Figure LT.9 on the following pages show these detail callouts as well as other typical symbols found on a lighting plan.

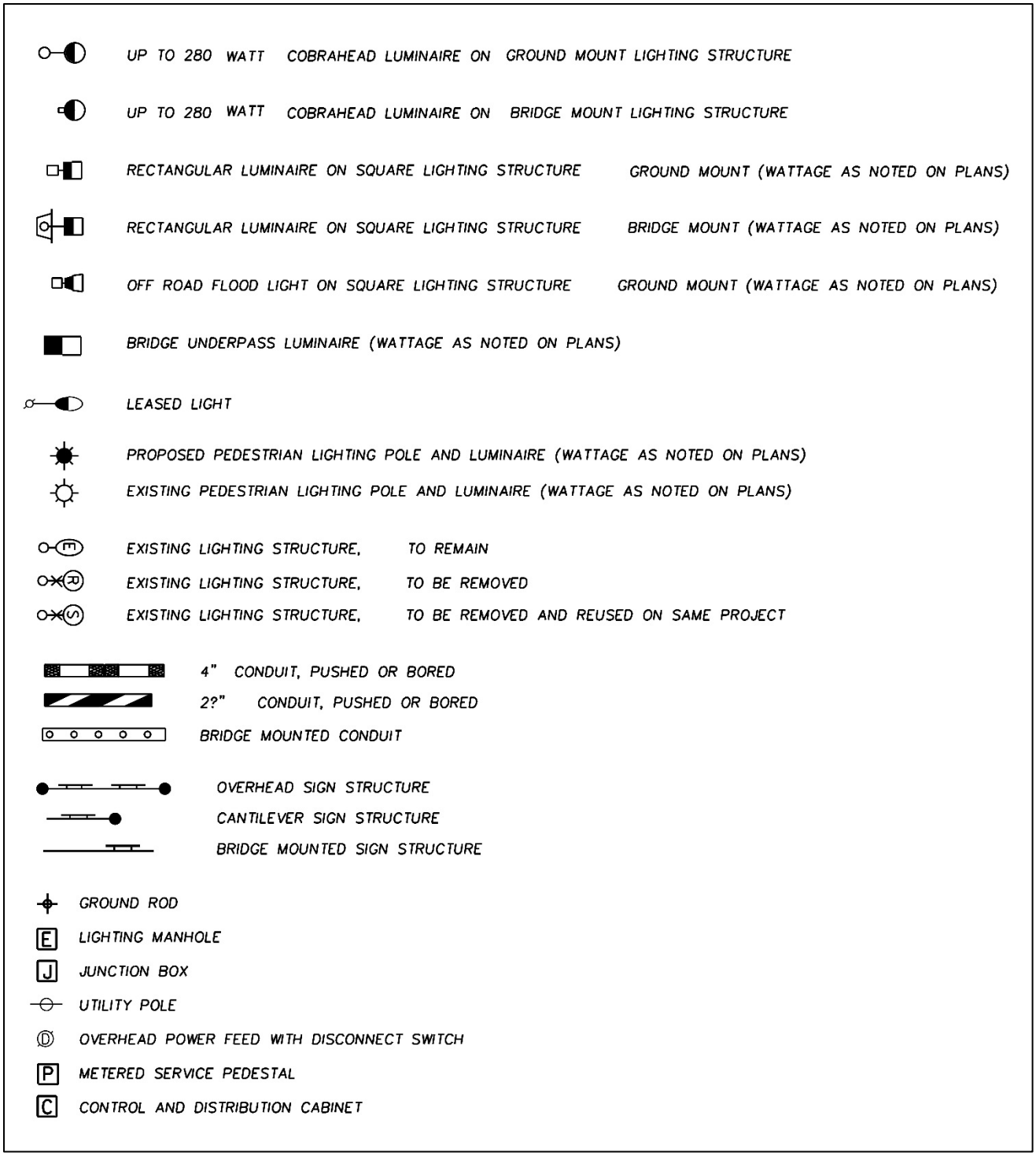


Figure LT.8 - Lighting Legend

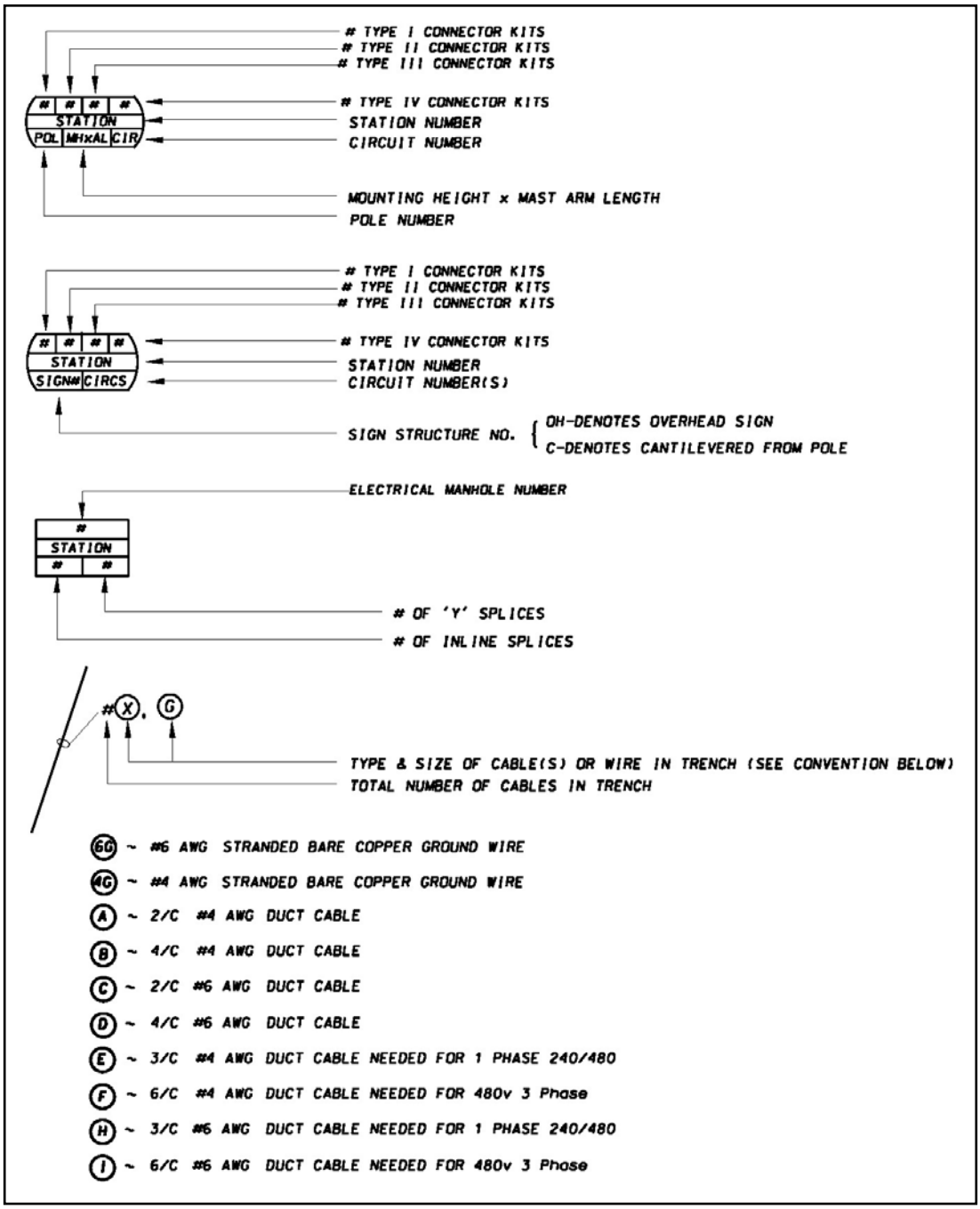


Figure LT.9 - Lighting Legend

ENGINEER’S ESTIMATE

ENGINEERS ESTIMATE

The Engineer's Estimate is an important part of the overall design process. It is a determination of the construction costs for any given project. The estimate is then used for programming and funding proposes. Preparing the estimate requires knowledge of construction methods, fabrication processes and construction costs based on the measurement and payment section in the Specifications. An Engineer's Estimate is required for all projects.

Every item that is called out on the plans shall be included in the estimate. There are also items not specifically called out on the plans that need to be included in the estimate. Each item must be paid for in some manner. It shall include the category code number (for Inserts), item number (for Areawides), item description, unit of measure, quantity, unit cost and total cost for each item. The total cost for each item is then summarized to receive the overall engineer's estimate. For signal, signing, pavement marking, and lighting designs, the estimate may include two types of construction items.

- First are items that are furnished by MSHA and installed by the contractor.
- Second are items that are furnished and installed, removed or only installed by the contractor.

Examples given in this section refer to equipment being "Furnished and/or Installed by the Contractor" unless otherwise indicated. It's important to note that the classifications mentioned above and as described throughout this chapter are only pertinent for Areawide and Insert Projects. While an Engineer's Estimates and the items described within this section are still necessary for Developer and Design-Build Projects, MSHA will not furnish any material unless stated in the RFP, thus all material and equipment costs are the responsibility of the Contractor/Builder.

The Engineer should be aware of the Engineering Change Notice (ECN) process and the content of a Specification. Knowing the ECN process and the hierarchy of Specifications will centralize the Engineer's understanding of how changes in directives, guidelines, standards, specifications, or engineering practices may affect his or her estimate and bid packages.

ESTIMATING QUANTITIES

The first step in producing an estimate is to calculate the quantities that will be required for the project. Quantities are calculated using the design as shown on the plan sheets. Quantities are measured in various ways. The most common units of measure are cubic yards, linear feet, each, lump sum or square feet. Each quantity shall have a unit of measure. This defines how the item is paid; refer to the latest approved version of the MSHA's *Standard Specifications for Construction and Materials*. The specifications and special provisions define how an item is paid for (unit of measurement) and what the payment does and does not include.

In the material following, various examples of items needed for signing, pavement marking, signals, and lighting are discussed.

Signs

Signs are paid for by the square foot (SF) area of the sign face, including all necessary mounting hardware for ground mounted and overhead signs. This is the same for both sheet and extruded aluminum, however they are paid for as separate items. This is due to the different associated costs. Sign overlays are always constructed from sheet aluminum.

Signs are typically furnished by MSHA and installed by the contractor for all signal related

signs under most Areawide Contracts. It is important to clarify in the early design stages whom will be supplying the signs for a given project.

Available Items	Unit
Sheet Aluminum Signs	Square Feet
Extruded Aluminum Signs	Square Feet
Overlay Overhead Signs	Square Feet
Overlay Ground Mounted Signs	Square Feet

Ground Mounted Sign Supports

Wood and Steel Ground Mounted Supports are paid for by the linear footage of installed support. Where breakaway steel posts are required, there will be one breakaway base support system for each post. For wood supports, the additional modifications for breakaway are incidental and not measured or paid for. Concrete foundations for steel supports are paid for separately based on the sizes listed in the Book of Standards.

The calculation of support length requires the collection of roadside cross sections, as discussed in the Field Review section of the Signing chapter. As an example, we will look at the following sign:

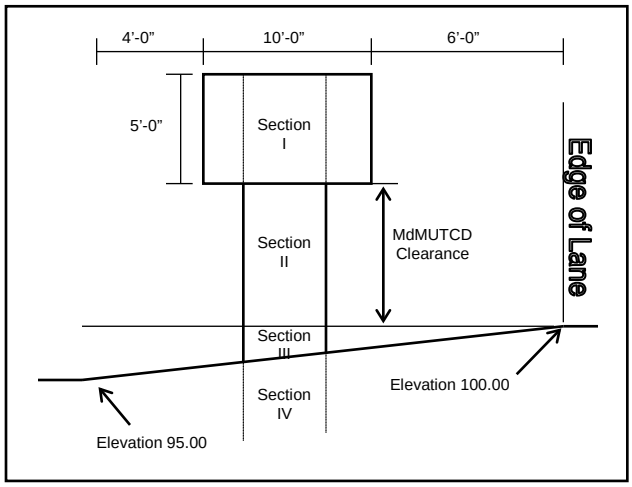


Figure EE.1 - Ground Mounted Support Lengths

The ground mounted support length can be calculated in four sections, numbered 1 to 4 in the picture above. The support length for each of these sections is determined as follows:

SECTION I: This section equals the sign height. New supports should extend to the top of the sign.

SECTION II: This section is equal to the MdMUTCD mounting height, 5'-0" minimum for rural areas and 7'-0" minimum in urban areas. This section will usually be 7'-6" for breakaway steel supports. Note that these dimensions are measured at a minimum from the top of curb or near edge of traveled way as specified in the MdMUTCD.

SECTION III: This section is the additional support length due to the roadside slope. It can be calculated as the overall embankment height (5.00 feet in the above example) times the ratio of support offset to slope length. For the sign shown above, this calculation for the right support would be as follows:

Support offset from top of slope (near edge of traveled way) = 6' + (10')1/5 = 6 + 2 = 8'-0"Section = (5.00) 8/20 = 2.00 Feet

SECTION IV: This section is the depth of bury below the ground line for the support. For steel supports, this number is zero (0'-0"). For 4"x4" and 4"x6" wood supports, it is 5'-0" and for 6"x6" and 6"x8" supports it is 6'-0".

The overall height of the right support in the above example (for wood supports) would be 5' (sign height) + 7' (mounting height) + 2' (addition for slope) + 5' (assuming 4"x6" wood) = 19'-0".

Available Items	Unit
Wood Supports (per size)	Linear Feet
Steel Supports (per size)	Linear Feet
Breakaway Base Support System (Type A or Type B)	Each
Concrete for Sign Foundation	Cubic Yards
Aluminum Angle (2½ x 3½ x ¼)	Linear Feet

Another item to be careful of is Aluminum Angles. They are considered incidental hardware and not paid for when used to mount extruded signs to wood supports. However, they are measured and paid for when used to mount a taller sign to existing steel supports. The angles are used to connect the new panels and provide stiffness that would have come from the supports. They are usually installed in pairs of two, with each angle being twice the height of the sign addition/extension (See "Extruded Aluminum Details and Vertical Support Attachment" in MSHA's *Book of Standards for Highways and Incidental Structures*). The maximum height that a sign can be extended with aluminum angles may require input from the TEDD structures team during the review process.

Overhead Structures

Overhead Supports, both cantilever and overhead structures, are paid for by each structure installed. This number includes anchor bolts, sign supports, and all hardware. Foundations are paid for separately based on the size specified by the plans.

Available Items	Unit
Cantilever Sign Structure	Each
Overhead Sign Structure	Each
Concrete for Sign Foundation	Cubic Yards
4" PVC Conduit in Sign Foundation	Linear Feet

Sign Lighting

Sign lighting requires quantities for luminaires, 1" rigid steel conduit, 1" flexible steel conduit, electrical cable, and ground wire. If the sign structure is new, the I-beam supports for the luminaires are incidental to the structure. If the sign lighting is being installed on an existing sign structure or being relocated, they will have to be quantified. The number of luminaires is determined from the Sign Lighting Tables in Appendix A-6 of this manual. The remaining quantities can be calculated as follows:

Flexible Steel Conduit = (3 LF) * (# of luminaires)

Rigid Steel Conduit = [(# of luminaires)*(6 LF + distance from bottom of truss to bend in I-beam luminaire support) + (distance from the upright support to the last luminaire along the truss)] + 5% increase to account for bending

Electrical Cable = [4*(distance from bottom of upright support to the bottom truss + the distance along the bottom truss from the upright to the farthest luminaire) + 4*(# of luminaires)*(6 LF + distance from bottom of truss to bend in I-beam luminaire support)] + 10% increase to account for bending and slack

Ground Wire = [(distance from bottom of upright support to the bottom truss + the distance along the bottom truss from the upright to the farthest luminaire) + 2*(# of luminaires)*(6 LF + distance from bottom of truss to bend in I-beam luminaire support)] + 10% increase to account for bending and slack

Miscellaneous Sign Items

When needed, sheet aluminum signs are used in conjunction with signals to achieve a desired message. They can be mounted on the mast arms, span wire, banded to the signal pole, or installed as a ground mounted sign. Signs may also be banded to overhead structures and light poles.

(Note: Equipment Furnished by MSHA)

Available Items	Unit
Install Span Wire Mount Sign	Square Feet
Install Mast Arm Mount Sign	Square Feet
Band Sign to Support	Each
Modify Message, Overhead	Each Character
Modify Message, Ground Mounted	Each Character

Depending on the type of installation you are designing, there are other miscellaneous quantities that may be necessary.

Sign Removal Items

Whenever the contractor must remove existing signs and supports, items must be included in the estimate. In general, sign removal is paid for by square footage (SF), including removal of the supports if specified on the plans. When signs will be removed and relocated, refer to the Special Provision for the appropriate pay items.

Available Items	Unit
Remove Overhead Sign/Luminaire Supports	Each
Remove Overhead Signs	Square Feet
Remove Ground Mounted Signs and Supports	Square Feet
Remove Existing Overhead Structure	Each
Remove Existing Cantilever Structure	Each

Pavement Markings

Lane lines, edge lines, channelizing lines and gore markings are paid for by linear footage (LF) of material installed. Arrow, word and symbol markings are paid for by square feet of material installed. When calculating quantities, they should be separated by line width, color, and material (for example 12" White Thermoplastic). The removal of existing pavement markings should be accounted for as a separate line item. All existing pavement markings, being replaced or removed, are paid for in linear feet.

Although snowplowable raised (including recessed) pavement markers (SRPMs) are not specifically called out on the marking plans, a separate line item is needed based on requirements of the MdMUTCD and Book of Standards. For instance, RPMs are paid for by each so the quantity should be doubled when side-by-side markers are needed along elephant tracks for freeway off-ramps.

Available Items	Unit
White/Yellow Paint (5”, 10” or 15”)	Linear Feet
White/Yellow Contrast Pavement Marking Tape (5” or 10”)	Linear Feet
White/Yellow Pavement Marking Tape (5”, 10” or 15”)	Linear Feet
White/Yellow Inlaid Pavement Marking Tape (5”, 10” or 15”)	Linear Feet
White/Yellow Epoxy Pavement Marking (5”, 10” or 15”)	Linear Feet
White Thermoplastic (5”, 10”, 12”, 15”, 16” or 24”)	Linear Feet
Yellow Thermoplastic (5”, 10” or 15”)	Linear Feet
White/Yellow 40 Mil High Binder Thermoplastic (5”, 10” or 15”)	Linear Feet
White Preformed Thermoplastic (5”, 10”, 12”, 15”, 16” or 24”)	Linear Feet
Yellow Preformed Thermoplastic (5”, 10” or 15”)	Linear Feet
White Preformed Thermoplastic Pavement Marking Legends and Symbols	Square Feet
Removal of Existing Pavement Marking Lines, Any Width	Linear Feet
Snowplowable Raised Pavement Markers	Each

* NOTE - see Category Code Book for exact item descriptions to be used on the plans and for other pay items.

Signal Cabinet and Controller

The cabinet and controller are items that are furnished by MSHA and installed by the contractor. These items are paid for per each. For new installations, the cabinet, controller and video interface equipment are all combined as one pay item but they can also be provided individually to meet specific project needs. The cabinet also requires a concrete foundation that is incidental for Areawide projects but paid for as a separate item in Insert projects. A Metered Service Pedestal is used to provide the power supply for new cabinets.

(Note: Equipment Furnished by MSHA)

Available Items	Unit
Controller ASC III with Telemetry	Each
Controller Cabinet (per size)	Each
Uninterrupted Power Supply	Each
Video Interface Equipment	Each
4-Channel Detector Amplifier (Rack Mount)	Each
Concrete for Foundation	Cubic Yards
Electrical Utility Service Equipment	Each
Metered Service Pedestal	Each
Cellular Modem, Antenna and Lead-in Cable	Each
Ethernet Extender, Repeater and Switch	Each
Install Controller and Cabinet – Base Mount	Each
Install Controller and Cabinet – Pole Mount	Each
2 Wire Central Control Unit	Each

Signal Structures

Signal structures are paid per structure, for each size. For example, “Furnish and Install 27’ Steel Pole with 50’ Mast Arm” is a different item than “Furnish and Install 27’ Steel Pole with 60’ Mast Arm”. Signal Structures also require concrete foundations that are incidental for Areawide projects but paid for as a separate item in Insert projects. These

items are typically furnished and installed by the contractor. Strain poles require the use of span wire to attach the signals and signs. Span wire is measured per linear foot (LF). This quantity should account for the sag and extra at either end to attach to the strain poles.

Available Items	Unit
Steel Pole with Mast Arm (per size)	Each
Strain Pole (per size)	Each
Breakaway Pedestal Pole (any size)	Each
Cut, Clean, Galvanize and Cap Signal Structure	Each
Concrete for Signal Foundation	Cubic Yards
Steel Span Wire (3/8” or 1/4”)	Linear Feet
Class 2 Excavation	CY
Audible/Tactile Pedestrian Pushbutton Station & Sign	Each

Signal Heads

Signal heads are paid for per section of standard. They are broken out per the size and type.

Available Items	Unit
LED Vehicular Traffic Signal Head Section (12”)	Each
LED Vehicular Traffic Signal Head Section with Louvers (12”)	Each
16” LED Countdown Pedestrian Signal Head Section	Each

Detectors

Microloop probes are typically paid per each, inclusive of the lead-in cable and three probes. Saw cuts are measured and paid per linear foot. Video detection camera to controller cable is incidental to the item for the camera and is available in any length.

Available Items	Unit
Microloop Triple Probe Set (up to 1000’ Lead-in Cable)	Each
Non Invasive Microloop Triple Probe Set (up to 1000’ Lead-in Cable)	Each
Saw Cut for Signal	Linear Feet
Loop Wire Encased in Flexible Tubing (No. 14 AWG)	Linear Feet
Video Detection Camera (including camera to controller cable)	Each

Signal Preemption

Using an optically activated priority control system requires the inclusion of the detector eye, emitter, a discriminator, card rack and cable. The first four items are paid per each. MSHA will typically install three emitters for use with firehouse preemption. The cable is paid for per linear foot from the detector eye to the cabinet. Account for an extra 20% in the length of cable for slack, coil, connections, etc.

When using a hard wire for preemption, a push button shall be installed in the firehouse.

Available Items	Unit
Optically Activated Priority Control System Detector Eye	Each
Optically Activated Priority Control System Detector Emitter	Each
Optically Activated Priority Control System Discriminator	Each
Optically Activated Priority Control System Card Rack	Each
Push Button for Preemption	Each
Optically Activated Priority Control System Detector Cable (4 conductor No. 20 AWG (7x8) stranded cable)	Linear Feet

Signal Removal Items

Remove and Dispose of Foundation 12" Below Grade is only used with Areawide projects.

Available Items	Unit
Remove and Dispose of Existing Signal Equipment	Lump Sum
Remove and Dispose of Foundation 12" Below Grade	Each

Pedestrian Facilities

ADA ramps and sidewalk are measured by square feet of concrete sidewalk. Other items associated with ramps are detectable warning surfaces, curb and combination curb and gutter. Backer curb is paid for by linear feet of curb and the quantity can be increased if the height of the backer curb is higher, such as 16" in certain areas.

Available Items	Unit
Type A Curb Any Height or Depth	LF
Type A Combination Curb and Gutter Any Height and Depth	LF
5 Inch Concrete Sidewalk	SF
Detectable Warning Surface	SF
Placing Furnished Topsoil 4 Inch	SY
Turfgrass Sod Establishment	SY

Traffic Barrier

Where required to protect roadside hazards, such as at sign structures and light poles, traffic barrier quantities must be included. There are separate items for the barrier and each type of end treatment.

Available Items	Unit
W-Beam Traffic Barrier	Linear Feet
Traffic Barrier End Treatment	Each
Trail End Anchorage	Each
Surface Adjustment for End Treatments	Cubic Yard
W Beam Barrier Reflective Delineators	Each
Remove Steel Post and Foundation	Each
Remove Existing Traffic Barrier	Linear Feet
Remove Existing End Treatment	Each

Wiring

When estimating cable, use total measured quantity plus 10-20% to account for the excess in handholes, cable slack,

connections, splices (loop wire to lead-in and ground mounted HIBs only), and drip loops. Remember to include the pole height and underground conduit bend depth in the measurements when a pole is used to transport the cable from overhead to underground. For loop wire, include the number of turns per sawcut, plus two times the distance from the detector to the handhole as well as an additional 5% to account for twisted cable.

Available Items	Unit
Signal Wiring	
Electrical Cable, No. 14 AWG (per number of conductors)	LF
Electrical Cable, 1 Conductor 250 kcmil, No. 4 or No. 8 AWG	LF
Electrical Cable, 2 Conductor No. 14 AWG, Aluminum Shielded	LF
Stranded Bare Copper Ground Wire (No. 4 or 6 AWG)	LF
12 Pair Communication Cable, Jellyfilled (Underground)	LF
12 Pair Communication Cable, Self-Supporting (Overhead)	LF
Electrical Cable, 3 Conductor No. 12 AWG Tray Cable	LF
Disconnect, Pull-Back and Reroute Cables	LF
Lighting Wiring	
Duct Cable (per # conductors and gauge size)	LF
Electrical Cable (per # conductors and gauge size)	LF
Stranded Bare Copper Ground Wire (per gauge size)	LF
Solid Ground Wire (per gauge size)	LF

Conduit

Conduit is paid for per linear foot (LF) and should be calculated by measuring the length plus some extra to account for grading and going around obstacles. Typically, in Areawide projects conduit is measured as "up to 4 inch," rather than measured by the linear foot, per specified size.

Available Items	Unit
Schedule 80 Rigid PVC Conduit – Trenched (per size)	Linear Feet
Schedule 80 Rigid PVC Conduit – Slotted (per size)	Linear Feet
Schedule 80 Rigid PVC Conduit – Bored (per size)	Linear Feet
1" Electrical Conduit, Galvanized Sleeve	Linear Feet
1" Liquid Tight Flexible Non-Metallic Conduit for Detector Sleeve (per size)	Linear Feet
1" Rigid Steel Conduit	Linear Feet
1" Flexible Steel Conduit	Linear Feet
Galvanized Steel Conduit (per size)	Linear Feet
EMT Conduit (per size)	Linear Feet

Light Structures

Highway lighting has several types of structures. The structures include the pole and bracket arm. The transformer bases and concrete foundations are paid for separately.

Available Items	Unit
Concrete for Light Foundation	Cubic Yard
High Mast Light Structure (per pole height)	Each
Light Structure and Bracket Arm (per pole height and arm length)	Each
Aluminum Light Structure and Bracket Arm (per pole height and arm length)	Each
Breakaway Base Support	Each
Lighting arm on Signal Structure (per arm length)	Each

Lamps and Luminaires

Highway and sign lighting has several types of luminaries and lamps. They are paid for together based on the style, type and wattage.

Available Items	Unit
LED Roadway Luminaire	Each
High Mast Lighting Assembly (including lowering device)	Each
LED Sign Luminaire	Each

Other Electrical Equipment

In addition to the wiring and conduit there is other electrical equipment that shall be defined. Connector kits for lighting are quantified as per each item, except at intersections. Handholes are commonly used with signals and electrical manholes with lighting design. Ground rods are usually incidental in Areawide projects but paid per each in Insert projects. With any electrical design there will also be a Pole or Base

Mounted Cabinet and associated equipment dependent on the power service. Refer to MSHA's *Standard Specifications for Construction and Materials* for appropriate equipment.

Available Items	Unit
Electrical Handhole	Each
Ground Rod	Each
Electrical Manhole	Each
Connector Kit, Type I	Each
Connector Kit, Type II	Each
Connector Kit, Type III	Each
Connector Kit, Type IV	Each
Base Mounted Lighting Cabinet (277/480 V, 3 Phase, 4 Wire)	Each
Base Mounted Lighting Cabinet (120/240 V, 1 Phase, 3 Wire)	Each
Pole Mounted Lighting Cabinet	Each
Embedded Service Pedestal	Each

Miscellaneous

Test pits are used to verify there are no underground utility conflicts with the proposed equipment. For signals and light structures, use one cubic yard for the cabinet and one cubic yard for every two pole foundations.

Maintenance of Traffic is paid per each for Areawide Contracts and is based on the total estimate amount (typically 1-3 EA). Otherwise, it is paid as Lump Sum based on items specified in the Standard Specifications for Construction and Materials Book.

Available Items	Unit
Test Pit Excavation	Cubic Yards
Maintenance of Traffic	Each

PRODUCING THE ESTIMATE

Once the final quantities have been determined, the steps required to produce a final estimate vary depending on the type of project. This is due to the different contracting procedures and construction forces available. The primary difference between the different estimate types lies in how the unit prices are determined. In the case of Shop Forces and Areawide projects, all unit prices have been established ahead of time. For Insert and advertised projects, the unit prices must be estimated based on similar projects.

Who Pays for What

Payment provisions for every item in a contract are defined by the Standard Specifications and the Special Provisions. These will tell you what items are paid for, how those items are measured, and what items are incidental to that payment. For each quantity, determine who will supply the appropriate materials to complete the work. This will be determined by current MSHA practice and also by the contract type. For example, Signs are MSHA supplied on Areawide contracts and can be Contractor supplied on Insert or Advertised jobs. As mentioned earlier, an estimate should include a separate section tabulating the quantities for all MSHA and contractor supplied equipment and materials (this is referred to as the "Equipment List" with sections "A" and "B" respectively).

Shop Forces/Areawide Projects

The unit prices used for Shop Forces and Areawide estimates are usually determined

before design of the project has begun based on the awarded bid prices for the Contract. In some instances, a project will require an item for which there is no unit price, and the designer must make a reasonable estimate. These items will then have to be either negotiated with the contractor or purchased and installed separately by MSHA.

On the other hand, if a project requires an item for which there is no unit price, review the existing items and determine if it makes sense to use another item in its place. For instance, if a 38 foot mast arm is required but doesn't exist in the contract, the designer could call for a 50 foot mast arm (that does have a unit price) and cut the arm to 38 feet.

Due to the diverse nature of Areawide construction, certain items have been customized for this contract and are paid for differently than on other projects. For instance, signal poles, ground rods and concrete foundations are usually paid for separately, however, for the Areawide contract they are paid for as a single, all-inclusive, item for signal poles. It is important to become familiar with the Special Provisions for a contract, where these differences are explained for each contract. An example of an Areawide estimate is shown below.

Advertised and Insert Projects

Unit prices for Advertised and Insert projects are calculated from the Price Index using similar projects bid over the previous 12 months. These prices are compiled in a database and made accessible in the MSHA "Estimator Program". They are applied to the quantities developed in the previous section to estimate the total project cost. On these projects the contractor usually furnishes all materials and equipment. However, MSHA still typically furnishes signs, signal cabinets and associated equipment. An example of an Advertised/Insert estimate is shown below.

Typical Areawide Engineer's Estimate

Item No.	Description	Unit	Quantity	Unit Cost	Total Costs
1001	MAINTENANCE OF TRAFFIC	EA	1	$1,000.00	$1,000.00
2001	CLASS 2 EXCAVATION	CY	7	$1.00	$7.00
2002	TEST PIT EXCAVATION	CY	4	$25.00	$100.00
5001	REMOVAL OF EXISTING PERMANENT PAVEMENT MARKINGS SYMBOLS OR LEGENDS	EA	4	$1.00	$4.00
5002	5" HEAT APPLIED WHITE OR YELLOW PERMANENT PAVEMENT MARKINGS	LF	40	$2.00	$80.00
5003	REMOVAL OF EXISTING PERMANENT PAVEMENT LINE MARKINGS	LF	625	$0.25	$156.25
5004	12 INCH WHITE PREFORMED THERMOPLASTIC PAVEMENT MARKING LINES	LF	490	$6.00	$2,940.00
5005	24 INCH WHITE PREFORMED THERMOPLASTIC PAVEMENT MARKING LINES	LF	210	$8.00	$1,680.00
6001	STANDARD TYPE A COMBINATION CURB AND GUTTER 12 INCH GUTTER PAN 8 INCH DEPTH	LF	420	$30.00	$12,600.00
6002	5 INCH CONCRETE SIDEWALK	SF	830	$7.50	$6,225.00
6003	DETECTABLE WARNING SURFACE FOR CURB RAMPS	SF	105	$40.00	$4,200.00
8001	12 INCH LED SIGNAL HEAD SECTION	EA	3	$240.00	$720.00
8002	2-WIRE CENTRAL CONTROL UNIT	EA	1	$2,600.00	$2,600.00
8005	ADJUST HANDHOLE TO GRADE WITH NEW FRAME AND COVER	EA	1	$325.00	$325.00
8008	AUDIBLE/TACTILE PEDESTRIAN PUSHBUTTON STATION AND SIGNS	EA	7	$575.00	$4,025.00
8009	BREAKAWAY PEDESTAL POLE (ANY SIZE)	EA	7	$1,900.00	$13,300.00
8016	LED 16 INCH COUNTDOWN PEDESTRIAN SIGNAL HEAD	EA	6	$575.00	$3,450.00
8017	LED SIGNAL HEAD MODULES (ANY SIZE)	EA	33	$120.00	$3,960.00
8024	REMOVE & DISPOSE OF EQUIPMENT (PER ASSIGNMENT)	EA	1	$1,000.00	$1,000.00
8040	UP TO 4 INCH SCHEDULE 80 RIGID PVC CONDUIT-TRENCHED	LF	135	$9.00	$1,215.00
8042	INSTALL OVERHEAD OR GROUND MOUNTED SIGN (INCLUDING ALL HARDWARE)	SF	7	$8.00	$56.00
8044	NO. 6 AWG STRANDED BARE COPPER GROUND WIRE	LF	185	$1.10	$203.50
8055	ELECTRICAL CABLE - 2 CONDUCTOR (NO. 14 AWG)	LF	1800	$1.00	$1,800.00
8057	ELECTRICAL CABLE - 5 CONDUCTOR (NO. 14 AWG)	LF	1740	$1.40	$2,436.00
				Total Contractor Cost	**$64,082.75**

Item No.	Description	Unit	Quantity	Unit Cost	Total Costs
9571	[UPDATED] SHEET ALUMINUM MAST ARM / POLE MOUNTED SIGN	SF	7	$21.00	$147.00
	R10-3(1) IKEA Way (9"x15")	EA	3		
	R10-3(1) I-95 Ramp (9"x15")	EA	2		
	R10-3(1) Baltimore Ave (9"x15")	EA	2		
				Total State Cost	**$147.00**
				Total Cost	**$64,229.75**

Figure EE.2 - Typical Areawide Estimate

Typical Insert Engineer's Estimate

Item No.	Description	Unit	Quantity	Unit Cost	Total Costs
203030	TEST PIT EXCAVATION	CY	3	$105.00	$315.00
500000	BRICK PATTERNED PREFORMED THERMOPLASTIC PAVEMENT MARKINGS	SF	3234	$15.00	$48,510.00
585621	12 INCH WHITE PREFORMED THERMOPLASTIC PAVEMENT MARKING LINES	LF	850	$7.25	$6,162.50
585625	24 INCH WHITE PREFORMED THERMOPLASTIC PAVEMENT MARKING LINES	LF	300	$13.50	$4,050.00
800000	16 INCH LED COUNTDOWN PEDESTRIAN SIGNAL HEAD SECTION PEDESTAL POLE MOUNT	EA	5	$1,055.00	$5,275.00
800000	2-WIRE CENTRAL CONTROL UNIT	EA	1	$3,375.00	$3,375.00
800000	AUDIBLE/TACTILE PEDESTRIAN PUSHBUTTON STATION AND SIGN	EA	6	$1,015.00	$6,090.00
800000	REMOVE SIGNAL HEAD FROM EXISTING STRUCTURE	EA	1	$30.00	$30.00
800000	REMOVE SIGNAL STRUCTURE	EA	3	$300.00	$900.00
800000	VIDEO DETECTION CAMERA AND CABLE UP TO 500'	EA	6	$7,130.00	$42,780.00
801004	CONCRETE FOR SIGNAL FOUNDATION	CY	1	$1,100.00	$1,100.00
801706	REMOVE SIGNS FROM EXISTING OVERHEAD STRUCTURE	SF	67.5	$11.00	$742.50
802501	NO. 6 AWG STRANDED BARE COPPER GROUND WIRE	LF	400	$1.35	$540.00
805115	3 INCH SCHEDULE 80 RIGID PVC CONDUIT-BORED	LF	190	$17.50	$3,325.00
805125	2 INCH SCHEDULE 80 RIGID PVC CONDUIT-TRENCHED	LF	95	$9.30	$883.50
805135	3 INCH SCHEDULE 80 RIGID PVC CONDUIT-TRENCHED	LF	25	$11.35	$283.75
805140	4 INCH SCHEDULE 80 RIGID PVC CONDUIT-TRENCHED	LF	105	$15.50	$1,627.50
805155	4 INCH SCHEDULE 80 RIGID PVC CONDUIT-SLOTTED	LF	180	$55.00	$9,900.00
810601	NONINVASIVE DETECTOR, 500 FOOT LEAD IN CABLE	EA	3	$1,750.00	$5,250.00
810605	NONINVASIVE DETECTOR, 1000 FOOT LEAD IN CABLE	EA	9	$2,100.00	$18,900.00
811001	FURNISH AND INSTALL ELECTRICAL HANDHOLE	EA	7	$1,225.00	$8,575.00
811002	REMOVE ELECTRICAL HANDHOLE	EA	10	$260.00	$2,600.00
813015	INSTALL OVERHEAD SIGN	SF	139	$18.10	$2,515.90
818004	10 FOOT BREAKAWAY PEDESTAL POLE	EA	5	$1,605.00	$8,025.00
837001	GROUND ROD - 3/4 INCH DIAMETER X 10 FOOT LENGTH	EA	1	$120.00	$120.00
860265	RELOCATE EXISTING SIGNAL HEAD	EA	2	$215.00	$430.00
861105	ELECTRICAL CABLE - 2 CONDUCTOR (NO. 14 AWG)	LF	1080	$1.35	$1,458.00
861107	ELECTRICAL CABLE - 5 CONDUCTOR (NO. 14 AWG)	LF	1110	$1.75	$1,942.50
861108	ELECTRICAL CABLE - 7 CONDUCTOR (NO. 14 AWG)	LF	815	$2.30	$1,874.50
				Total Contractor Cost (Signal)	**$187,580.65**

Item No.	Description	Unit	Quantity	Unit Cost	Total Costs
9000	[UPDATED] VIDEO DETECTION INTERFACE EQUIPMENT: 1-8 CAMERAS	EA	1	$2,025.00	$2,025.00
9571	[UPDATED] SHEET ALUMINUM MAST ARM / POLE MOUNTED SIGN	SF	139	$21.00	$2,919.00
	D-3(1) '85th AVE' (VAR.x16")	EA	2		
	D-3(1) 'Annapolis RD' (VAR.x16")	EA	2		
	M1-5(6) 'EAST MD 450 <-' (48"x72")	EA	1		
	M1-5(6) 'EAST MD 450 ->' (30"x48")	EA	1		
	M1-5(6) 'WEST MD 450 <-' (48"x72")	EA	1		
	M1-5(6) 'WEST MD 450 ->' (30"x48")	EA	1		
	R10-3(1) '85TH AVE' (9"x15")	EA	4		
	R10-3(1) 'ANNAPOLIS RD' (9"x15")	EA	2		
	R3-5(MOD) (30"x36")	EA	1		
	R3-5a 'THRU ONLY' (30"x36")	EA	1		
	R3-5L 'LEFT ONLY' (30"x36")	EA	1		
				Total State Cost	**$4,944.00**

Total Contractor Cost	**$187,580.65**
Total State Cost	**$4,944.00**
Total Cost	**$192,524.65**

Figure EE.3 - Typical Advertised/Insert Estimate

WRITE-IN ITEMS

A Write-in item is an item identified in the preliminary design of an Advertised contract that does not have an associated category code number. This item may not have been used by MSHA in the past or is very different from what has been used. In these circumstances a Write-in item will be requested and given a category code number of 800000. Accordingly, a Special Provision to the Standard Specifications for Construction and Materials will be developed for that particular contract.

NEGOTIATED ITEMS

A negotiated item is an item specified in the project design that does not exist in an Areawide contract's bid items list. Hence, there is no associated bid price for such items and a unit price must be agreed upon between the State and the Areawide Contractor. Similarly, if there is a need for a new item during construction of an insert project, the item will be added as a redline revision and a unit price must be agreed upon between the State and the General Contractor.

Under existing Areawide contracts the need for negotiable items shall be determined during preliminary design. The project schedule will be adjusted if necessary, and research for negotiable item vendors, model numbers, costs, etc. shall begin.

At this point a cost estimate to furnish and install the item will be produced. This should include the cost of the items plus a 20% markup and 6% tax. The man-hours and $ rate plus 65% to install shall be included in the estimated price. The equipment hours and $ rate plus 20% shall also be included in the estimate to install the item. Wage rates are provided in the IFB, and the Equipment rates are from the Rental Rate Blue Book.

When negotiable items and cost estimates have been recognized, a prepared memo for the negotiable item to be negotiated shall be submitted to MSHA's Traffic Operations Division (TOD). This memo shall include a detailed description of the item, and provide specifications, typicals for the work to be completed, and any other pertinent information such as vendors, phone numbers, addresses, etc.

Following this, TOD will contact the Contractor and request a price based on the information provided. The response is to be requested within 3 weeks. The Contractor shall submit a price including a detailed breakdown of cost, labor, tax and profit to complete the work.

If the Contractor's cost is within 10% of the engineers estimated cost, the item shall be approved. If the Contractors cost is more than 10% of the engineers estimate, TEDD shall reevaluate their estimate to determine where the discrepancies are and make the appropriate adjustments as needed.

At this time the Design Engineer shall re-evaluate the PS&E schedule and adjust as necessary with approval from the PM. TEDD and TOD will then agree on the price and/or re-negotiate. Once the price has been agreed upon, TOD will set up the item for the remainder of the Contract. TEDD will then PS&E the project to CFD. Note: No project should go to PS&E without approved negotiable items.

PROJECT PROCESS

PROJECT PROCESS

TYPES OF PROJECTS

The project steps refer to the work path a project must follow in progressing from the recognition stage through design to construction and final acceptance for maintenance. The Traffic Engineering Design Division regularly processes projects that fall into one of the following five categories:

1. Shop-Forces Projects – These projects are usually small in nature and are designed for construction by MSHA personnel.
2. Areawide Projects – These projects typically range from small sized to medium sized and are designed for construction by one of the on-call Areawide Contractors.
3. Insert Projects – These projects are typically medium to large construction. They are designed to be inserted (thus the name) into plan sets that will be advertised by another Division that is acting as the project lead (typically Highway Design, District Engineering Systems Team, Bridge Design, or Landscape Design).
4. Advertised Projects – These are projects of various sizes that are advertised directly by TEDD. Occasionally, these also include the advertisement of specific projects. For example, MSHA might advertise a project to upgrade all the traffic control devices along a particular stretch of roadway.
5. Developer Projects – These projects are designed and constructed by entities hired by private developers but are located on or impact roadways owned and maintained by the state and therefore must be reviewed and approved by MSHA.

Most projects, no matter which type, are initiated with a Design Request (DR) from the District Office. The DR provides background information on the project and identifies specific improvements that are required such as signing and pavement markings to latest standards, upgrading signal equipment, phasing modifications, interchange lighting, etc.

The administrative and approvals processes for each of these five categories are slightly different, and they follow slightly different time frames. For the purposes of this manual, we will focus on the design, review and approval processes as well as necessary coordination. This manual will not cover the procedural steps required to secure funding, schedule construction, and obtain Federal Aid approval.

Shop Forces Projects

These projects may be initiated by phone call, fax (knock-downs), Design Request (DR), or hand-written note. They tend to be less formal and can follow a rapid schedule when required.

Typically, the Shop Forces design process is uncomplicated and involves minimal coordination beyond the shop and possibly the District Traffic office. For this reason, these projects are ideal for quick turn-around construction with short schedules.

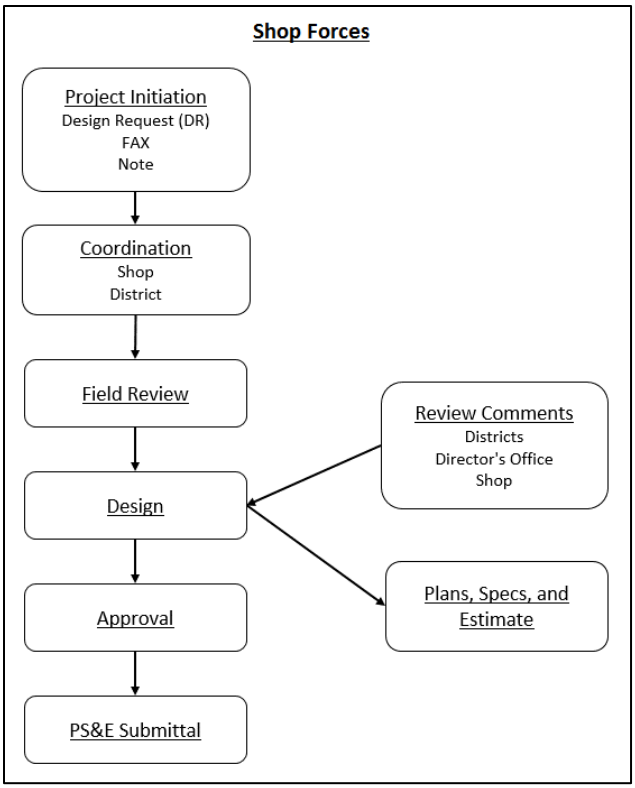


Figure PP.1 - Shop Forces Project Flow Chart

Areawide Projects

Areawide projects are usually initiated when the District Traffic Office completes a Design Request (DR) and sends it to the OOTS Director for approval. The actual design process begins when the appropriate TEDD Team Leader receives the approved DR.

Areawide projects have a few coordination items that must be initiated as early as possible in the design process. A preliminary and final 25C form must be submitted for federal funding. In order to comply with Federal Aid requirements, an environmental review must be performed. This does not require detailed design information, and is usually done early on in the project to avoid delays. Plan Review Division (PRD) and National Pollutant Discharge Elimination System (NPDES) approval may be required depending upon the amount of ground disturbance that the project will require. The Federal Aid process also requires a review of utility conflicts, and where appropriate an estimate of the relocation costs. **For projects that require a new power feed, the confirmation of power location should be sent to the utility company as early as possible.** This will confirm if power is available early in the design process. Note that some service requests require an official application for power which should be completed and submitted during the design stage. In order to ensure that a project is not delayed, it is recommended that these requests be submitted as early as possible.

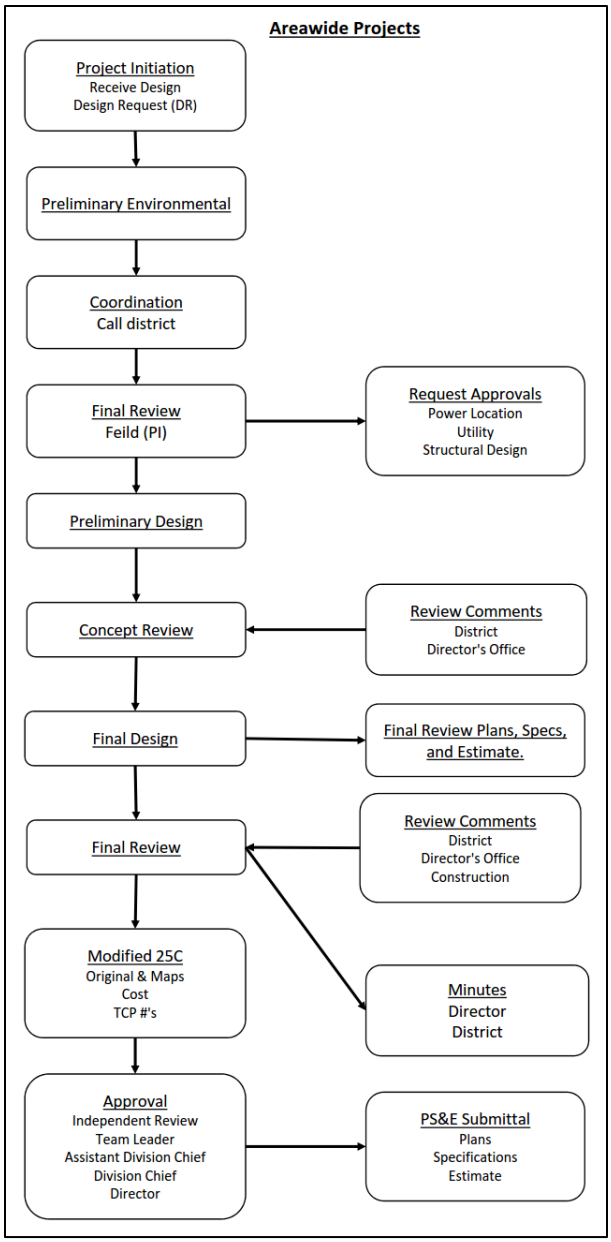


Figure PP.2 - Areawide Project Flow Chart

Insert Projects

Insert projects are also initiated when the District Traffic Office completes a Design Request (DR) and sends it to the OOTS director for approval. Although the actual traffic design process begins when the approved DR reaches TEDD, in most cases, the lead division has already commenced preliminary design.

On Insert Projects, Highway Design or another division acts as the project lead for tracking schedules, budgets and estimates. This eliminates the Areawide project steps of submitting preliminary and final 25C forms and getting environmental and utility certification. The remaining steps in the design process involve coordination and review, and are largely dependent on the overall project schedule and progress.

The reviews specified in the Insert Projects flow chart do not necessarily correspond to the formal Highway Design Reviews at PI, Semi-Final Review and Final Review. While participation in these reviews is helpful for both TEDD and all other project participants, the Concept Review must take place separately from these reviews.

It is important for these projects to coordinate the design schedule around the Highway Design schedule. For example, since the signing and marking is designed to fit the roadway design, selection of final structure and sign locations cannot take place until after the Semi-Final Review and sometimes Final Review. **Prior to the Semi-Final Review, locations can be selected and checked on a preliminary basis, with the understanding that they must be checked and possibly revised after the Final Review.**

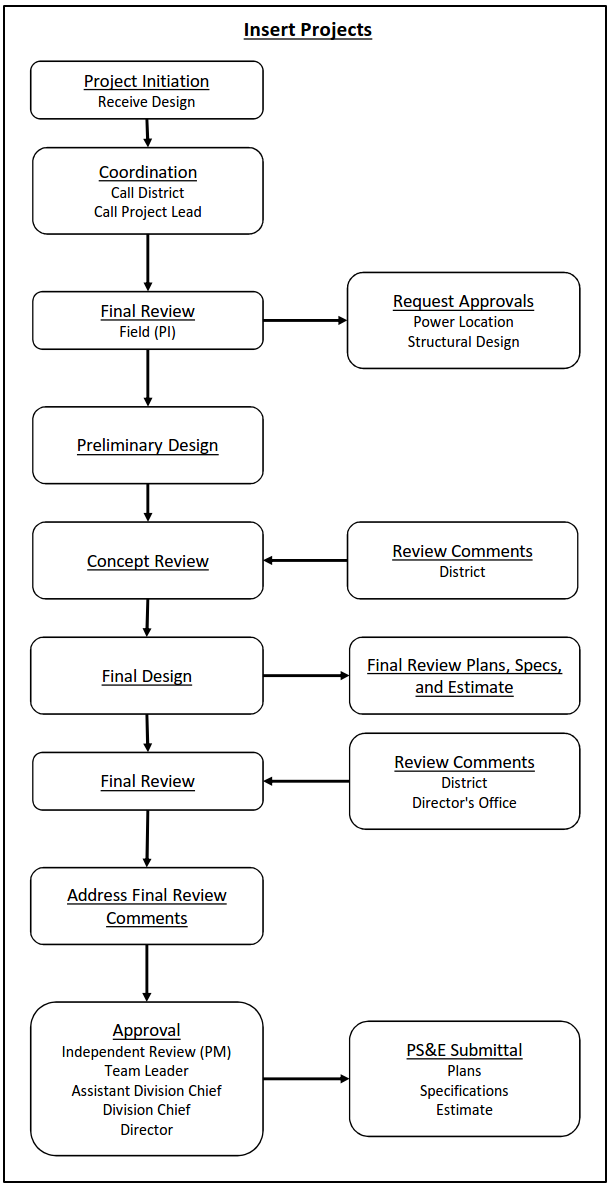


Figure PP.3 - Insert Project Flow Chart

Advertised Projects

Advertised projects are both designed and advertised by TEDD, who is the project lead. In most circumstances, they are developed entirely within TEDD, and no other divisions are involved. This is typical for corridor signing upgrades and multiple signalized intersections within the same vicinity or corridor. The TEDD Project Manager sets the schedule and milestone dates, and is also responsible for obtaining all the permits and certifications. Additionally, TEDD is responsible for creating the IFB. When the designer creates the estimate for the design, category codes and the MSHA Price Index need to be used for the items and unit prices. Additionally, the designer should include and note any necessary items that are not in the Category Code. Specifications or special provisions are typically needed for these (sometimes non-standard) items.

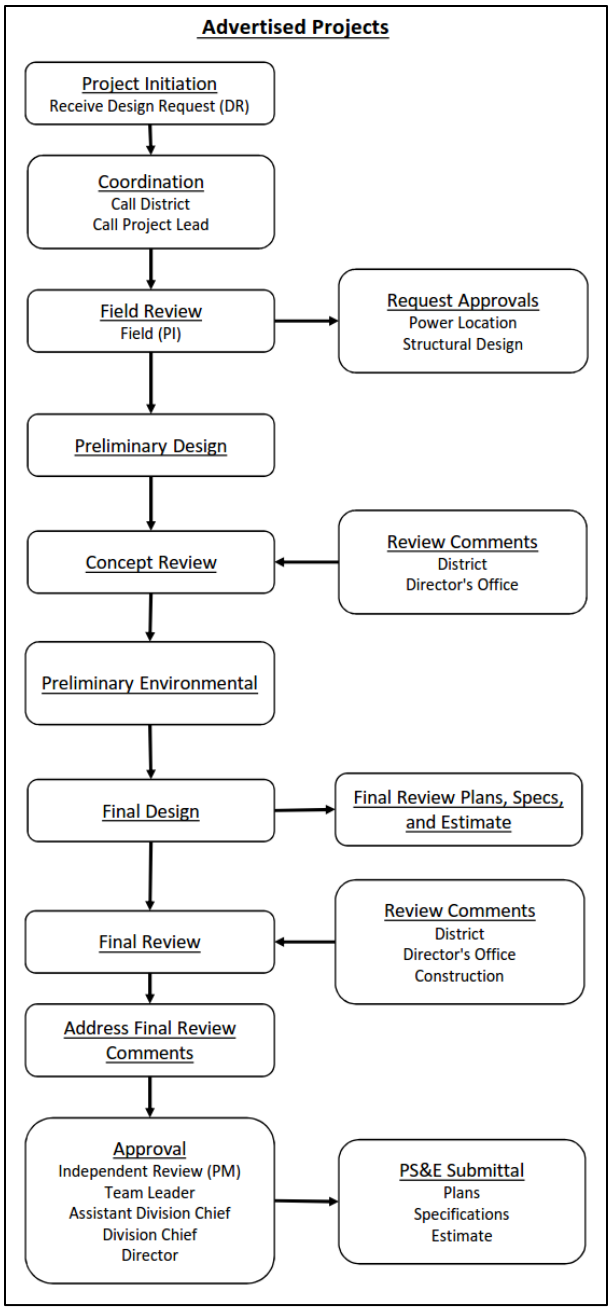


Figure PP.4 - Advertised Project Flow Cart

Developer Projects

Developer projects are designed by a private developer but must be reviewed and approved by MSHA to ensure that standards are met, the design is constructible, all necessary coordination with other projects and utilities occurs, and there are no Right of Way conflicts. The developer must initiate the DR process by contacting the District Engineer. Design consultants for private developers should contact the District Access Management to determine which engineering and inspections fees are applicable for the project.

The developer is responsible for a thorough on-site survey, reviewing any existing as-built plans, and contacting Miss Utility to locate all utilities within the vicinity of proposed construction. Next, the developer should prepare design plan sheets based on the approved DR. The developer must submit the plans and a cost estimate which should include the expenses for any state supplied equipment that will be paid for by the developer. The TEDD Project Manager will notify the developer when they have all comments on the project and the developer will update the plans and estimate. The final design package is then resubmitted to TEDD along with documentation of all comments and how they were addressed.

Once the Contract Documents are approved, MSHA prepares an agreement for the developer that must be signed and returned along with a check from the developer to cover the estimated expenses of MSHA for the project. The developer can then hire a contractor to perform the work. The developer or their designer should forward copies of the approved plans to EAPD for distribution to necessary parties.

Construction must be started within six months of approval, or the plans must be revised according to current standards and resubmitted for approval. Once construction is complete, the developer must provide an electronic copy of as-built plans to MSHA.

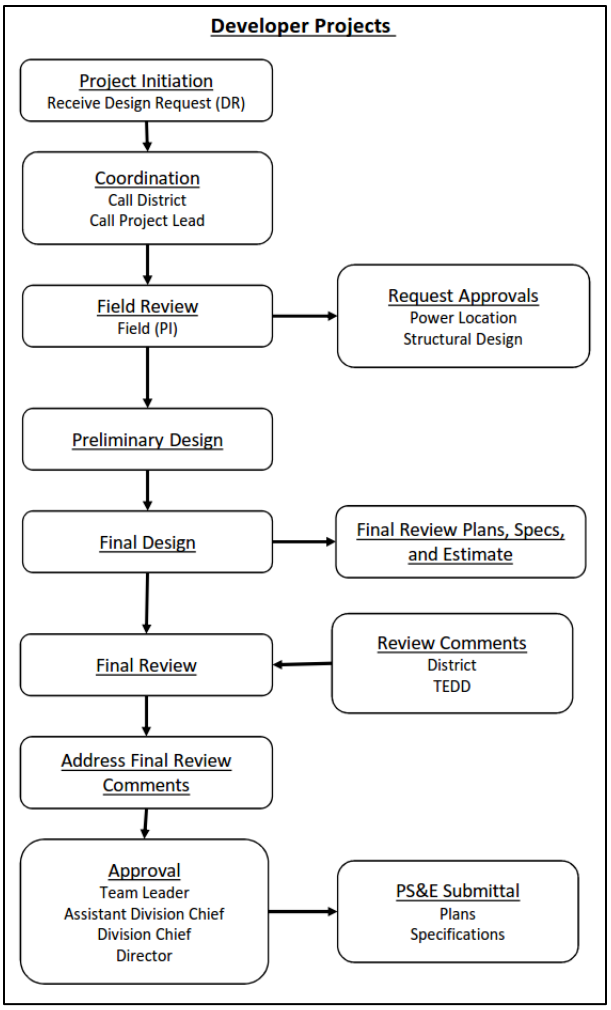


Figure PP.5 - Developer Project Flow Chart

SUBMITTALS PROCESS

The requirements for milestone submittals will be defined by the project manager for each specific project and may include a concept review, semi-final review, peer or constructability reviews. However, all projects include a final review and a PS&E submittal.

Final Review

The final review takes place at about 90% design completion, and it provides all key players a last chance to comment on the plans and specifications. The final review meeting may take place in conjunction with the Highway Design or District Final Review (for inserts), but it is common for a separate meeting to take place that focuses on traffic issues. As with the Concept Review, it is important for TEDD, District Traffic, the Directors Office, and construction to be present. This is the last chance to verify the plans and specifications coordinate with other disciplines, comment on the traffic control devices, and check that all relevant issues are addressed.

PS&E

The final package, which is submitted when design is complete, is referred to as a PS&E package, short for Plans, Specifications and Estimate. What is included in a PS&E package depends on the requirements for a given project type. Generally, In House projects require the least detail and Insert/Advertised projects require the most. Table PP.1 lists PS&E package contents and plan sheet requirements for each project type.

Specifications

SP's (Special Provisions), and SPI's (Special Provisions Inserts) define the materials, construction, measurement, and payment terms for every item in a construction project. They are used in conjunction with the *Standard Specifications for Construction and Materials*. According to the governing order defined in the Terms and Conditions, Special Provisions govern and take precedent over the Standard Specifications. It is important to use the latest version of these documents and any SP changes must be approved by OOTS/TEDD. These documents are used as follows:

Standard Specifications: These are the standard set of contract specifications, defining materials, construction, measurement and payment terms for common construction items. They are considered a part of every contract advertised by MSHA.

Special Provisions: These are written to define materials, construction, measurement, and payment terms for items on a specific contract.

When the terms of the Standard Specifications need to be changed for a project, a special provision must be included in the contract. They also must be written for every contract item not covered by the standard specifications.

Table PP.1 - Contents of PS&E Package

Item	Shop Forces	Areawide	Insert/ Advertised
Transmittal	X	X	X
Checklist		X	X
FR Minutes	X	X	X
Power Confirmation		X	X
Location Map	X	X	
Work Description	X	X	X
Signing and Pavement Markings			
Title/General Notes (SN-1)			X
Sign Plans (8½ x 11)	X		
Sign Plans (SN-2)		X	X
Sign Details (8½ x 11)	X		
Sign Details (SN-3)		X	X
GM Supports (SN-4)		X	X
Overhead Structures (SN-8 & SN-9)		X	X
Index of Quantities (SN-11)		X	X
Signals			
Title/General Notes			X
Signal Plans	X	X	X
Signal General Information		X	X
Signal System Plans	X	X	X
Lighting			
Title/General Notes			X
Lighting Plans	X	X	X
Lighting Schedules	X	X	X
Lighting Details	X	X	X
Index of Quantities		X	X
Environmental			
PRD Package			X
Modified 25C		X	