TRAFFIC SIGNAL DESIGN IN PENNSYLVANIA

pennsylvania
DEPARTMENT OF TRANSPORTATION

Highway Administration Deputate

There are hyperlinks throughout this document that should provide network connections to other publications, regulations, Vehicle Code, etc. There are also hyperlinks that reference other sections, exhibits, or appendices within the same chapter, and these should assist you in navigating within the manual.

Although not obvious by their color, the Table of Contents and the List of Exhibits within the individual chapters also work as hyperlinks. Simply left click on the section or exhibit number, title, or page number and your computer should take you to the proper page.

You may also find the bookmarks on the left side of the screen helpful.

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This training course was developed in partnership with the Pennsylvania Department of Transportation's Business Leadership and Administrative Services Office and the Highway Safety and Traffic Operations Division, and Albeck + Associates, Inc. It is offered as part of the Pennsylvania Department of Transportation's Highway Administration Comprehensive Training Plan exclusively through the Technical Training and Development Section.

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CHAPTER 1. INTRODUCTION

1.1 Overview

The purpose of this manual is to present the fundamental concepts and standard practices related to the design of traffic signal systems within the Commonwealth of Pennsylvania. This manual is structured to parallel the progression of decisions, activities and functions related to the design of traffic signal systems.

1.2 Manual Layout

This Traffic Signal Design course manual has been designed to match the flow and chapters of Publication 149, the Department's Traffic Signal Design handbook. Many of the topics of importance are covered in detail in Publication 149 and are included in this manual as a handout. In some cases, an entire chapter from Publication 149 is included in this manual as a handout. In other cases, only select pages from the Publication is included. When necessary, additional information that has not been included in Publication 149 is included in this training manual.

It is important to note, that the publications, forms and documents referenced in this training manual can and are updated at some point in the future. The holder of this manual is responsible to check the source material to ensure they are using the most up-to-date information. The latest version of the documents can be found on the traffic signal portal (see Section **1.4**).

1.3 Goals of the Course

At the end of this Traffic Signal Design in Pennsylvania course, you are able to:

- ✓ List the steps required to plan, design, and implement a signalized intersection
- ✓ Devise an appropriate data collection plan for planning, designing, and operating a signalized intersection
- ✓ Perform a warrant analysis using the MUTCD warrants, including PennDOT warrants
- ✓ Design basic phasing of the intersection - which movements will get a separate phase, and how they are numbered
- ✓ Determine location of signal supports, displays and detection
- ✓ Design the electrical distribution system for an intersection
- ✓ Select signal-related signs and pavement markings, including turning-movement signs, stop bars and crosswalks
- ✓ Create a traffic signal design report

1.4 Traffic Signal Portal Website

The Department's Traffic Signal Portal can be found at:

www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html

Exhibit 1-1 PennDOT Traffic Signal Resource Portal

The portal serves as a central location for information on traffic signals in Pennsylvania. It includes, but is not limited to, the following sources:

- ✓ Publications, policies, forms, and other documents
- ✓ Approved products listing
- ✓ Frequently asked questions
- ✓ Traffic signal processes and procedures
- ✓ Automated red light enforcement (ARLE)
- ✓ Mapping and spreadsheets
- ✓ Training updates
- ✓ Traffic signal performance measures
- ✓ Recent news

1.5 PennDOT Traffic Signal Publications

The portal referenced in **Exhibit 1-1** includes a page related to publications (refer to the website for these documents). **Exhibit 1-2** illustrates how these publications are used in design, construction and maintenance. Some of the more commonly used publications are presented in additional detail in the following sections.

Exhibit 1-2 Primary and Secondary Publications for Design, Construction and Maintenance

Design

Pub. 149
Design criteria and step-by-step guidance on developing a traffic signal plan

MUTCD
Part 4 is the "bible" on traffic signals, and includes warrants and design criteria.

Pub. 46
Internal traffic engineering policy. Chapter 4 discusses responsibilities, proprietary equipment, removal, etc.

PA Vehicle Code
Law that addresses the installation of traffic control devices and required driver responses.

Chapter 212
PA regulations on traffic control devices. Subchapter D addresses a few traffic signal items, including a PA warrant.

Pub. 10
This Design Manual Part 1, Transportation Project Development Process explains the Department's project development process.

Pub. 13M
This Highway Design Manual, Part 2, is for highways, but Chapter 6 addresses design of pedestrian facilities.

Pub. 14M
This Design Manual Part 3, Plans Presentation, provides the general format and detail for the development of plan sheets – specifically, Chap. 4 addresses traffic control in work zones and Chap. 10 addresses traffic signal plans.

Pub. 236
Identifies all approved signs for use within Pennsylvania and includes layout details for manufacturing.

Construction

Pub. 408
Provides detailed material and construction specs for traffic signal equipment, and field testing procedures

Pub. 35
Lists manufacturers of approved materials that can be used for construction.

Pub. 148
Standard drawings showing design details, e.g., mast arm clearances, pole foundations, junction boxes, etc.

Pub. 213
Provides schematics defining the minimum acceptable traffic control within various types of work areas.

Pub. 111M
Standard drawings for the installation of signs and pavement markings.

Pub. 72M
Standard drawings for road construction. RC67M provides details for curbs, sidewalks, ADA, etc.

Pub. 647
Civil and Structural Standards for Intelligent Transportation Systems, ITS-1000M Series. Graphically illustrates the design and construction details for supports (poles and other structures), CCTV mountings, cabinet, trenches, fiber optics, etc., for ITS.

Pub. 8
Construction Manual. Supplements Pub. 408 by providing some helpful information for inspectors, containing information generally not found in other manuals. It uses the same section numbering as Pub. 408.

Maintenance

Pub. 191
Guidance on maintenance and operation of traffic control signals and periodic review

ITE's Traffic Signal Maintenance
Provides a summary of best and suggested maintenance practices.

Pub. 669
Traffic Signal Inspection Guide.

FHWA's Traffic Signal Timing Manual
Comprehensive guide to the traffic signal timing engineer and technician on traffic signal control logic principles, practices, and procedures.

1.6 Glossary of Terms and Abbreviations

Not all of the terms shown on the following table are used in this manual but they are included as a resource to the holder of the manual.

Term	Definition
85^{th} Percentile Speed	This is the speed at which 85% of the traffic is travelling at or below.
AASHTO	The American Association of State Highway and Transportation Officials.
Actuated Operation	A type of traffic control signal operation in which some or all signal phases are operated on the basis of actuation (vehicle detection, pushbutton, etc.).
Actuation	The presence of a vehicle or pedestrian as indicated by an input to the controller from a detector. The action of a vehicle or pedestrian which causes a detector to generate a call to the signal controller.
ADA	Americans with Disabilities Act (1990).
Adaptive Traffic Control	A software program that is designed to adjust the signal timing to accommodate changing traffic patterns and ease traffic congestion. By receiving and processing data from sensors to optimize and update signal timing settings, adaptive signal control technologies can determine when and how long lights should be green.
All-Red	An interval during which all signal indications at an intersection display red indications.
Approach	All lanes of traffic that enter the intersection from the same direction.
As-Built (or Record) Plans	A modified traffic signal plan showing the roadway geometrics and the traffic signals after completion of the construction project, showing any field adjustments due to structural shifts of signal supports, unanticipated corner radius changes, etc.
Annual Average Daily Traffic (AADT)	The total volume of vehicle traffic of a highway or road for a year divided by 365 days. AADT is a useful and simple measurement of how busy the road is.
Average Daily Traffic (ADT)	The total volume of vehicle traffic of a highway or road for a period of time less than 1-year divided by the number of days of the count.
Call	A demand for service registered in a controller. A call indicates a vehicle or pedestrian is waiting for a green light or walk indication.
Clearance Interval(s)	The interval(s) from the end of the right-of-way of one phase to the beginning of a conflicting phase. This is usually the yellow plus any all red phase.

Term	Definition
Conflict Monitor	A device housed in the controller cabinet which continuously checks for the presence of conflicting signal indications such as simultaneous green signal indications on both the mainline and side road approaches. If a conflict is detected, the monitor places the signals into a flashing operation.
Controller	The electronic device that controls the sequence and duration of traffic signal indications.
Cycle Length	The time taken for a complete sequence of all phases at an intersection. This time is counted from a given point on any phase (usually main street end of green) until that same point occurs again. Pretimed cycle lengths do not vary, but actuated cycle lengths do because of phases skipped, extensions, etc.
Delay	Time lost while traffic impeded in its movement by some element over which it has no control. Usually expressed in seconds per vehicle.
Department	Term used to reference the Pennsylvania Department of Transportation.
Design Modifications	A proposed change to the approved design and operation of an existing traffic signal or signal system to accommodate changes in prevailing traffic or physical conditions, or update the installation to current state-of-the-art design. Typical modifications include addition or removal of signal phases or special functions; changes in signal displays, configurations, or locations; detector modifications; upgrading of equipment and communication systems; and revisions to related signs and pavement markings. These changes can be initiated by any involved party, but cannot be physically implemented until the signal permit is updated.
Detector	A device that provides an input to the controller to indicate that a vehicle or pedestrian is present.
Documentation	The information for the traffic signal or signal system, including the traffic signal permit, equipment manuals and warrantees, summary and detailed listing of all signal maintenance, and design modifications, etc.
Free Flow	Traffic flow which is not impeded.
Full Traffic-Actuated Controller Unit	A type of traffic-actuated controller unit which accommodates for traffic actuation on all approaches to the intersection.
Gap (Time Gap)	The interval in time or distance from the back of one vehicle to the front of the following vehicle.
Green Interval	The right-of-way portion of a traffic phase.

Term	Definition
Headway	The distance or (usually) time between vehicles measured from the front of one vehicle to the front of the next.
HDPE	High-Density Polyethylene Conduit.
HOP	Highway Occupancy Permit.
Incandescent Indications	Vehicular or pedestrian signals, or a blank-out sign, that are illuminated with a traditional light bulb having a thin tungsten filament.
Infrared Detection	An overhead mounted device that illuminates a select area with low-power infrared energy supplied by light-emitting diodes (LEDs) or laser diodes, and then converts the reflected energy into an electrical signal to indicate the presence of a vehicle or person. Infrared detectors may have special applications for detecting pedestrians and bicyclists.
Intersection	The area embraced between the prolongation and connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways (i.e., the traveled portion) of two or more streets or highways.
Intersection Leg	The roadways entering or leaving one side of the intersection.
Interval	Any one of the several divisions of the cycle during which signal indications do not change.
Interval Sequence	The order of appearance of signal indications during successive intervals of a cycle.
Isolated Controller Unit Operation	The operation of a controller unit at an intersection without master controller supervision dial-up communication.
Isolated Intersection	A signalized intersection that is located far enough from other signalized intersections so that the signal timing at the other intersections do not influence the traffic flow at this intersection.
Local Authorities	Definition from Section 212.1 of Title 67 of the Pennsylvania Code. i. County, municipal and other local boards or bodies having authority to enact regulations relating to traffic. ii. The term also includes airport authorities except where those authorities are within counties of the first class or counties of the second class. iii. The term also includes state agencies, boards and commissions other than the Department, and governing bodies of colleges, universities, public and private schools, public and historical parks.

Term	Definition
Local Controller	The controller located at an intersection and which operates the traffic signals only at that intersection, and does not control or directly influence any other intersection.
Loop Detectors	A commonly used device to monitor traffic on the approach to a traffic control signal, consisting of multiple circles of wire in a basic square or rectangular shape that is buried within the roadway and which detects changes in their magnetic field caused by the metal in passing vehicles.
Maintenance Service Manuals	The document provided by the manufacturer of a piece of equipment that specifies how to adjust, clean, lubricate, calibrate, and otherwise maintain the equipment to ensure its proper operation and its longevity.
Maintenance Service Records	An accumulation of paperwork that captures all service performed to the traffic signals at a specific intersection. This paperwork identifies all inspections, cleaning, tightening, calibrations, adjustments, replacements, lubrications, etc., that were performed from either a preventive view point, or repairs due to crashes or equipment failure.
Malfunction Management Unit (MMU)	The malfunction management unit (MMU) can be configured to check for conflicting signal indications and various other malfunctions including absence of an OK status output from the controller (watchdog output), short or missing clearance intervals, and out-of-range operating voltages. If a malfunction is detected, the MMU automatically places the signal in an all-red flashing state, overriding the outputs of the controller.
Master Controller	The controller that supervises and directs the timing patterns for all local controllers within a traffic control signal system for the purpose of coordinating the operation of the signal system to improve traffic flow and safety.
Maximum Green	A longest period of green time allowed when there is a demand on an opposing phase.
Median Refuge	Raised islands or medians of sufficient width that are placed in the center area of a street or highway to serve as a place of refuge for pedestrians who are attempting to cross. Center islands or medians allow pedestrians to find an adequate gap in one direction of traffic at a time, as the pedestrians are able to stop, if necessary, in the center island or median area and wait for an adequate gap in the other direction of traffic before crossing the second half of the street or highway.

Term	Definition
Microwave Detection	Equipment that transmits an electromagnetic signal and compares the reflected signal from all objects in the protected area by use of the Doppler Effect. Based on a selected sensitivity level, it determines if the detection criteria are met; and if so, advises the controller of the presence of traffic.
Minimum Green	The shortest green time allowed in a phase.
MUTCD	Manual on Uniform Traffic Control Devices
Offset	The relationship in time between a point in the cycle at a particular intersection and a similar point in the cycle at another intersection or reference.
NTCIP	National Transportation Communications for ITS Protocol
Operations	As it relates to traffic, this is the day-to-day control of traffic systems, including the analysis of the systems, detection of problems and deficiencies, setting of priorities, assignment of resources, and development of improvements through geometric design, traffic control, or other means. Frequently referred to as “traffic operations.”
Passage Period	The time allowed for a vehicle to travel at a selected speed from the detector to the nearest point of conflicting traffic, i.e., from the detector into the intersection.
Pedestrian "WALK" Interval	The controller interval during which the "WALK", symbolized by the "WALKING PERSON", indications of the pedestrian signals are illuminated.
Pedestrian Clearance Interval	The first clearance interval following the pedestrian walk interval, normally symbolized by the flashing "HAND." The pedestrian clearance interval shall allow a pedestrian, who has already begun to cross, time to reach the far side of the roadway or a safe refuge. A pedestrian shall not begin to cross during this interval.
Pedestrian Detection	Hardware used to notify the traffic controller of the presence of a pedestrian, typically via a pushbutton.
Pedestrian Phase	A traffic phase allocated exclusively to pedestrian traffic.
Pedestrian Signal Indication	The illumination of a pedestrian signal lens or equivalent device.
Phase	The part of a cycle allocated to any combination of traffic movements receiving the right-of-way simultaneously during one or more intervals, i.e., for example a left turn phase.
Preemption	The transfer of the normal control of signals to a special signal control mode, i.e., to accommodate emergency vehicles.

Term	Definition
Pre-Timed Controller Operation	A method for operating traffic signals where the cycle length, phases, green times, and change intervals are all preset.
Preventive (Routine) Maintenance	Maintenance scheduled on a regular basis to minimize future maintenance and to maximize the life of the equipment. It includes inspection, calibration, cleaning, testing, sealing, painting, etc., in accordance with a predefined schedule. This maintenance is similar to the maintenance schedule for a vehicle.
Publication 111M	The Department's Traffic Control Pavement Markings and Signing Standards – TC-8600 and 8700 Series.
Publication 13M	The Department's Design Manual Part 2: Highway Design.
Publication 148	The Department's Traffic Standards (TC-8800 Series Signals).
Publication 149	The Department's Traffic Signal Design Handbook.
Publication 212	The Department's Official Traffic Control Devices, that contains the regulation, Chapter 212 of Title 67 of the Pennsylvania Code (67 Pa. Code Chap. 212). The Chapter 212 regulation adopts and supplements FHWA's Manual on Uniform Traffic Control Devices (MUTCD)
Publication 213	The Department's Temporary Traffic Control Guidelines.
Publication 236M	The Department's Handbook of Approved Signs.
Publication 287	The Department's publication showing the unit cost bid prices for construction projects during recent years.
Publication 35	The Department's listing of Approved Construction Materials, commonly referred to as Bulletin 15.
Publication 408	The Department's Highway Specifications.
Publication 441	The Department's regulation entitled "Access to and Occupancy of Highways by Driveways and Local Roads."
Publication 46	The Department's Traffic Engineering Manual.
Publication 70M	The Department's Guidelines for the Design of Local Roads and Streets.
Publication 72M	The Department's Roadway Construction Standards.
Push Button Detection	A mechanical switch that, when pushed or activated, tells the controller of the presence of a pedestrian.
Radar detection	A detector that uses radar waves to track vehicles as they approach and leave an intersection.

Term	Definition
Red Clearance Interval	An interval which follows the yellow change interval during which no green indication is shown on any conflicting phase.
Response Maintenance	Emergency repair performed on an as-needed basis due to either equipment failure or a crash. Upon notification, the maintenance service team is dispatched to secure the site, diagnose the problem, perform the repairs, and record its activities as quickly as possible.
Rest	The state in which a controller unit rests until called out of the phase.
Semi-Traffic-Actuated Controller Operation	A type of traffic operation in which means are provided for traffic actuation on one or more, but not all, approaches to the intersection.
Signal Face	That part of a signal head provided for controlling traffic in a single direction. Turning indications may be included in a signal face.
Signal Head	An assembly containing one or more signal faces which may be designated accordingly as one-way, two-way, etc.
Signal Indication	The illumination of a traffic signal lens or equivalent device or a combination of several lenses or equivalent devices at the same time. (Note: This term usually means indications to vehicular traffic; however, pedestrians may be using these indications if no Pedestrian Signal Indications are present.)
Source of Power (SOP)	The location of the electrical service equipment associated with a traffic signal, or the location where electrical connection is made to the power company distribution system.
Split Time	A division of the cycle allocated to each of the various phases green, yellow, and all-red time.
Title 67 of the PA Code	The “Transportation Title” of the Pennsylvania Code which contains regulations of the Department, typically in response to a legislative mandate.
Traffic Control Signal	The specific type of traffic signal that provides alternating stop-and-go traffic control with red-yellow-green (R-Y-G) signal indications.
Traffic Signal	The broad category of highway lights including traffic control signals (provide alternating stop and go), pedestrian signals, flashing beacons, lane-use control signals, ramp metering, and in-roadway lights.
Traffic Signal Housing	The outer part of a traffic signal section that protects the light and other required components from the elements.

Term	Definition
Traffic Signal Permit	The document approved by the Department to authorize the installation and operation of the traffic signal. The traffic signal permit is for a traffic signal at a specific intersection. It includes the Traffic Engineering Form TE-964, and traffic signal plans showing the intersection plan sheets with the locations of the traffic signals, traffic signal supports, controller cabinet, junction boxes, detectors, stop lines, street names, approach grades, distance to nearest signals, etc., plus the traffic signal phasing diagram.
Traffic Signal Support	The physical means whereby signal heads, signs, and luminaires are supported in a particular location. Structural supports are to be designed to carry the loads induced by attached signal heads, signs, luminaires, and related appurtenances.
Traffic Signal System	Two or more traffic control signals operating in coordination with each other.
Traffic Signal Timing	The analysis of intersection geometrics, speeds, and historical traffic volumes used to identify the specific duration in seconds for the green, yellow, red, Walk, and Don't Walk intervals of each phase. For traffic actuated signals, the traffic signal timing also includes information on the incremental extensions of the green intervals due to the continued presence of approaching vehicles.
Uninterrupted Power Supply (UPS)	A battery backup system designed to instantly provide electrical power for the operation of the controller and traffic signals during a power outage.
Video Detection	The process of using a video imaging system to analyze the feed from a video camera mounted above the roadway to determine the presence or passage of vehicles in one or more specific travel lanes on an approach to the intersection.
Walk Interval	The portion of a traffic phase that permits pedestrians to leave the curb.
Wireless Detection	The use of equipment coupled with a radio transmitter that informs a receiver in the controller cabinet of the presence or passage of vehicles in one or more specific travel lanes. The type of detection may vary, but the radio transmission is used in lieu of wire or coaxial cable.
Yellow Change Interval	The first interval following the green right-of-way interval in which the signal indication for that phase is yellow, indicating that the right-of-way for that phase is about to terminate.

CHAPTER 2. PRELIMINARY ENGINEERING

The purpose of this chapter is to familiarize the designer and project manager (PM) with the preliminary traffic signal design process. As noted in Section **1.2 - Manual Layout**, this training manual is laid out with the same chapter headings as Publication 149. The sub-sections in Chapter 2 of Publication 149 are:

- ✓ Pre-Design Activities
- ✓ Field View for Design
- ✓ Preliminary Engineering Considerations

The above topics are included as a handout starting in Section **2.6** of this training manual. This chapter expands on those topics and includes the additional information:

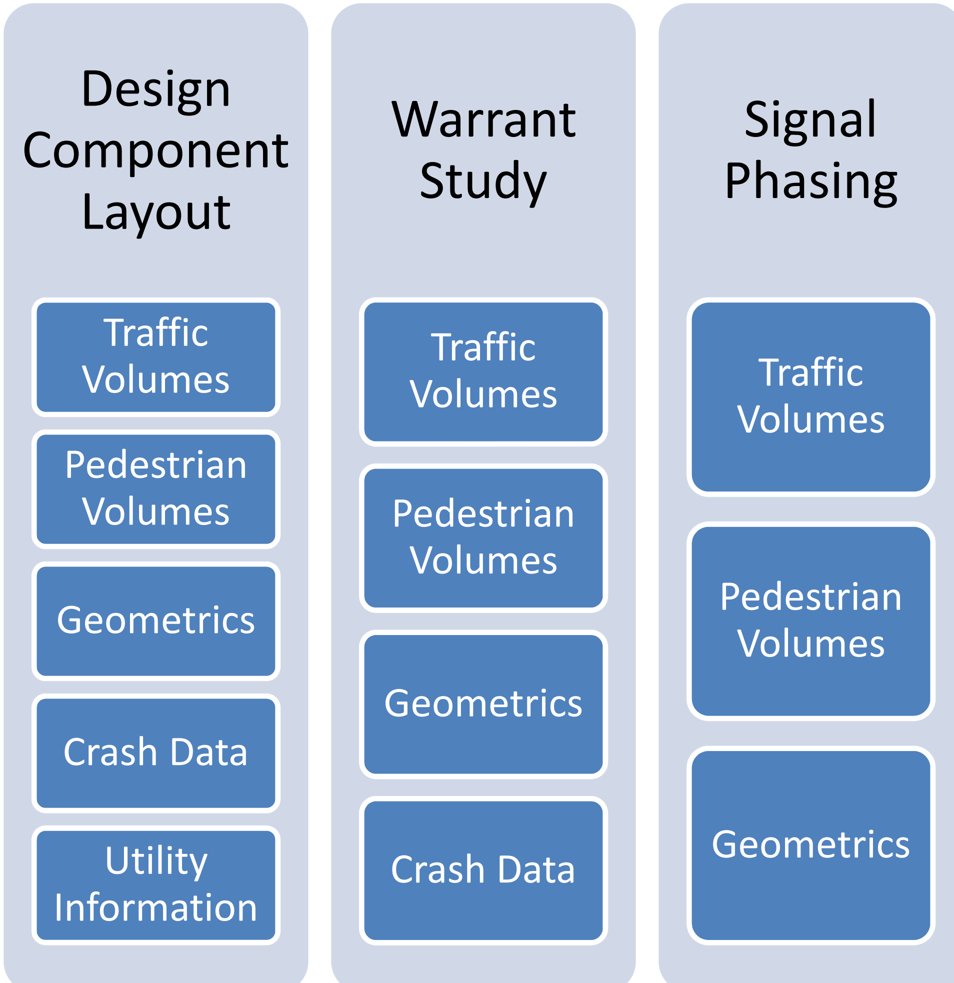
- ✓ Data Collection (Section **2.1**)
- ✓ Regulations, Laws and Publications (Section **2.2**)
- ✓ Traffic Signal Studies for Design (Section **2.3**)
- ✓ Preliminary Design Considerations (Section 2.4)
- ✓ Traffic Signal Proprietary Approvals (Section **2.5**)

Preliminary Engineering is a critical element for signal design. Be sure to fully investigate the topics discussed in this section. The checklists provided are particularly useful to ensure that important items are considered.

2.1 Data Collection

Before a traffic signal system is designed, various pieces of data must be collected. The data collected is used to perform the engineering study to determine if the signal is warranted. Other uses for data is to determine the appropriate signal phasing for an intersection and how that operation effects the design, to classify vehicles and determine how that vehicle mix effects placement of elements, etc. **Exhibit 2-1** illustrates typical uses of traffic data.

Exhibit 2-1 Traffic Data Uses



2.1.1 Traffic Volume Data

Traffic counts are the most basic type of data collected in the field of traffic engineering. Quite simply, traffic counts involve counting vehicles passing a point for varying intervals of time. They can range from 24 hours per day, 365 days per year, to five minutes of a peak period.

Volume counts play a major role in traffic signal design. Their uses include:

1. Determining the need for traffic control devices (warrants)
2. Obtaining various factors (hourly, daily, weekly, etc.)
3. Determining peak periods and peak hours
4. Signal phasing and timing
5. Determining trends
6. Determining the need for channelization
7. Simulation studies

8. Vehicle classifications
9. Calculating crash rates

Discuss with the District Office staff the traffic volume requirements for the particular study.

2.1.2 Pedestrian Volume Information

When collecting data, it is important to collect pedestrian counts when pedestrians are present. This information is needed for studies and signal timing. This data also aids in making the decision to add pedestrian facilities, including Accessible Pedestrian Systems (APS), to the intersection.

Refer to **Chapter 4** for additional information on pedestrian data requirements.

2.1.3 Crash Data

A list of all the crashes that have occurred at the intersection should be obtained from the District. Only those crashes that have occurred during the most recent 12-month period (in which data are available) should be used in analyzing the Crash Experience Warrant (see Section 2.3.3).

2.1.4 Geometrics

Existing Geometrics

The existing geometrics of the intersection being considered for design improvements must be documented. The geometry of the intersection can affect the efficiency of the traffic signal. It is preferable to provide a layout or graphical display of the intersections showing lane configurations with existing striping, lane widths, parking lanes, shoulders and/or curb treatments, medians, pedestrian and bicycle facilities, right-of-way limits and access driveways or adjacent roadways for all approaches. The posted speed limit and the current traffic control of each roadway should also be shown or stated. Adjacent structures, overhead utilities, and vaults should also be outlined such as buildings, bridges, box culverts, power poles, etc.

The locations of schools or other significant land uses, which may require more specialized treatment for pedestrians or vehicles, should be documented, if applicable.

Geographic features must be shown if they will influence the selection of an alternative, such as severe grades, wetlands, parkland, etc.

Proposed Geometrics/Traffic Control Alternative

A layout or conceptual plan showing the proposed geometrics for the recommended traffic control alternative must be included. An electronic copy of the design is preferred and may be required depending on the intersection alternative. The plan should document all changes from the existing conditions.

2.1.5 Utility Information

Coordination with utilities is essential for traffic signal construction projects. Aerial (overhead) utilities, such as electric, telephone, and cable lines, are typically attached to wooden utility poles. Underground utilities, such as gas, sewer, and water lines, can vary greatly in depth. Any time traffic signal equipment is installed under a crossing or attached to an overpass owned by a railroad, the PA Public Utilities Commission (PUC) must be contacted. Refer to **Chapter 12** for full details on utilities.

2.2 Regulations, Laws and Publications

Refer to the Introduction to Traffic Signals Training Manual (Section 2.2) for additional details on signal regulations, laws and publications. The items covered in that manual include:

- ✓ The Pennsylvania Vehicle Code (Title 75) [75 Pa.C.S. §101]
- ✓ Transportation Code (Title 67) [67 Pa. Code]
- ✓ The Manual on Uniform Traffic Control Devices (MUTCD)

2.3 Traffic Signal Studies for Design

Always base the decision to use a particular device at a specific location on an engineering study and the application of engineering judgment. While many sources provide guidance on performing some traffic studies, it is not a substitute for engineering judgment.

Exercise engineering judgment in the selection and application of traffic control devices, as well as in the location and design of the roads and streets that the devices complement. Therefore, a traffic engineer should make the final decision concerning the application of traffic restrictions.

Refer to **Chapter 17** - **Traffic Signal Design Report** for additional details.

2.3.1 TE-160 Application for Traffic Signal Approval

Form TE-160 is used as an application for traffic signal approvals. This form replaces the following existing documents:

- ✓ Traffic Signal Maintenance Agreement (Preapproved Form # 18-K-392), which was required for all state and federally-funded traffic signal installations by PennDOT that were then transferred to the municipality to own, maintain and operate
- ✓ TE-952 (Application for Permit to Install and Operate Traffic Signals)
- ✓ TE-669 (Application for Permit to Install and Operate Flashing Warning Devices)

2.3.2 TE-160 Handout

The information on the following pages is a handout of form TE-160. The most current version of the form can be downloaded from the PennDOT traffic signal portal:

www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html.

It is recommended that you review all original reference material to check for updates.

TE-160 (6-12)

Application for Traffic Signal Approval

Please Type or Print all information in Blue or Black Ink

pennsylvania DEPARTMENT OF TRANSPORTATION

Sheet 1 of 5

DEPARTMENT USE ONLY

County : ____

Engineering District : ____

Department Tracking # : ____

Initial Submission Date : ____

A - Applicant's (Municipal) Contact Information

Municipal Contact's Name : ____ **Title :** ____

Municipal Name : ____

Municipal Address : ____

Municipal Phone Number : ____ **Alternative Phone Number :** ____

E-mail Address : ____

Municipal Hours of Operation : ____

B - Application Description

Location (*intersection*) : ____

Traffic Control Device is : ☐ **NEW** Traffic Signal ☐ **EXISTING** Traffic Signal **(*Permit Number*) :** ____

Type of Device (*select one*) ☐ Traffic Control Signal (*MUTCD Section 4D, 4E, 4G*) ☐ Flashing Beacon (*MUTCD Section 4L*) ☐ School Warning System (*MUTCD Section 7B*)

☐ Other : ____

Is Traffic Signal part of a system? : ☐ YES ☐ NO **System Number (*if applicable*) :** ____

If YES, provide locations of all signalized intersections in system.

Explain the proposed improvements :

Associated with Highway Occupancy Permit (HOP)?: ☐ YES ☐ NO **If YES, HOP Application # :** ____

C - Maintenance and Operation Information

Maintenance and Operations are typically performed by? :

☐ Municipal Personnel ☐ Municipal Contractor ☐ Municipal Personnel & Contractor

☐ Other : ____

Maintenance and Operations Contact Name : ____ **Company/Organization :** ____

Phone # : ____ **Alternative Phone # :** ____ **E-mail :** ____

D - Attachments Listing

☐ Municipal Resolution (*required*)	☐ Location Map	☐ Traffic Volumes / Pedestrian Volumes
☐ Letter of Financial Commitment	☐ Photographs	☐ Turn Lane Analysis
☐ Traffic Signal Permit	☐ Straight Line Diagram	☐ Turn Restriction Studies
☐ Warrant Analysis	☐ Capacity Analysis	☐ Other : ____
☐ Crash Analysis	☐ Traffic Impact Study (TIS)	
☐ Traffic Signal Study	☐ Condition Diagram	

TE-160 (6-12)

Sheet 2 of 5

DEPARTMENT USE ONLY

County : ______

Engineering District : ______

Department Tracking # : ______

Initial Submission Date : ______

Application for Traffic Signal Approval

Please Type or Print all information in Blue or Black Ink

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E - Applicant (Municipal) Certification

The applicant desires to own, operate, and maintain the traffic control device in the location indicated above; and the Vehicle Code requires the approval of the Department of Transportation ("Department") before any traffic signals may be legally erected or modified. A signed Application for Traffic Signal Approval (TE-160) must be submitted in conformance with the instructions provided by the Department, and a Traffic Signal Permit must be issued, before any work can begin.

If the Department approves a traffic signal after a traffic engineering study and engineering judgment indicates the need, the traffic signal shall be installed, owned, operated, and maintained within the parameters indicated in the Vehicle Code and the Department's regulations relating to traffic signs, signals, and markings. The Department may direct appropriate alterations to the design or operation (including, but not limited to, hours of operation) of the traffic signal, or require removal of the traffic signal, if traffic conditions or other considerations necessitate alteration or removal.

All items associated with the traffic control device (geometric features, signs, signals, pavement markings, pedestrian accommodations, and other traffic control device associated items) are the applicant's responsibility. The Traffic Signal Permit will then document all of the items associated with operation of each traffic control device. The applicant, at its sole expense, shall provide the necessary inspection, maintenance, and operation activities in conformance with the Department's Publication 191 or as otherwise agreed to by the Department. The applicant shall perform the preventative and responsive maintenance requirements and recordkeeping in accordance with the exhibits specified below. If the applicant fails to provide the required inspection, maintenance, or operation services within thirty (30) days of receipt of written notice from the Department, the Department shall have the right to perform the required inspection, maintenance, or operation services in the applicant's stead and the applicant shall reimburse the Department for all costs incurred. Federal- and/or state-aid participation may be withheld on all future projects if the applicant fails to demonstrate to the Department the ability to provide all required maintenance and operation services. The applicant certifies that it has funds available and committed for the operation and maintenance of the traffic control device and that it will make available sufficient funds for all required future inspection, maintenance, and operation activities.

The applicant shall indemnify, save harmless and, defend (if requested) the Commonwealth of Pennsylvania, its agents, representatives, and employees from and against any damages recoverable under the Sovereign Immunity Act, 42 Pa. C.S. §§ 8521-8528, up to the limitations on damages under said law, arising out of any personal injury or damage to property which is finally determined by a court to be caused by or result from acts or omissions of the applicant and for which a court has held applicant, its officials, or employees to be liable. This provision shall not be construed to limit the applicant in asserting any rights or defenses. Additionally, the applicant shall include in any contracts into which it enters for maintenance, operation, or inspection of the traffic control device this same obligation to indemnify the Commonwealth and its officers, agents, and employees; and it shall require its contractor(s) to provide public liability insurance coverage, naming the Commonwealth and the applicant as additional insureds for bodily injury, including death and property damage, in the minimum amounts of $500,000 per person, $1,000,000 per occurrence, it being the intention of parties to have the contractor fully insure and indemnify the Commonwealth and the applicant.

The applicant shall comply with the study and ordinance requirements of 75 Pa. C.S. § 6109. The applicant submits this application with the intention of being legally bound.

Neither this application nor any Traffic Signal Permit creates any rights or obligations with respect to parties other than the applicant and the Department. Third parties may not rely upon any representations made by either the applicant or the Department in connection with the submission or approval of this application or any work permitted or approved that is related to this application, as regards either payment of funds or performance of any particular item of maintenance precisely as specified.

The applicant agrees to comply with the attached Exhibits:

- Exhibit "A": Preventative and Response Maintenance Requirements (Sheet 3 of 5)
- Exhibit "B": Recordkeeping (Sheet 4 of 5)
- Exhibit "C": Signal Maintenance Organization (Sheet 5 of 5)

Printed Municipal Contact Name : ______ **Date :** ______

Signed By : ______ **Witness or Attest :** ______

Title of Signatory : ______ **Title of Witness or Attester:** ______

TE-160 (6-12)

Sheet 3 of 5
DEPARTMENT USE ONLY

Exhibit "A":
Preventative and Response Maintenance Requirements

County :
Engineering District :
Department Tracking # :
Initial Submission Date :

Preventive Maintenance

The APPLICANT or its contractor will provide preventive maintenance for each individual component of the traffic signal installation covered by this application at intervals not less than those indicated in the Preventive Maintenance Summary, PA DOT Publication 191, current version. This is the recommended level of maintenance to keep the intersection control equipment and signals in mechanically, structurally and aesthetically good condition.

Response Maintenance

The APPLICANT or its contractor will provide response maintenance in accordance with the provisions of the Response Maintenance Schedule. It encompasses the work necessary to restore a traffic signal system to proper and safe operation. Includes Emergency Repair and Final Repair.

FINAL REPAIR:
Repair or replace failed equipment to restore system to proper and safe operation in accordance with permit within a 24-hour period.

EMERGENCY REPAIR:
Use alternative means or mode to temporarily restore system to safe operation within a 24-hour period. Final repair must then be completed within 30 days unless prohibited by weather conditions or availability of equipment.

Response Maintenance Schedule

KNOCKDOWNS	TYPE OF REPAIR PERMITTED
Support - Mast arm	Emergency or Final
Support - Strain pole	Emergency of Final
Span wire/tether wire	Final Only
Pedestal	Emergency or Final
Cabinet	Emergency of Final
Signal heads	Final Only
EQUIPMENT FAILURE	
Lamp burnout (veh. & ped.)	Final Only
Local controller	Emergency or Final
Master controller	Emergency or Final
Detector sensor	
- Loop	Emergency or Final
- Magnetometer	Emergency or Final
- Sonic	Emergency or Final
- Magnetic	Emergency or Final
- Pushbutton	Emergency or Final
Detector amplifier	Emergency or Final
Conflict monitor	Final Only
Flasher	Final Only
Time clock	Emergency or Final
Load switch/relay	Final Only
Coordination unit	Emergency or Final
Communication interface, mode	Emergency or Final
Signal cable	Final Only
Traffic Signal Communications	Final Only
Traffic Signal Systems	Final Only

TE-160 (6-12)

Exhibit "B":
Recordkeeping

Sheet 4 of 5
DEPARTMENT USE ONLY

County :

Engineering District :

Department Tracking # :

Initial Submission Date :

Recordkeeping

Accurate and up-to-date recordkeeping is an essential component of a good traffic signal maintenance program. In recognition of this fact, the APPLICANT must prepare, retain, and make available to the COMMONWEALTH, on request, a record of all preventive and response maintenance activities performed on the traffic signal equipment covered by this application.

The APPLICANT shall establish a separate file for each installation and keep its records in the municipal building, signal maintenance shop, or other weather-protected enclosure.

At a minimum, the following records will be kept by the APPLICANT or its contractor for each traffic signal. These forms can be found in Section 10.0, Maintenance Record Forms, PA DOT Publication 191, current version.

FORM 1 - Master Intersection Record

This form, which lists all maintenance functions performed at the intersection, should be updated within one day of the activity but no more than one week later.

FORM 2 - Response Maintenance Record

Each time response maintenance is required at the intersection, this form is to be completed. Once the pertinent information is transferred to the master intersection record, this form is to be placed in the intersection file.

FORM 3 - Preventive Maintenance Record

This form will be used to provide a record of the preventive maintenance activities performed at each intersection. The date, the activities performed, and the signature of the person in charge of the work must be recorded in the form.

This form may be kept at the intersection, if it is adequately protected from the weather. Form 1 must be updated at the central file, however, to reflect the date and activity.

TE-160 (6-12)

Exhibit "C":
Signal Maintenance Organization

pennsylvania
DEPARTMENT OF TRANSPORTATION

Sheet 5 of 5
DEPARTMENT USE ONLY

County : ____________

Engineering District : ____________

Department Tracking # : ____________

Initial Submission Date : ____________

Personnel Classifications

In order to properly maintain the traffic signal equipment covered by this applicant, the APPLICANT agrees to provide, as minimum, the following staff throughout the useful life of equipment. The APPLICANT agrees to abide by all guidance provided in PA DOT Publication 191.

Traffic Engineer - The administrative position which has prime responsibility for the proper operation of traffic signal equipment. The principal function of this position is the supervision and control of subordinate personnel and the planning of their activities to ensure adequate preventive and response maintenance programs.

Minimum Position Requirements
1. A thorough understanding of traffic signal design, installation and maintenance.
2. A working knowledge of the interaction between the following traffic characteristics: Intersection geometry, traffic flow theory, control type (fixed time, actuated, etc.), signal phasing and timing, and interconnection.
3. An ability to supervise subordinate personnel effectively in the assignment of their work.
4. Possession of a college degree in engineering, which includes course work in traffic engineering.
5. Either four years experience in the field of traffic engineering or its equivalent in graduate college work.

Signal Specialist - The individual responsible for the diagnostics and repair of all traffic signal equipment including solid state equipment.

Minimum Position Requirements
1. Extensive training and troubleshooting skills in electronics and software.
2. Ability to repair modules in the shop and to design test equipment needed to diagnose and repair a problem.
3. Ability to make design and modifications to implement or omit special functions.
4. Ability to implement a recordkeeping system to include maintenance activities, inventory control and identification of recurring problems.
5. Ability to perform all tasks required of a signal technician.

Signal Technician - Individual responsible for the operation and maintenance of traffic signals and electromechanical equipment.

Minimum Position Requirements
1. Ability to perform response maintenance on solid state equipment up to the device exchange level.
2. Capability to diagnose a vehicle loop failure and initiate corrective action.
3. Ability to tune detector amplifiers.
4. Ability to follow wiring schematics, check and set timings from plan sheet and check all field connections.
5. Ability to perform preventive maintenance on all equipment and to maintain accurate records of all work perform.

Training

The APPLICANT agrees to secure training in order to upgrade the ability of its present staff to properly perform the required maintenance functions. The APPLICANT agrees to abide by all guidance provided in PA DOT Publication 191.

Budget Requirements

The APPLICANT agrees to provide, in its annual operating budget, dedicated funds which are sufficient to cover the cost of the personnel, training, contractors (if utilized) and specialized maintenance equipment which are required, by virtue of this application. The APPLICANT agrees to abide by all guidance provided in PA DOT Publication 191..

TE-160 (6-12)

Application Instructions

pennsylvania DEPARTMENT OF TRANSPORTATION

A - Applicant's (Municipal) Contact Information

Municipal Contact's Name: Provide the municipal contact name that is (or will be responsible) for the traffic signal. Typically this is either the Municipal Manager or Roadmaster.

Title: Provide the title of the municipal contact name.
Municipal Name: Provide the official municipal name.
Municipal Address: Provide the full address of the municipal building.
Municipal Phone Number: Provide the municipal phone number of the municipal contact.
Alternative Phone Number: Provide an alternative phone number of the municipal contact.
E-mail Address: Provide the e-mail address of the municipal contact.
Municipal Hours of Operation: Please provide the municipalities normal operating hours (i.e. Monday-Thursday 9 AM - 2 PM)

B - Application Description

Location (*intersection*): Please provide a detailed location of the device or devices being considered for approval.

Please include any State Route and/or local road names in your description.

Traffic Control Device is: (Please select one of the two following categories)

NEW Traffic Signal: This item should be selected when requesting approval of a traffic signal that is currently not in operation at the device location indicated above.

EXISTING Traffic Signal: This item should be selected when requesting approval to make a modification or update to an existing traffic signal.

(*Permit Number*): Please provide the traffic signal permit number.

Type of Device (select one): (Please select one of the four following categories)
Traffic Control Signal: As defined in federal Manual on Uniform Traffic Control Devices (MUTCD) Sections 4D, 4E, and 4G. When selecting this category this is the typical red/yellow/green and pedestrian signal indications
Flashing Beacon: As defined in federal Manual on Uniform Traffic Control Devices (MUTCD) Section 4L. When selecting this category, this is typically either the flashing yellow/red signal at an intersection and/or the flashing yellow warning sign.
School Warning System: As defined in federal Manual on Uniform Traffic Control Devices (MUTCD) Section 7B. When selecting this category, this is typically the flashing school warning sign with a 15 mph indication.
Other: When selecting this category, this pertains to all other permitted electrically powered traffic control devices approved by the Department.

Is Traffic Signal part of a system?: Check off the appropriate box, either YES or NO. If YES, please fill in the **System Number (*if applicable*):** line.

Explain the proposed improvements: Provide a description of the proposed improvements to the intersection. This may be as complex as installing and/or upgrading a traffic signal or as non-complex as placement of a new traffic sign to supplement an existing traffic signal.
Associated with Highway Occupancy Permit (HOP)?: Check off the appropriate box, either YES or NO. If YES, please fill in the **Application #:** line.

C - Maintenance and Operation Information

Maintenance and Operations are typically performed by?: Please indicate if maintenance and operation will be performed by Municipal Personnel or through Contract Services.

Maintenance and Operations Contact Name: Provide the primary maintenance contact name for the individual that is (or will be responsible) for the maintenance and operation of the traffic signal.

Company/Organization: Provide the name of the company/organization with which the primary maintenance contact is affiliated.

Phone #: Provide the phone number for the primary maintenance contact.

Alternative Phone #: Provide an alternative phone number for the primary maintenance contact or affiliated company/organization.

E-mail: Provide the e-mail address for the primary maintenance contact.

D - Attachments Listing

Check off all documents which will be submitted along with this application. Note that a Municipal Resolution, authorizing the municipal contact to submit and sign the application, is a required document.

A sample Municipal Resolution has been provided on the next page.

E - Applicant (Municipal) Certification

Printed Municipal Contact Name: Please print the name of the municipal contact person signing the application.

Date: Please provide the date on which the application was signed.

Signed By: Please provide the signature of the named municipal contact.

Title of Signatory: Please provide the title of municipal contact.

Witness or Attest: Please provide the signature of the person witnessing or attesting the signature.

Witness or Attester: Please provide the title of the person witnessing or attesting the signature.

RESOLUTION

BE IT RESOLVED, by authority of the ______________________________________
(Name of governing body)

of the __________________________________ , _________________________ County, and it
(Name of MUNICIPALITY)

is hereby resolved by authority of the same, that the _____________________________________
(designate official title)

of said MUNICIPALITY is authorized and directed to submit the attached Application for Traffic

Signal Approval to the Pennsylvania Department of Transportation and to sign this Application on behalf of the MUNICIPALITY.

ATTEST: _______________________________________
(Name of MUNICIPALITY)

____________________________________ By: ____________________________________
(Signature and designation of official title) (Signature and designation of official title)

I, _______________________________ , _____________________________________
(Name) (Official Title)

of the ____ , do hereby certify that the foregoing
(Name of governing body and MUNICIPALITY)

is a true and correct copy of the Resolution adopted at a regular meeting of the

______________________________________ , held the ______ day of ____________ , 20_____ .
(Name of governing body)

DATE: ____________________ _______________________________________
(Signature and designation of official title)

2.3.3 Warrant Studies

Traffic signal warrants are found in the MUTCD Chapter 4C, December 2009. These warrants are summarized in **Exhibit 2-2**. PennDOT Publication 46 (Pub 46) includes a summary of the nine warrants from the MUTCD, plus two additional Pennsylvania-only warrants (PA-1 and PA-2). The two PA warrants are summarized in **Exhibit 2-3**. Refer to the Introduction to Traffic Signals in Pennsylvania training manual and online modules for additional details on signal warrants.

Exhibit 2-2 Summary of National MUTCD Traffic Signal Warrants

Warrant	Name	Description
Warrant 1	Eight-Hour Vehicular Volume	This warrant is used when a large volume of intersecting traffic, or where the traffic volume on the major street, is so excessive that traffic on the minor street suffers undo delay. This warrant requires at least eight hours' worth of traffic volume data.
Warrant 2	Four-Hour Vehicular Volume	The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal. This warrant requires at least four hours' worth of traffic volume data.
Warrant 3	Peak Hour	The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of one hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street. This warrant requires just one hour of data and is often used for land use or impact studies; however, Department approval is required if this is the only warrant that is used to justify the signal.
Warrant 4	Pedestrian Volume	The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.
Warrant 5	School Crossing	The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word "school children" includes elementary through high school students.
Warrant 6	Coordinated Signal System	Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.
Warrant 7	Crash Experience	The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.
Warrant 8	Roadway Network	Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.
Warrant 9	Intersection Near a Grade Crossing	The Intersection Near a Grade Crossing signal warrant is intended for use at a location where none of the conditions described in the other eight traffic signal warrants are met, but the proximity to the intersection of a grade crossing on an intersection approach controlled by a STOP or YIELD sign is the principal reason to consider installing a traffic control signal.

Additional Pennsylvania Warrants

PennDOT has included two warrants that are not included in the national MUTCD and they are summarized below.

Exhibit 2-3 Additional Pennsylvania Traffic Signal Warrants

Warrant	Name	Description
Warrant PA-1	ADT Volume Warrant	This warrant applies to a proposed intersection, an intersection revised by a highway construction project, or at the driveway of a proposed commercial or residential development where vehicle counts cannot be taken. If this warrant is used, a traffic count must be taken within six months of the opening of a development or within two years of the opening of a highway.
Warrant PA-2	Mid-Block Crossing Warrant	This warrant is intended for mid-block pedestrian or trail crossings. It is based on guidelines for a Hybrid Pedestrian Signal in the MUTCD (PennDOT does not allow the Hybrid signal).

2.3.4 Capacity Analysis

A summary table of delays for all movements, approaches and overall intersection delay must be provided for AM and PM peak hours, both existing and future conditions, for each alternative analyzed. Software output should be included in an appendix. An electronic copy of the analysis is preferred.

Additional data may be necessary depending on the location and alternatives analyzed. These could include: community considerations (need for parking, sidewalks, bike lanes, etc); future development plans, which may influence access; types of vehicles intersecting the roadway, if unusual; transit routes and frequency; compatibility with corridor plans or local transportation plans; Interregional Corridor performance and political considerations.

Refer to Publication 46, Traffic Engineering Manual Chapters 10 and 12 for additional details on traffic capacity analysis.

2.3.5 Traffic Signal Phasing

The signal designer must work closely with the signal operator. Decisions on items such as signal phasing convention and left turn signal phasing are critical to the design steps. In addition, decisions made during the design process impact the flexibility (or lack of) that the signal operator ultimately has. For instance, the placement of detectors impacts the signal controller settings.

Refer to **Chapter 3** for full information on traffic signal timing and phasing.

2.4 Preliminary Design Considerations

2.4.1 Field Review

As noted in Publication 149 (included as a handout in this chapter), the design engineer should complete a thorough field investigation in order to become familiar with the project intersection. Whether an existing or proposed traffic signal, the designer needs to gather relevant data about the intersection and understand how the intersection operates prior to moving forward with a design or modifying an existing traffic signal. It is also critical that the effect of the proposed improvement be considered relative to existing conditions so as not to create any undesirable results such as safety or congestion issues. All modes of transportation that regularly traverse the intersection need to be carefully considered as well as other modes that may be planned or anticipated.

Exhibit 2-1 in Publication 149 may be used as a basic checklist for traffic signal design field views. This list is not considered exhaustive of all items to be considered. Engineering judgment should be used to determine the full extent of information to be collected in the field.

2.5 Traffic Signal Proprietary Approvals

Note: Refer to Publication 51 on the use of proprietary items.

Occasionally, the Department receives requests from municipal officials to specify a particular brand of traffic signal equipment in the special provisions for a project. Although it is the policy of the Department and the Federal Highway Administration to use non-proprietary specifications on all projects, review requests of this type to determine if this equipment is essential for compatibility with existing signal equipment or if it is in the public interest to obtain major signal hardware from a particular manufacturer.

It is important to consider any proprietary specifications early in preliminary design to obtain any necessary approvals and to help the municipal officials understand all cost implications.

Therefore, if there is more than one non-proprietary product or material that will fulfill the requirements for an item of work or project, prepare the PS&E for the project to allow all such materials providing:

- ✓ All products are of satisfactory quality and are equally acceptable based on an engineering analysis.
- ✓ The anticipated prices for the related items of work are approximately the same.

2.6 Handout from Publication 149

The information in this section is a handout of all pages of Chapter 2 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 2 - PRELIMINARY ENGINEERING

2.1 Pre-Design Activities

Prior to designing or modifying a traffic signal, all stakeholders must be in agreement with the scope of work and expected outcome. Publication 46, Chapter 4 outlines the requirements for municipal financial commitments, Application for Traffic Signal Approval (TE-160) , stakeholder coordination, and other pre-design activities.

2.2 Field View for Design

The design engineer should complete a thorough field investigation in order to become familiar with the project intersection. Whether an existing or proposed traffic signal, the designer needs to gather relevant data about the intersection and understand how the intersection operates prior to moving forward with a design or modifying an existing traffic signal. It is also critical that the effect of the proposed improvement be considered relative to existing conditions so as not to create any undesirable results such as safety or congestion issues. All modes of transportation that regularly traverse the intersection need to be carefully considered as well as other modes that may be planned or anticipated.

Exhibit 2-1 on the following page may be used as a basic checklist for traffic signal design field views. This list is not considered exhaustive of all items to be considered. Engineering judgment should be used to determine the full extent of information to be collected in the field.

2.3 Preliminary Engineering Considerations

The preliminary engineering of a traffic signal involves the consideration of several interdependent factors that must ultimately satisfy the various criteria contained within this publication. Discussed in this publication, these factors generally include: signal phasing, signal timing, control types, pedestrian accommodation, location of supports, signal head visibility, detection types, electrical distribution, preemption, traffic signal systems, lack of right-of-way, etc.

During preliminary engineering the designer must consider all of these factors and carefully layout the traffic signal design so to ensure that all criteria is satisfied. For example, signal head visibility and push button placement is dependent on pole placement. Pole placement may depend on the availability of right-of-way and potential conflict with overhead or underground utilities. These types of design challenges must be carefully and thoroughly considered. Once preliminary engineering activities are completed, a meeting is recommended with the appropriate engineering district.

Exhibit 2-1 Traffic Signal Design Field View Checklist

- ❑ Measurements
  - ❑ All lane widths
  - ❑ Storage lane lengths
  - ❑ Bay taper and lane shift taper lengths
  - ❑ Crosswalks

- ❑ Existing Features
  - ❑ Utility poles and numbers
  - ❑ Curb ramps
  - ❑ Depressed curb areas
  - ❑ Driveways
  - ❑ Underground utilities evident at grade

- ❑ Photographs
  - ❑ Proposed or existing pole locations
  - ❑ Existing signal equipment (when applicable), photograph signal heads to see visors and louvers
  - ❑ Roadway approaches
  - ❑ Controller Cabinet

- ❑ Speed study
- ❑ Grades of each approach
- ❑ Nearest signals in each direction
- ❑ Speed limits for each approach
- ❑ Pavement condition for loop installation
- ❑ Possible locations for poles and conduit runs
- ❑ Sight Distances
  - ❑ For left turning vehicles (if separate lane is provided). Is protected phasing necessary?
  - ❑ For No Turn On Red needs
  - ❑ For Signal Ahead needs
  - ❑ For Emergency Preemption emitters/detectors

For an existing traffic signal

- ❑ Mast arm lengths
- ❑ Signal heads and louvers and visors
- ❑ Junction Boxes
- ❑ Conduit Runs
- ❑ Loop detectors
- ❑ Pedestrian push buttons
- ❑ Signs
- ❑ Controller
  - ❑ Controller unit brand
  - ❑ Detection
  - ❑ Preemption?
  - ❑ Interconnection / TBC?
  - ❑ Load switches
  - ❑ Amplifiers
  - ❑ BIUs
  - ❑ CMUs/MMUs

CHAPTER 3. TRAFFIC SIGNAL OPERATIONS

In this chapter, you are introduced to traffic signal phasing as it relates to signal design. Refer to Publication 149 (portions included as a handout at the end of this chapter), Publication 46 and the Introduction to Traffic Signals in Pennsylvania training manual for additional details.

As noted in Chapter 2, decisions on the traffic signal timing factor into the signal design process. It is important for the signal designer and signal project manager to coordinate with the signal operator(s) and other interested stakeholders.

Several examples of how traffic signal timing and phasing can impact the design, include, but are not limited to:

- ✓ The phasing convention (labeling phase numbers) is shown on the signal design plans (see Section **3.1**);
- ✓ The determination of the left turn operation (protected, permitted, split, etc.) determines the type of signal head arrangement (see the Pub. 149 Handout in Section 3.6 and see the information on **Left Turn Phases**);
- ✓ The type of signal operation (pretimed, actuated-coordinated, fully-actuated, density, etc.) factors into the detector placement (see Section **3.2** and **3.3**); and,
- ✓ The actuated phasing parameters and timing are shown on the signal plans and factor into the placement of components such as the detectors (See Section **3.4**).

3.1 Controller Timing

A traffic signal controls traffic by assigning right-of-way to one traffic movement or several non-conflicting traffic movements at a time. Right-of-way is assigned by turning on a green signal for a certain length of time or an interval. Right-of-way is ended by a yellow change interval during which a yellow signal is displayed, followed by the display of a red signal. The device that times these intervals and switches the signal lamps is called a controller unit. This section covers the operation of controller units and the various features and characteristics of the types currently available.

3.1.1 Signal Phasing

Definition of a Traffic Signal “Phase”:

> *That part of the cycle length allocated to a traffic movement receiving the right-of-way, or to any combination of movements receiving the right-of-way simultaneously.*

3.1.2 Ring and Barrier Structure

Ring

A ring is a term that is used to describe a series of conflicting phases that occur in an established order. A ring may be a single ring, dual ring, or multi-ring and is described in detail below. By understanding the ring structure, you will understand the operation of multiphase controllers.

Barrier

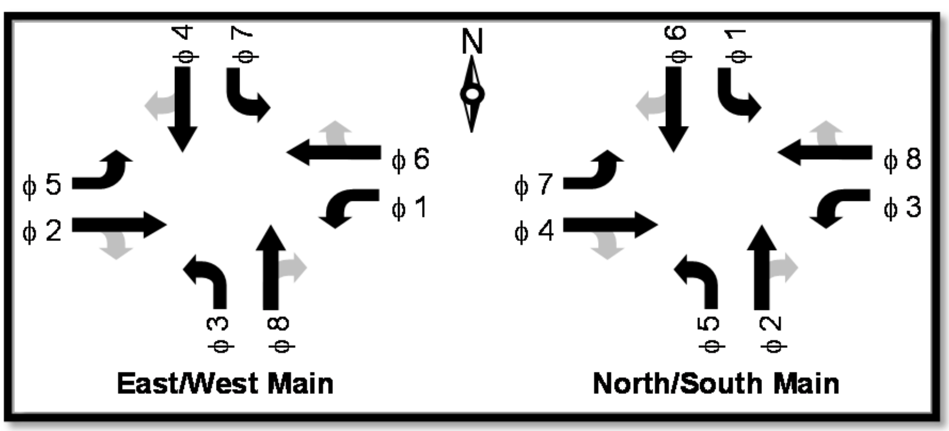
A barrier (compatibility line) is a reference point in the preferred sequence of a multi-ring controller unit at which all rings are interlocked. Barriers assure there are no concurrent selection and timing of conflicting phases for traffic movements in different rings. All rings cross the barrier simultaneously to select and time phases on the other side.

Phase Numbers

Phase numbers are the labels assigned to the individual movements around the intersection. For an eight phase dual ring controller (see definition of dual ring on the next page), it is common to assign the main street through movements as phases 2 and 6. In addition, it is common to use odd numbers for left turn signals and the even numbers for through signals. A rule of thumb is that the sum of the through movement and the adjacent left turn is equal to seven or eleven.

Exhibit 3-1 illustrates a typical phase numbering scheme for an East/West arterial and a North/South arterial.

Exhibit 3-1 Typical Phase Numbering Convention

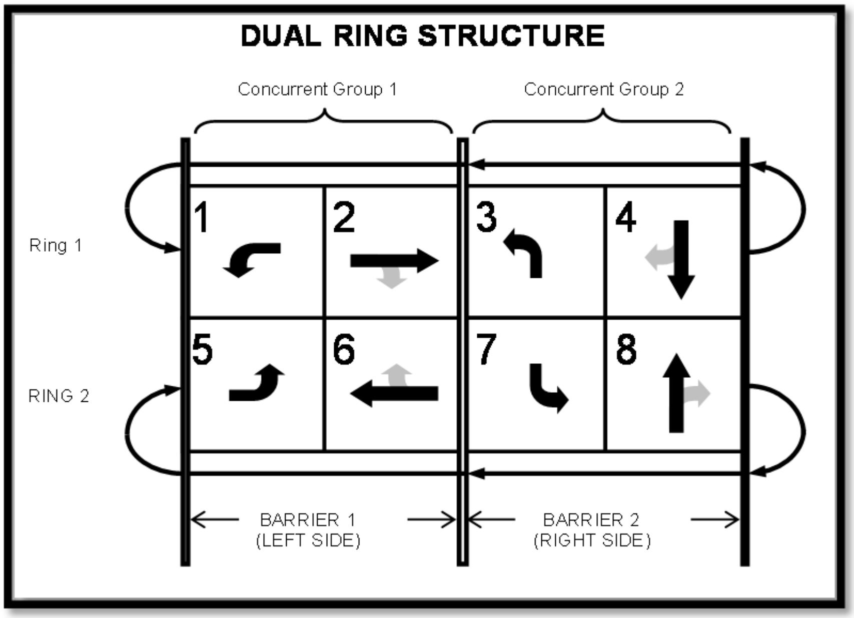


Local standards may have the phases mirrored from that shown in **Exhibit 3-1**. In addition, **Exhibit 3-1** is for dual ring control. Depending on the situation, unique phasing combinations may be required and the phase numbers shown in the figure are not applicable.

Dual Ring Control

The traffic actuated controller usually employs a "dual ring concurrent" timing process. The National Electrical Manufacturers Association (NEMA) dual ring concept with the major route in the east/west direction is illustrated in **Exhibit 3-2**.

Exhibit 3-2 Ring and Barrier Structure



The dual-ring controller uses a maximum of eight phase modules, each of which controls a single traffic movement with red, yellow and green display. The eight phases are required to accommodate the eight movements (four through and four left turns) at the intersection. Phases 1 through 4 are included in ring A, and phases 5 through 8 are included in ring B. The two rings operate independently, except that their control must cross the barrier (see definition of barrier previously) at the same time.

If the movements to be controlled by these eight phases are assigned properly, the controller operates without giving the right-of-way simultaneously to conflicting movements. All of the movements from one street (usually the major street) must be assigned to the left side of the barrier. Similarly, all movements from the other street must be assigned to the right side.

Exhibit 3-2 shows how the phases are arranged. At any given time, the controller displays one phase from Ring A and one phase from the Ring B. Both phases must be either from the left side of the barrier or from the right side of the barrier. Phase 1 can be displayed with phase 5 or 6 for example, but not with any other phase.

3.2 Cycle Length

The cycle length is the total time to complete one sequence of signalization around an intersection. In an actuated controller unit, a complete cycle depends on the presence of calls on all phases. In a pre-timed controller unit, it is a complete sequence of signal indications.

3.3 Types of Operation

Traffic control concepts for isolated intersections fall into two basic categories, pre-timed and traffic-actuated.

3.3.1 Pretimed Control

The signal assigns right-of-way at an intersection according to a predetermined schedule. The sequence of right-of-way (phases) and the length of the time interval for each signal indication in the cycle is fixed. No recognition is given to the current traffic demand on the intersection approaches unless detectors are used. The major elements of pre-timed control are: (1) fixed cycle length, (2) fixed phase length, and (3) number and sequence of phases.

Advantages to pre-timed control include:

- ✓ Simplicity of equipment provides relatively easy servicing and maintenance.
- ✓ Can be coordinated to provide continuous flow of traffic at a given speed along a particular route, thus providing positive speed control.
- ✓ Timing is easily adjusted in the field.
- ✓ Can be programmed, under certain conditions, to handle peak conditions.

Disadvantages to pre-timed control include:

- ✓ Does not recognize or accommodate short-term fluctuations in traffic.
- ✓ Can cause excessive delay to vehicles and pedestrians during off-peak periods.

3.3.2 Traffic Actuated Control Operations

Traffic-actuated control attempts to adjust green time continuously, and, in some cases, the sequence of phasing. These adjustments occur in accordance with real-time measures of traffic demand obtained from vehicle detectors placed on one or more of the approaches to the intersection. The full range of actuated control capabilities depends on the type of equipment employed and the operational requirements.

Advantages to actuated signals include:

- ✓ Usually reduce delay (if properly timed).
- ✓ Adaptable to short-term fluctuations in traffic flow.
- ✓ Usually increase capacity (by continually reapportioning green time).
- ✓ Provide continuous operation under low volume conditions as an added safety feature, when pre-timed signals may be put on flashing operation to prevent excessive delay.
- ✓ Especially effective at multiple phase intersections.

Disadvantages to actuated control include:

- ✓ Cost of installation is higher than the cost of a pre-timed installation.
- ✓ Actuated controllers and detectors are much more complicated than pre-timed signal controllers, increasing maintenance and inspection skill requirements and costs.
- ✓ Detectors require careful inspection and maintenance to ensure proper operations.

Traffic actuated signal controls are either semi-actuated or fully-actuated.

Semi-Actuated Control. In semi-actuated control, the major movement receives green unless there is a conflicting call on a minor movement phase. The minor phases include any protected left-turn phases or side street through phases. Detectors are needed for each minor movement. Detectors may be used on the major movement if dilemma zone protection is desired.

In semi-actuated coordinated systems, the major movement is the “sync” phase. Minor movement phases are served only after the sync phase yield point and are terminated on or before their respective force off points. These points occur simultaneously during the background signal cycle and ensure that the major road phase is coordinated with adjacent signal controllers.

In semi-actuated non-coordinated systems, the major movement phase is placed on minimum (or maximum) recall. The major movement rests in green until a conflicting call is placed. The conflicting phase is serviced as soon as a gap-out or max-out occurs on the major phase. Immediately after the yellow is presented to the major phase, a call is placed by the controller for the major phase, regardless of whether or not a major phase vehicle is present.

Full Actuated Control. In full actuated control, all signal phases are actuated and all signalized movements require detection. Generally used at isolated intersections; however, can also be used at high-demand intersections in coordinated systems.

Volume-density operation can be considered to be a more advanced form of full-actuated control. It has the ability to calculate the duration of minimum green based on actual demand (calls on red) and has the ability to reduce the maximum allowable time between calls from passage time down to minimum gap. Reducing the allowable time between calls below the passage time improves efficiency by being better able to detect the end of queued flow.

3.3.3 Isolated Intersection Operation

An isolated intersection is a signalized intersection that is located far enough from other signalized intersections so that the signal timing at the other intersections does not influence the traffic flow at this intersection. Often, this intersection operates with actuated operation.

3.3.4 Coordinated Signal Operation

Green intervals of certain phases at adjacent intersections are controlled to provide a relationship between them such that groups of vehicles can proceed through the intersections at a planned speed without stopping. Additional details can be found in Section **11.1 - Coordinated Systems**.

3.3.5 Vehicle Change and Clearance Intervals

In general, the vehicle change and clearance intervals should be dependent upon the approach speeds at the intersection and other factors. They should be sufficient to allow a motorist to safely bring his/her vehicle to a stop under normal conditions, or if he/she is too close to stop, then to proceed safely through the intersection.

Use the procedures contained in this section, along with engineering judgment, to determine the vehicle change and clearance intervals for each approach to a signalized intersection.

The Department uses the recommended Institute of Transportation Engineers (ITE) formulas for yellow and all-red clearance intervals to ensure compliance with the 2009 MUTCD requirement of using established engineering practices. If engineering judgment is used to vary from the established ITE formulas, then this should be documented in the traffic signal file.

Yellow Change Interval

A yellow change interval should have a duration of approximately three to six seconds. The longer intervals should be reserved for use on approaches with higher speeds. Excessively long change intervals may result in abnormal running of the change and clearance intervals.

The yellow change interval should be calculated using the following equation:

$$Y = t + \frac{1.47V}{2a \pm 64.4g}$$

Where:

Y = Yellow change interval; s (typically 3 to 6 seconds)

t = Perception-reaction time; s (typically 1 second)

v = Approach speed of the roadway; mph

a = Deceleration rate; (typically 10 ft/s^2)

g = Grade of approach; %/100

Exhibit 3-3 provides yellow change intervals using the required information. (Refer to the following charts for informational purposes; document all calculations.)

Exhibit 3-3 Yellow Change Interval

	V (Approach Speed, mph)	*g* (Grade of Approach)												
		Uphill						Level	Downhill					
		6%	5%	4%	3%	2%	1%	0%	-1%	-2%	-3%	-4%	-5%	-6%
$t + \frac{1.47V}{2a \pm 64.4g}$	25	2.5	2.6	2.6	2.7	2.7	2.8	2.8	2.9	3.0	3.0	3.1	3.2	3.3
	30	2.8	2.9	3.0	3.0	3.1	3.1	3.2	3.3	3.4	3.4	3.5	3.6	3.7
	35	3.2	3.2	3.3	3.3	3.4	3.5	3.6	3.7	3.7	3.8	4.0	4.1	4.2
	40	3.5	3.5	3.6	3.7	3.8	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.6
	45	3.8	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.1
	50	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.1	5.2	5.4	5.6
	55	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.2	5.3	5.5	5.6	5.8	6.0
	60	4.7	4.8	4.9	5.0	5.1	5.3	5.4	5.6	5.7	5.9	6.1	6.3	6.5
	65	5.0	5.1	5.2	5.4	5.5	5.6	5.8	5.9	6.1	6.3	6.5	6.7	6.9

The perception-reaction time (*t*) was assumed to be 1 second, and a deceleration rate (*a*) of 10 ft/s^2 was assumed.

All-Red Clearance Interval

The yellow change interval should be followed by an all-red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released.

The all-red clearance interval should be calculated using the following equation:

$$AR = \frac{(W + L)}{1.47V}$$

Where:

AR = All-red clearance interval; s

V = Approach speed of the roadway; mph

W = Width of intersection (from the stop bar to the end of the farthest traveled lane); (ft)

L = Length of vehicle, (typically 20 ft)

Refer to **Exhibit 3-4** for a graphical definition of the terms used in the all-red interval calculation.

Exhibit 3-4 Definition of Terms for All-Red Clearance Intervals

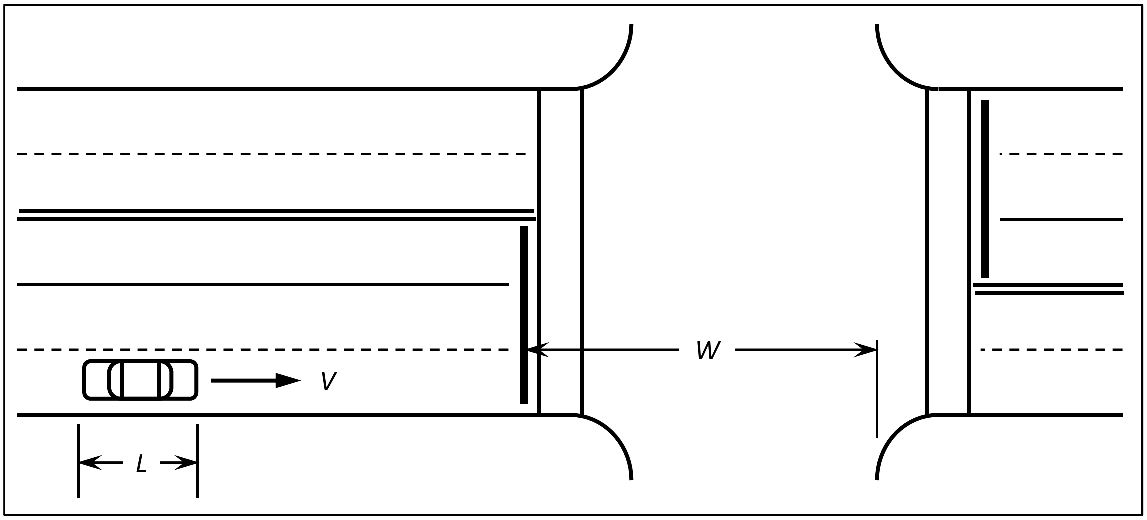


Exhibit 3-5 provides all-red clearance intervals using the required information. (Refer to the following charts for informational purposes; document all calculations.)

Exhibit 3-5 All-Red Clearance Interval

	V (Approach Speed, mph)	*W* (Width of Intersection), ft										
		20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
	25	1.1	1.4	1.6	1.9	2.2	2.4	2.7	3.0	3.3	3.5	3.8
	30	0.9	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.9	3.2
	35	0.8	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.7
	40	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4
$\frac{W+L}{1.47V}$	45	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1
	50	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6	1.8	1.9
	55	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7
	60	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6
	65	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.3	1.4	1.5

The length of vehicle was assumed to be 20 feet.

3.3.6 Pedestrian Timing

Refer to the MUTCD 2009 Edition Section 4E.06 Pedestrian Intervals and Signal Phases and Section 4E.07 Countdown Pedestrian Signals.

When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.

A pedestrian clearance time shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. The first portion of the pedestrian clearance time shall consist of a pedestrian change interval during which a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed. The remaining portions shall consist of the yellow change interval and any all-red clearance interval (prior to a conflicting green being displayed), during which a flashing or steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed.

The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk, who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication, to travel at a walking speed of 3.5 ft per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. The distance is typically measured in the middle of the crosswalk. Where pedestrians who walk slower than 3.5 ft per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of 3 ft per second should be considered in determining the pedestrian clearance time. A slower walking speed should be considered when near elementary schools and elderly facilities.

When countdown pedestrian signals are used, the numeric countdown signal indication shall be displayed only during the pedestrian change interval (flashing DONT WALK interval) and no numeric indication shall be visible during a steady upraised hand indication or walking person indication.

WALK Interval

The WALK interval allows pedestrians to access the intersection and provides enough time for pedestrians to enter the crosswalk before the pedestrian change interval (flashing DON'T WALK interval) commences. The WALK interval should be at least 7 seconds in length so that pedestrians have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins. If pedestrian volumes and characteristics do not require a 7-second WALK interval, then intervals as short as 4 seconds may be used. Longer WALK intervals are often used when the duration of the vehicular green phase associated with the pedestrian crossing is long enough to allow them.

Pedestrian Change Interval (FLASHING DONT WALK)

The pedestrian change interval (flashing DONT WALK) allows pedestrians to clear the intersection approach, alerts pedestrians of an upcoming changing phase, and provides time for pedestrians to cross the intersection approach completely upon termination of the WALK interval.

Use the following equation to calculate the length of the pedestrian change (flashing DON'T WALK) interval:

$$T_{pc} = \frac{L}{S_w}$$

Where:

T_{pc} = Pedestrian change (flashing DON'T WALK) interval; s

L = Pedestrian walking distance from the curb or edge of shoulder to the far edge of the traveled way; ft

S_w = Walking speed; s (typically 3.5 ft/s)

Total Duration of Walk Interval and Pedestrian Clearance Time

The total of the WALK interval and pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the pedestrian detector (or, if no pedestrian detector is present, a location 6 ft from the face of the curb or from the edge of the pavement) at the beginning of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3 ft per second to the far side of the traveled way being crossed. Any additional time that is required to satisfy the conditions of this paragraph should be added to the walk interval.

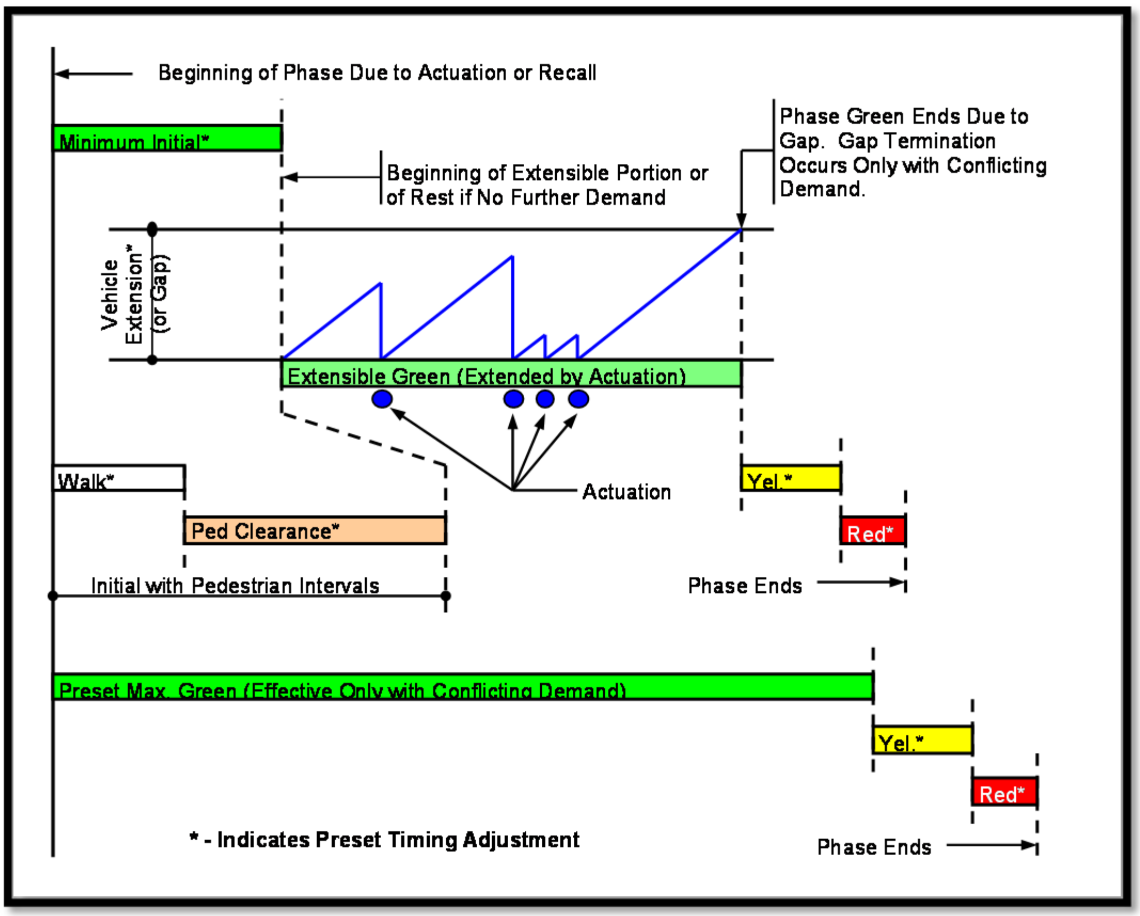
3.4 Actuated Phasing Parameters

Some of the basic principles of timing the green interval in a traffic actuated controller unit is as follows:

- ✓ There must be a minimum green time so that a stopped vehicle that receives a green indication has enough time to get started and partially cross the intersection before the yellow signal appears. This time is termed the minimum green (or minimum initial) portion of the green interval.
- ✓ Each following vehicle requires green time. This is called vehicle extension or gap. Gap refers to the distance between vehicles as well as the time between vehicles.
- ✓ There must be a maximum time that the green interval can be extended if opposing cars are waiting – this is called the maximum or extension limit.

Exhibit 3-6 shows a timing diagram for one traffic-actuated phase. The other phases in the controller operate in the same manner.

Exhibit 3-6 Actuated Phase Timing Diagram



3.4.1 Minimum Green

There must be a minimum green time so that stopped vehicles have enough time to get started and partially cross the intersection before the clearance interval appears. This time is often termed the minimum initial portion of the green interval. A typical value would be 4 seconds and could range from 2 to 30 seconds. This value is also called minimum green by some controllers.

3.4.2 Vehicle Extension Time

The vehicle extension (also known as passage time or gap time) is the unit time extension for each vehicle actuation during the extensible portion as shown in **Exhibit 3-6**. The extensible green portion is that portion of the green interval of an actuated phase following the initial portion that may be extended, for example, by traffic actuation. Each detector actuation resets the vehicle extension timer. The green interval of the phase may terminate on expiration of the extension time.

With no opposing calls for other phases, the phase rests in green. The vehicle extension continues to time but has no effect on the green interval. Upon receipt of an actuation on an opposing phase, the vehicle extension checks to see if the time between actuations is greater than the vehicle extension time. If so, the green is terminated, the yellow interval shows, and the next phase in sequence with demand is serviced. This is commonly referred to as "gap-out". These vehicles actuations (calls) can be received at the detector in either a locking or non-locking mode. In locking mode, the call is held in the controller when the vehicle leaves the detection zone. In non-locking mode, the call is dropped when the vehicle leaves the detection zone.

The vehicle extension time is typically set to allow an average speed vehicle to move from the detector to and through the intersection. This time can be reset by continuous vehicle actuation up to the maximum green time. Typical values of vehicle extension range from 0 to 9 seconds.

3.4.3 Maximum Green

The maximum green time is the maximum limit to which the green time can be extended on a phase in the presence of a call on a conflicting phase. The maximum green is illustrated in **Exhibit 3-6**.

The maximum green time begins timing at the start of the green interval when there is a serviceable vehicle demand on a conflicting phase. The phase is allowed to "max-out" if the preset time is reached even if actuations are close enough in time to prevent gap termination. If the phase terminates due to reaching the maximum, a recall is placed on the phase and it is returned to at the earliest opportunity.

The maximum green time typically ranges in values from 0 to 99 seconds (or more in some cases).

3.4.4 Recall

In the absence of an actuation, a controller unit normally rests on the current phase being serviced. A recall forces the controller to return to a particular phase's green interval, even with no demand.

Every phase has the capability of operation with the following types of recall:

Minimum Recall

When active and in the absence of a vehicle call on the phase, a temporary call to service the minimum initial time is placed on the phase. If a vehicle call is received prior to the phase being serviced, the temporary call is removed. Once the phase is serviced, it can be extended based on normal vehicle demand.

Maximum Recall

With the maximum vehicle recall active a constant vehicle call are placed on the phase. This constant call will force the controller to time the maximum green. Maximum recall is generally used to call a phase when local detection is not present or inoperative.

Pedestrian Recall

This feature provides vehicle green and pedestrian walk and clearance intervals. After that, normal green timing is in effect except that pedestrian calls do not recycle pedestrian intervals until opposing phases are serviced.

3.5 Traffic Signal Systems

If the intersection is to be included in a system, it factors into the design regarding communication (interconnect, communications, etc.). Refer to **Chapter 11** for details on traffic signal systems.

3.6 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 3 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 3 - OPERATIONAL REQUIREMENTS

3.1 Phasing

A signal phase is defined as any combination of vehicle movements and/or pedestrian movements that may occur during the same time period. Each phase will have pre-determined parameters to effectively operate that phase. Phasing shall be selected using an engineering study and engineering judgment to allow safe and efficient operation of the intersection.

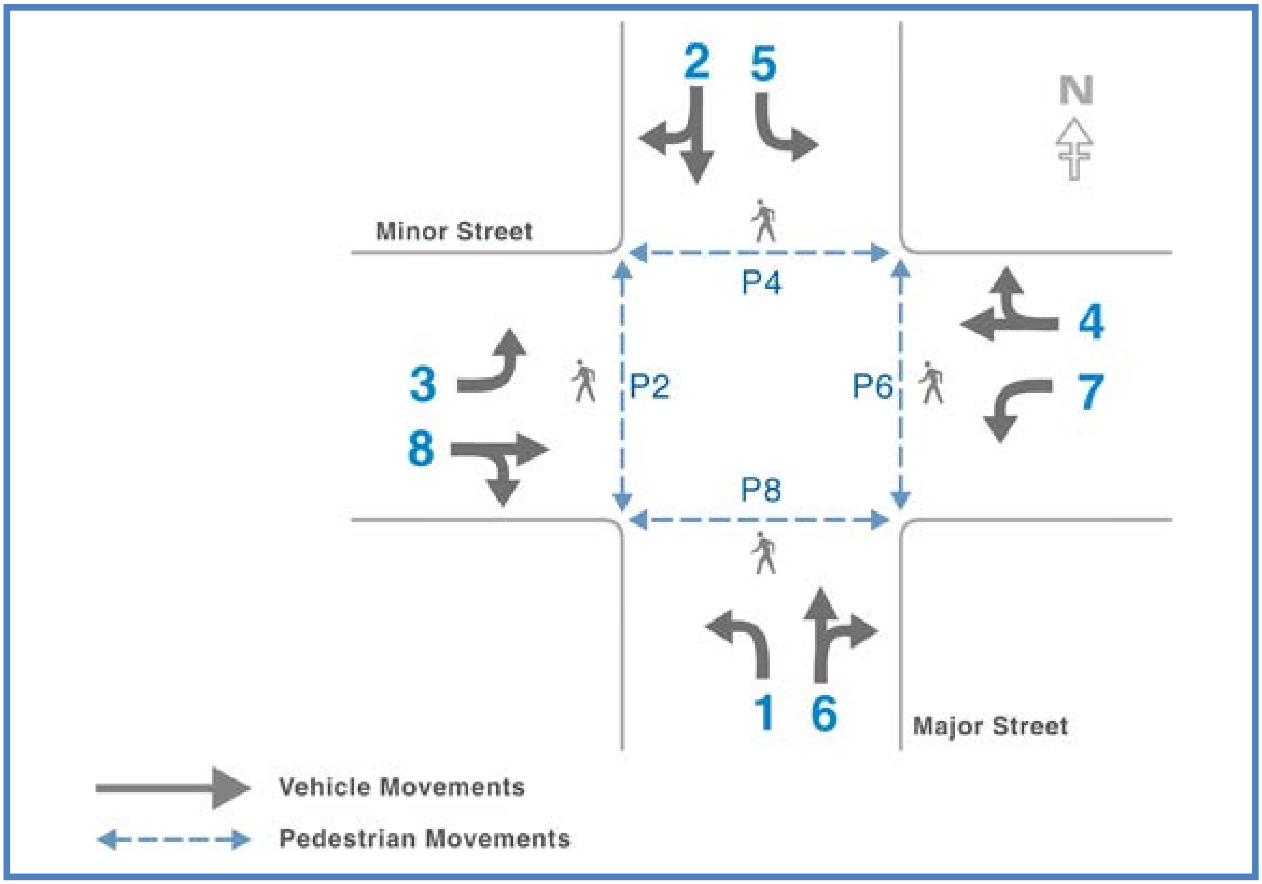
Standard NEMA Phasing

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual Chapter 4.2, Phasing Overview.

NEMA (the National Electrical Manufacturers Association) defines a specific procedure on how to label the eight standard vehicle movements at a signalized intersection. Generally, even numbers are used to designate the through movements while odd numbers are used to designate left turning movements. Standard NEMA phasing diagrams are used to graphically represent vehicle movements. A rule of thumb is that the sum of the through movement and adjacent left turn is equal to 7 or 11.

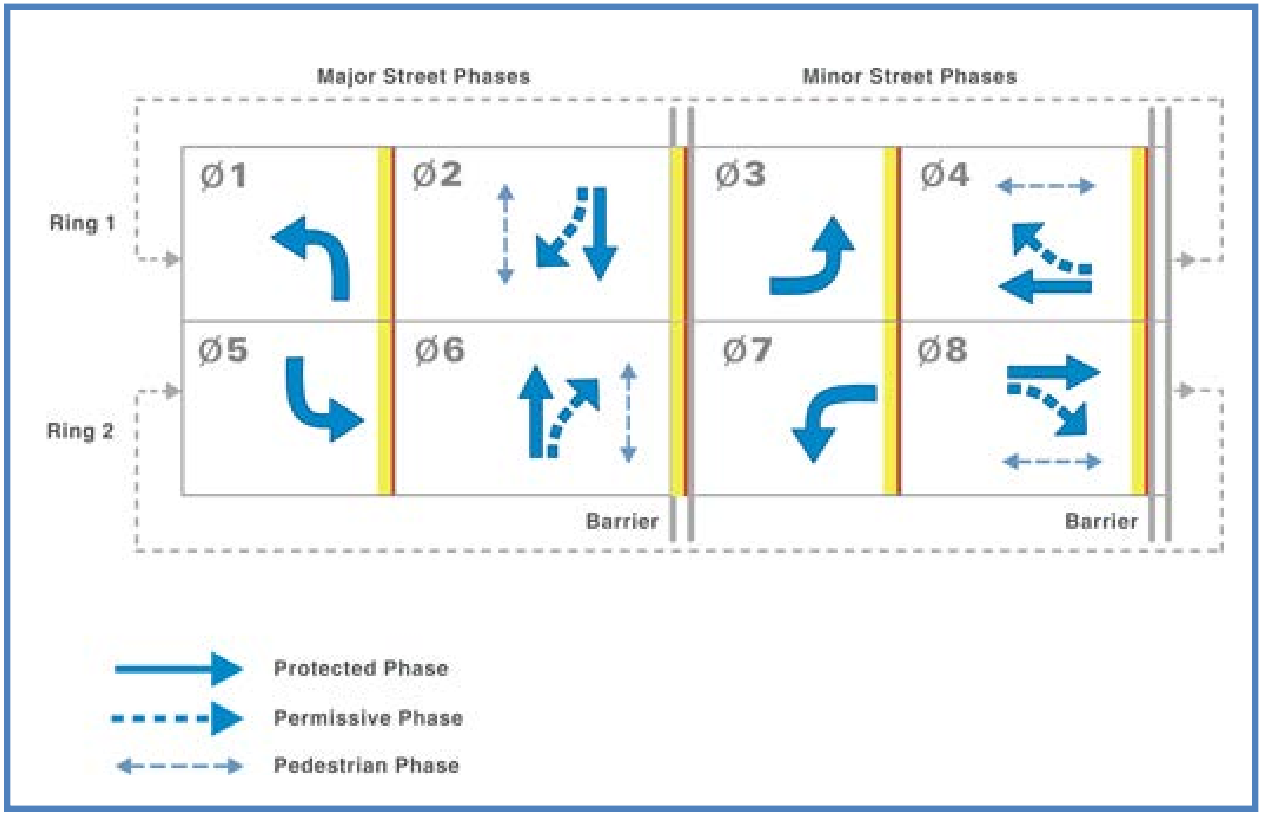
Exhibit 3-1 accurately shows standard NEMA phasing for the anticipated movements *(where applicable)*.

Exhibit 3-1 **Standard NEMA Phasing** *(from FHWA Signal Timing Manual)*



Additionally, Exhibit 3-2 shows a standard ring and barrier diagram. The ring shows phases that may operate sequentially and are typically conflicting. The barrier typically separates east-west movements from north-south. For additional information regarding ring barriers reference Publication 46 Chapter 4, Traffic Signals.

Exhibit 3-2 Standard Ring and Barrier Diagram *(from FHWA Signal Timing Manual)*



Phase Recall and Memory Determination

Recall

Recall means that the phase will recur during every full cycle of the signal. Determination of the phase recall is very important because it allows the intersection to operate more efficiently during non-peak traffic periods. The operation should be located on the traffic signal permit plan so that the proper operation may be maintained. The types of operation include:

a) **Minimum recall** places a call on a phase and then keeps the phase green for at least as long as the initial minimum setting. This phase will always be recalled to, the initial minimum setting, but green intervals may be increased if vehicle actuation occurs prior to termination of the passage time (see 3.2 Timing).

b) **Maximum recall** places a call on a phase and then keeps the phase green for a time equal to the maximum setting. If other conflicting phase calls are received at the intersection, the green interval for the phase on maximum recall will exactly equal the maximum setting.

c) **Soft recall** is similar to minimum recall, but a phase will discontinue its call for the green interval if there are conflicting phase calls at the intersection with a higher priority based on vehicle demand.

d) **Pedestrian recall** places a call for pedestrian service on a phase and then keeps the phase green for at least as long as the pedestrian intervals times. This phase will always be recalled to the pedestrian walk interval but green interval's may be increased if actual vehicle actuation occurs prior to termination of the pedestrian change interval.

Memory

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.7.3, Controller Memory Modes.

a) **Locking mode** is when a particular phase receives a call and the call remains until the phase has been serviced.

b) **Non-locking mode** allows particular phase calls to be processed, but if the call is dropped during a conflicting phase, it will be removed from memory and the phase will not be serviced.

Left Turn Phases

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.3, Left Turn Display Options.

Determination of the need for advance or exclusive phases for left turning vehicles should be made as indicated below in this Section. The left turn phase calculations should always be completed to current and/or opening day conditions and engineering judgment shall be used to determine the most appropriate intersection operation. For additional information regarding left turn phasing criteria reference Publication 46, Chapter 4, Section 4.6.

Criteria for Signalization of Left Turn Movements

Traffic volumes are the most reliable and useful method of analyzing the need for special phasing for left-turning vehicles; however, consideration must be given to the delay experienced by left-turning vehicles, safety, characteristics of the traffic stream, roadway and intersection geometry, and the type of signal operation in the area or along the street. Therefore, the following criteria have been established with the realization that a complete study for the entire intersection will be a necessary part of any evaluation of the need for consideration of a protected left turn movement. This study shall discuss each of the following criteria and include a capacity analysis for both the existing and proposed signal consideration. The engineering study shall include calculations and evaluations as indicated below. The results of the engineering study and engineering judgment shall be used to determine the most appropriate intersection operation.

Volume

A minimum approach volume of two left turns for each existing cycle during two or more separate one-hour periods of a normal weekday has been established as the minimum volume necessary before any type of left turn phasing should be considered due to volume parameters. In addition, the following conflict factor

(CF) thresholds should also be exceeded for two separate one-hour periods during a normal weekday. Opposing right turn movements may be added to the opposing through movement when appropriate and/or specified by the District Traffic Engineer or designee. A conflict factor (CF) is the product of the left turn volume and the opposing through traffic volume for any one-hour period of a normal weekday. Engineering judgement is needed for conflict factor determination. Meeting these thresholds only indicates the need for a left turn phase, but the type of operation should be the most safe and efficient operation.

Consider Protected/Permitted Left Turn Phasing

When:

a) A separate turn lane is NOT present and:
   a. One opposing lane exists; then two or more one-hour period conflict factors (CF) need to be greater than 35,000.
   b. Two opposing lanes exist; then two or more one-hour period conflict factors (CF) need to be greater than 45,000.
b) A separate turn lane is present and:
   a. One opposing lane exists; then two or more one-hour period conflict factors (CF) need to be greater than 50,000.
   b. Two opposing lanes exist; then two or more one-hour period conflict factors (CF) need to be greater than 65,000.

Consider Protected/Prohibited Left Turn Phasing (must have a separate turn lane)

When:

a) One opposing lane exists; then two or more one-hour period conflict factors (CF) need to be greater than 67,500.
b) Two opposing lanes exist; then two or more one-hour period conflict factors (CF) need to be greater than 90,000.

For dual left turn lanes Protected/Prohibited is mandatory.

Geometric and Operational Characteristics

Other factors to be considered in the evaluation of left-turn phasing at an intersection should include the following:

Crash Records

A review of the crash records should be made to determine the number of crashes which may be corrected by a left turn phase that have occurred within a continuous 12-month period over the last three years. A minimum of five correctable crashes within this period may justify consideration of a left turn phase.

Geometric

A field review of the intersection and approach geometry should be conducted to consider any items which may have an adverse effect on the safe movement of the left-turning vehicles. Consideration should be given to the width of approaches, vehicle speeds, sight distance, channelization, etc.

Vehicle Characteristics

The number and type of vehicles using the intersection and their effect on its operation may be considered. (Specifically, review the effect of trucks and buses on the traffic flow because of their braking and acceleration characteristics and their size.)

Adjacent Traffic Signals

Consideration should be given to the traffic signals (type and phasing) which are operating at adjacent intersections. Also, the effect that a newly-installed left turn phase would have on the signal operation at adjacent intersections may be considered.

Types of Left Turn Phasing

a.k.a Protected/Prohibited

Protected Only Left Turn Phasing

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.3.2, Protected Only Left-Turn Phasing.

With protected only left turn phasing, motorists can only turn left on the green arrow. Therefore, this is the most restrictive manner to treat left turns, aside from completely restricting left turn movements. Typically, a three-section signal head (having yellow and green arrow indications) with proper signing is used (*see Exhibit A-1 of Appendix A*).

Protected-Permissive Left Turn Phasing

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.3.3, Protected-Permissive Left-Turn Phasing.

Protected-permissive left turn phasing allows vehicles to make left turns on a protected left turn arrow indication. Upon completion of that phase, if a sufficient gap in opposing traffic is available, a left turn can be made on a circular green indication. Typically, a five-section signal head with proper signing is used (*see Exhibit A-1 of Appendix A*).

Permitted Left Turn Phasing

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.3.1, Permissive Only Left-Turn Phasing.

Permissive left turn phasing allows a left turn to be made on a circular green indication when there is a sufficient gap in opposing traffic. Typically, a standard three-section signal head is used.

Left Turn Phase Sequence

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.4, Left-Turn Phase Sequence Options.

Lead/Lead Left Turn Phasing

As a part of the standard NEMA phase rotation, turning vehicles get the left turn arrow before the opposing through traffic gets a circular green. Typically, simultaneous left turn arrow indications may be present for non-conflicting left turn movements (e.g., Phase 1+5 or Phase 3+7).

Lead/Lag Left Turn Phasing

Lead/lag left turn phasing allows left turn traffic to get a green arrow before or after opposing traffic gets a circular green depending on traffic demand or a progression analysis. The design must avoid the yellow trap as discussed below.

Conditional Service

Conditional service allows a left-turn phase, which is normally set as a leading phase, to re-service as a lagging phase if the opposing through phase has gapped out and sufficient time is available for a minimum green plus vehicular clearance intervals. Note that the through movements should be actuated. Protected only left turn phasing should be used to avoid a yellow trap (described below).

Yellow Trap

a.k.a. Left Turn Trap

For normal (non-preemption phasing) traffic signal operations, lagging left turn phasing should not be used indiscriminately, and generally should be avoided. Exceptions may include where the left turn movement opposite the lagging phase is made fully-protected or the phasing is changed to provide lagging permissive-protected phasing for both approaches at the same time (with the through traffic phase terminating for both directions at the same time). Otherwise, motorists turning left during the permitted period may encounter a phenomenon called the "yellow trap." The yellow trap occurs when a motorist making a permitted left turn from the approach that is opposite the lag phase observes the signal heads on their side of the intersection turning yellow. Seeing the yellow, the motorist may assume that the opposing through traffic is also receiving a yellow and is in the process of stopping whereas, in reality, the opposing through traffic still has a circular green that is running concurrently with the lagging left turn. This set of circumstances could induce the motorist to turn left into an oncoming vehicle.

Split-phasing

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.3.4, Split Phasing.

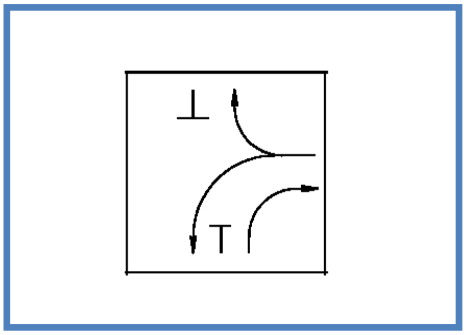
Split phasing is where two opposing approaches flow in totally separate phases that time consecutively rather than concurrently (e.g., all movements originating from the west flow together followed by all movements from the east).

Overlap

For additional information not provided in this chapter, consult the FHWA Signal Timing Manual, Chapter 4.6, Right-Turn Phasing.

An overlap is a vehicle movement, generally a right turn, which is allowed to run concurrently with two standard phases. **Exhibit 3-3** shows an example of a right turn overlap.

Exhibit 3-3 Example of a Right-turn Overlap



Overlapping of non-conflicting phases may be a desirable option at some signalized intersections. Certain considerations (e.g. prohibition of U-turns from the complementary left turn, pedestrian clearance, and physical vehicular conflict) must be examined to ensure that an overlap phase is appropriate for an intersection.

Other Phasing and Operational Options

Other phasing and operational options may be available when using modern traffic signal controllers, but an engineering study and engineering judgment need to be applied to ensure safe and efficient operations.

a) The ***adaptive split*** feature allows the controller to select a split, either based on its demand or priority.

b) Designers may wish to implement a delay on a detector call to the controller. At intersections where the side street right turn is not prohibited on red, a delay should be used to avoid calling the side street phase and stopping major street traffic when the right turning vehicle may not need the benefit of the traffic signal. Values may range from five seconds for a shared movement lane up to fifteen seconds for an exclusive right-turn lane.

c) The ***detector switching*** setting allows calls on a detector to transfer from a primary phase to a secondary phase.

d) An ***exclusive pedestrian phase*** is one in which all vehicular movements receive a red signal and every pedestrian movement, regardless of direction, is free to traverse the intersection (including diagonally).

e) A ***fixed force-off*** is a setting that, during coordination, allows the unused time of a phase to be allocated to the next phase in the sequence instead of the coordinated phase. Once the coordinated phase is reached, the remainder of unused time is used by the coordinated phase.

f) The ***inhibit max*** feature allows the controller to disregard the Maximum Green timing for a phase to allow the phase to be extended. This feature is typically used during coordination.

g) The ***delay*** setting accounts for the amount of delay incurred, before a vehicle is recognized by a delay detector. This is a user-selectable value that typically ranges between 1 and 30 seconds.

h) A ***leading pedestrian interval*** is one in which the pedestrians receive a walk symbol prior to the adjacent vehicular movement green signal. This allows the pedestrian to establish a presence in the crosswalk prior to the turning movements of adjacent vehicles. The leading pedestrian interval should typically be in the range of three to seven seconds depending on the length of the crossing, how far a pedestrian needs to traverse to establish the desired presence, and the crossing speed.

h) The ***pedestrian recycle*** setting allows the pedestrian interval of a phase to start after the beginning of green for the concurrent vehicular phase if the pedestrian clearance times can still be serviced in their entirety.

i) The ***simultaneous gap-out*** setting requires that two phases running concurrently must gap-out together. This setting is typically turned on.

Number of Phases

The number of signal phases utilized at a signalized intersection has a direct effect on the ultimate traffic capacity of the intersection. Each phase requires a clearance interval; thus, more phases necessitate more clearance time. The time used for clearance intervals is lost in terms of adding roadway capacity because the time is utilized only for clearing vehicles which have previously entered the intersection. In general, the fewer the number of signal phases in the operation, the more efficient the operation. Also, the phasing should be completed prior to evaluating traffic signal timing.

The specific number of signal phases required for efficient operation at a particular intersection is dependent upon the physical geometry of the intersection and the traffic movements through the intersection. The turning movements are significant in the consideration of the number of signal phases required. The smallest number of signal phases should be used which will accommodate the traffic demands through the intersection.

Give serious consideration before adopting multiphase operation at intersections to ensure that the multiphase operation is justified. At locations where the volumes are near or at the design capacity of the intersection, the use of multiphase signal equipment may cause the intersection to become congested due to the inefficiency of additional signal phases which may not be warranted. For example, if one approach to an intersection has a left turn arrow in operation during the non-peak hour when the volumes are low enough that the left turn movement can be accommodated without the exclusive left turn arrow, the left turn arrow results in a waste of green time that could otherwise be applied to other movements within the intersection.

Two-Phase Operation

Two-phase signal operation is the simplest form of phasing. Two-phase operation should be considered at locations where all of the following criteria are satisfied:

a) Simultaneous traffic movement in the opposing directions does not present a potential hazard.

b) The intersection has four approaches or less.

c) According to capacity analysis procedures, the volume of left turn traffic during any hour on each approach can be accommodated during the through green movement with the traffic opposing during that same hour or the left turn traffic can be accommodated during the vehicular clearance time.

d) The crash reports show exclusive left turn movements are not justified.

Two-phase operation may be used at complex intersections where the intersection has been simplified through channelization and other methods to meet the considerations for two-phase operation.

Three-Phase Operation

Three-phase signal operation may be justified if any of the following conditions exist:

a) Movements during the same phase cannot occur safely from any two opposing approaches.

b) The intersection has more than four approaches and the approaches cannot be simplified to reduce the number to four or less.

c) The intersection approaches are offset in such a manner to require separate phasing for each offset approach.

d) The left turn volume is so great in relation to the available signal timing and opposing traffic during each respective hour that the left turn movement cannot be safely and adequately handled with two-phase operation.

e) The crash reports show that a certain movement through the intersection is justified to have an exclusive movement for safety reasons.

Three-phase operation may also be used at locations where the intersection geometry can be simplified to meet the above considerations.

When it is found that the three-phase operation is justified exclusively for a minor pedestrian or vehicular movement, the movement should be actuated so that the phase may be omitted when there is no demand.

In a three-phase signal installation, experience has shown that the safest operation is provided when the movement from one approach along a particular roadway is followed by the movement from the opposite approach on the same roadway.

Four-Phase Operation

Four-phase signal operation may be applicable at locations where the intersection geometrics cannot be simplified and any of the following conditions are met:

a) The intersection has more than four approaches and the simultaneous movement cannot safely take place from any two opposing approaches.

b) The volume of left turn traffic from any one of opposing approaches is greater than the capacity during the allotted phase time for the through movements and the clearance intervals.

c) The capacity and safety requirements for the intersection cannot be satisfied by three-phase signal operation.

d) When a minor pedestrian or vehicular movement requires the fourth phase in the signal operation, the phase should be actuated.

Five-Phase to Eight-Phase Operation

Five-phase to eight-phase operation of traffic control signals may be necessary at locations that cannot be adequately signalized with a four-phase installation. The most common application of this phasing is the provision of exclusive left turn movement on all approaches with the left turn movements on opposing approaches actuated and operated independently.

The sequencing of signal phasing for the five-phase to eight-phase signal operation will vary depending upon traffic demands. The equipment provided for this operation shall have the ability to skip phases on which there are no demands.

Note for Signal Design Course: Additional pages of Pub. 149 exist beyond this page. The relevant topics for the Signal Design Course are included in the Signal Design Course Manual.

CHAPTER 4. PEDESTRIAN ACCOMMODATIONS

This chapter is related to pedestrian accommodations at signalized intersections. Pedestrian accommodations include: pedestrian indications, pedestrian push buttons, pedestrian pavement markings (crosswalks), pedestrian ramps, sidewalks, type R signs, and accessible pedestrian signal (APS) features.

Pedestrian accommodations at signalized intersections do change on a relatively frequent basis. For instance, the current design standards for APS may change based on ADA requirements. Since Publication 149 is the official signal design manual for the Department, this chapter includes the entire chapter 4 from the Pub. Be sure to check for updates to Publication 149 for up-to-date information.

An additional note that is not included in Pub. 149 is that the designer should refer to Pub. 236, the Handbook of Approved Signs. It includes signs, such as the regulatory (R series) signs used at pedestrian crossings.

4.1 Pedestrian Accommodations Considerations

Included below is a list of questions not fully addressed in Pub. 149, therefore they are included here. Engineering judgment and experience directs the responses to the questions.

4.1.1 Preliminary Considerations

- ✓ What are the concerns of the local municipality and/or road authority? Are these concerns political or engineering related? Do these concerns have merit?
- ✓ Are there any documented pedestrian concerns for the area and/or particular intersection? Review if available.
- ✓ What is the current zoning for undeveloped property? Is development imminent? Is the zoning likely to change?
- ✓ Is the area residential, urban or rural in development, commercial business district?
- ✓ Are there pedestrian generators in the area?
- ✓ What pedestrian movements are provided at near signals?
- ✓ What are the in place or planned bus routes/light rail/ bike paths/sidewalk?
- ✓ What warrants are applicable to the signal? (school/pedestrian volumes)
- ✓ Is the age of likely pedestrians an issue? (schools/retirement complexes)

4.1.2 Roadway Geometric Considerations

- ✓ What median is in place or shall be constructed for system? Is the median width appropriate for pedestrian haven?
- ✓ Are there geometric limitations to the system that restrict pedestrian movements? (i.e. adjacent bridge without pedestrian provisions, adjacent retaining walls/ physical constraints, etc.).
- ✓ With what type of roadway geometrics will the system operate? (4 legs, 3 legs, etc.).

4.1.3 Preparatory Work for Specific Design Situation

- ✓ Review accident studies.
- ✓ Review available pedestrian counts. If not available, is it appropriate/feasible to obtain accurate pedestrian counts?
- ✓ Perform a field review. What are the in place pedestrian crossings and amenities? Is it appropriate to propagate all the in place crossings?
- ✓ Are there any known safety issues such as pedestrian paths or visibility?
- ✓ Are there in place utilities that will impact the design?

4.1.4 General Operational Considerations

- ✓ Are pedestrians being prohibited inappropriately?
- ✓ Is a single crossing over the trunk highway mainline appropriate?
- ✓ Are standard operational considerations appropriate? (i.e., 4 feet (1.2 m) per second rate, coordination, pedestrian recall). Note: 3.5 feet per second may be required in the future as the pedestrian walking speed.

4.1.5 Pedestrian Facilities for Signal System

- ✓ What can be accomplished? Is the signal work a revision/rebuild (existing pedestrian patterns)? / new signal?
- ✓ Are push buttons in the median feasible – geometric, maintenance and operational (winter and safe haven) concerns? If placed within the median, on which side or sides should the push buttons be placed?
- ✓ Are pedestrian ramps and sidewalk in place within the median and in appropriate locations? If not in conformance or not in place, should ramps and/or sidewalk be placed?
- ✓ Are pedestrian ramps and pavement markings in place? Are in place ramps and markings in conformance with the 2010 ADA Standards with Amendment? Are plow friendly corners needed?
- ✓ Is sidewalk in place? Does in place sidewalk coincide with pedestrian ramps and movements? Is new or additional sidewalk necessary?
- ✓ For identified pedestrian crossings, are both indications (international) and push buttons appropriate or are combinations of the items appropriate?
- ✓ If pedestrian indications and/or push buttons are not provided at specific crossings, it may be appropriate to include spare wires for possible future use.

4.2 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 4 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 4 - PEDESTRIAN ACCOMMODATIONS

4.1 Current ADA Criteria for Signalized Intersections

The Summary of ADA Title II (28 CFR PART 35) requirements are stated at http://www.ada.gov/reg2.html. When it is determined that pedestrians are present, then proper access shall be provided for pedestrians, including those with disabilities. An engineering study and engineering judgment shall determine the design and operational features of the traffic signal, which shall accommodate all pedestrians that are present.

4.2 Engineering Studies and Engineering Judgment

As specified in the MUTCD, Section 4E, an engineering study shall be conducted to determine the need for pedestrian accommodation at signalized intersections and the related design and operational features.

Based on an engineering study and engineering judgment, proper documentation shall be made at all new signalized intersections and modifications to existing signalized intersections. Documentation may be provided with guidance from TE-672 "Pedestrian Accommodation at Intersections Checklist."

4.3 Determination of the Need for Pedestrian Accommodation

Section 4E of the MUTCD states that; *"an engineering study shall be conducted and engineering judgment exercised to determine pedestrian presence and accessibility. Therefore, all new and/or alterations to existing signalized intersections shall evaluate pedestrian accommodation and ADA compliance. "*

Signalized Intersections Not Requiring Pedestrian Accommodation

Not all signalized intersections require pedestrian accommodation, but proper documentation of this determination shall be provided.

All documentation must be reviewed and approved by the District Traffic Engineer, and the Assistant District Executive Design, Maintenance, or Services.

If an approved documentation concludes that pedestrian accommodation is not needed, the municipality shall be advised of the findings as specified in an example municipal letter in **Exhibit 4-2**. The Department will not provide new pedestrian accommodations at the intersection based on the approved documentation. The existing pedestrian features at the intersection not requiring pedestrian accommodation may be removed by the municipality. As an alternative, the existing pedestrian features at an intersection not requiring pedestrian accommodation may remain in-place and be maintained until they are no longer functional, at which point they must be removed.

Signalized Intersections Requiring Pedestrian Accommodation

If it is determined upon completion of an engineering study that pedestrian accommodation is required at a signalized intersection, then the intersection shall be in compliance with current Publication 13M (DM-2), Publication 72M (RC Standards), Publication 212, the MUTCD, Section 4E, and ADA requirements. Consult Publication 148 (TC-8803) for guidance on pedestrian signal infrastructure.

It is recognized that there may be cases where an engineering study determines that pedestrians may be present at a signalized intersection, but that there may be a legitimate need to restrict pedestrian movement across one or more approaches due to the following reasons:

a) Physical restrictions that prohibit pedestrian activity as specified in ADA Title II [i.e., sidewalks less than 3 feet wide or shoulders less than 4 feet wide].

b) Where pedestrian accommodations should not be installed for an approach due to pedestrian crash history or geometrics.

For additional direction as to determining pedestrian accommodation, please refer to TE-672 "Pedestrian Accommodation at Intersections Checklist".

Signalized Intersections Requiring Accommodation of Pedestrians with Visual Disabilities

Accessible Pedestrian Signals (APS) are used at intersections where the approved engineering study determines that pedestrians with visual disabilities may be present. Accommodations for pedestrians with visual disabilities should follow the guidance located in the MUTCD, Section 4E.09 - 4E.13 and the Public Rights of Way Accessibility Guidelines (PROWAG).

ADA and Pedestrian Accommodation for Signalized Intersection Project Types

Maintenance Type Projects

The following examples represent traffic signal projects that include routine maintenance and repair work that generally does not impact, disturb, or improve pedestrian usability. Therefore, these types of work may be completed without triggering other simultaneous modifications to ensure full ADA compliance. For additional information not provided in this chapter, consult the Publication 13M (DM-2), Chapter 6, Section 6.3. **Exhibit 4-1** provides examples of maintenance type projects and activities which do not typically trigger ADA compliance upgrades.

Exhibit 4-1 Acceptable Maintenance Type Projects and Activities

Project Types	Activity Types				
	Maintenance	Repair (**minor repair only)	Modification	Replacement	Relocation
Traffic signal poles.				✓	
Traffic signal wiring.	✓	✓	✓	✓	
Traffic signal conduit outside of the pedestrian accessible route.	✓	✓	✓	✓	
Traffic Signal conduit within the pedestrian accessible route.	✓	✓**			
Traffic signal timing and phasing.	✓		✓		
Electrical service equipment.	✓	✓	✓		
Traffic signal coordination equipment.	✓	✓	✓	✓	
Traffic signal controllers, controller cabinet assemblies, and related electronic equipment.	✓	✓	✓	✓	
Pavement markings on roadways.	✓	✓	✓	✓	
Pedestrian pushbuttons.	✓	✓**			
Accessible pedestrian signals (APS).	✓	✓**			
Circular LED vehicle traffic signal modules.	✓	✓		✓	
LED pedestrian signal head modules or LED countdown pedestrian signal head modules.	✓	✓**		✓	
LED modules to replace incandescent or other light sources.				✓	
Vehicular detectors.	✓	✓	✓	✓	
Traffic control signage.	✓	✓	✓	✓	
Roadway lighting.	✓	✓	✓	✓	
Video surveillance equipment.	✓	✓	✓	✓	
Emergency vehicle preemption systems.	✓	✓	✓	✓	
Junction boxes. (Including junction boxes outside the pedestrian accessible route).	✓	✓	✓	✓	
Conduit and utility repairs that result in small portion (< 30 meters and < 46 square meters (< 100 feet and < 500 square feet)) of accessible route being removed and replaced would require only repair in kind and would not trigger any new installation or upgrades to existing sidewalk or curb ramps.	✓	✓		✓	✓
Traffic signal preventive maintenance activities.	✓	✓	✓	✓	✓
Note: *Emergency traffic signal pole replacements and other emergency repairs to an existing traffic signal installation are acceptable.*					

Alteration Type Projects

When an existing pedestrian feature is altered, it must either meet current PennDOT standards or have an approved Technically Infeasible Form for any element that does not meet full compliance. The work does not require any additional work beyond the altered facilities; however, it may be beneficial to upgrade other unaltered pedestrian facilities as part of the project to improve access. For additional information not provided in this chapter, consult the Publication 13M (DM-2), Chapter 6, Section 6.3. Examples of Alteration Type Projects include:

a) A utility company and/or contractor decides to install or relocate its utility lines or conduit underground, requiring the reconstruction of a substantial length [equal to or greater than 100 feet] of existing accessible route. The newly constructed accessible route will need to meet PennDOT standards.
b) Installation of new pedestrian pushbuttons or accessible pedestrian signals (APS) or relocation of existing pushbuttons.
c) Installations of new curb ramps or relocation, repair, and/or modifications to existing curb ramps.
d) Relocation of traffic signal poles.
e) The addition of pedestrian features to an intersection.
f) Minor widening or geometric improvements to an intersection (i.e., the addition of bulb outs).
g) The addition of sidewalks at or near the intersection that will generate pedestrian activity at the signalized intersection.

Reconstruction and New Construction Type Projects

Traffic signal projects; including new construction, reconstruction, retrofit projects, sidewalk retrofit projects, and community enhancement projects, will be held to the highest standards regarding pedestrian usability and ADA compliance. A Technically Infeasible Form will be required for any reconstructed element that does not meet PennDOT's standards. These projects must evaluate the need for a complete pedestrian route between logical termini. For additional information not provided in this chapter, consult the Publication 13M (DM-2), Chapter 6, Section 6.3.

Examples of Reconstruction and New Construction include:

a) Intersection geometric modifications and/or reconstruction.
b) Addition of lanes and/or shoulders to the existing intersection.

4.4 ADA Accommodation Guidance for Signalized Intersections

Proper ADA pedestrian accommodation at signalized intersections shall be placed where applicable. Therefore, all new and/or alterations to existing signalized intersections shall be evaluated for ADA compliance. The following provisions shall be followed:

a) The determination of pedestrian need and the accessible route(s) should be documented through an engineering study and engineering judgment prior to beginning an intersection alteration or new construction.

b) If pedestrian need is present, accommodate pedestrians on all intersection approaches unless the need for a pedestrian restriction is justified and documented in an engineering study.

c) Does not use the need for ADA accommodations as the basis to restrict pedestrians, when this otherwise would not be considered.

d) When the need for pedestrian accommodation is present but a pedestrian movement should be restricted at an intersection, always first consider a physical barrier to preclude the pedestrian movement. If a physical barrier is infeasible, documentation shall be contained in the engineering study and Technically Infeasible Form.

e) The "No Pedestrian Crossing Sign" (R9-3A) as shown in Publication 236 shall be used when pedestrian need is determined and the accessible route is restricted. The placement of the "No Pedestrian Crossing Sign" shall supplement a physical barrier and shall be used when a physical barrier cannot be placed.

f) The engineering study should document all restrictions of pedestrian accommodation or modifications to a natural pedestrian accessible route. The study shall be reviewed and approved by the appropriate PennDOT District Traffic Engineer and Assistant District Executive. All documentation shall be maintained in the signal permit files for future reference and shall be submitted to the PennDOT District ADA Coordinator.

g) ADA compliant curb ramps shall only be placed when the pedestrian need for accommodation is present and new pushbutton locations shall be ADA compliant.

h) Pedestrian pushbuttons should be evaluated in an engineering study and a determination using engineering judgment will be made as to the required capabilities of the pedestrian pushbutton. PennDOT will approve APS installations requested by municipal signal owners.

i) If the municipality has not requested APS, the engineering study shall determine if APS is required as outlined in the MUTCD, Sections 4E.09 and shall include outreach to municipalities, school districts, transit organizations and others.

j) All additional guidelines specified in Publication 13M (DM-2) and Publication 72M (RC Standards) must be followed.

k) If pedestrian accommodations are not needed, then an approved engineering study shall document all conclusions.

l) If an approved engineering documentation concludes that pedestrian accommodation is not needed based on the engineering judgment, the municipality shall be notified of the findings. The Department will not provide new pedestrian accommodations at the intersection based on the approved documentation. The existing pedestrian features at the intersection without pedestrians may be removed by the municipality. As an alternative, the existing pedestrian features at an intersection where pedestrian accommodation is not required may remain in-place and be maintained until they are no longer functional, at which point they must be removed.

4.5 ADA Compliance Documents

For more information on proper ADA practices, please review the following documents:

1) PennDOT Publication 13M Design Manual Part 2: Highway Design
2) PennDOT Publication 72M Roadway Construction Standards (RC Standards).
3) PennDOT Publication 148 Traffic Standards (TC-8800 Series) Signals
4) Federal Guidelines for ADA Best Practices Tool Kit for State and Local Governments Chapter 6 Under Title II of the ADA & Chapter 6 Addendum: Title II Checklist
5) ADA Accessibility Survey Instructions: Curb Ramps
6) Bike/Ped Checklist, Appendix J of Design Manual, Part 1A, PennDOT Publication 10A
7) Technically Infeasible Form in Publication 13M Design Manual Part 2: Highway Design, Appendix A
8) PennDOT Pedestrian Facilities Design Checklist in Publication 13M Design Manual Part 2: Highway Design, Appendix B
9) 2011 Public Right-of-Way Accessibility Guidelines (PROWAG)

Exhibit 4-2 Example Municipal Letter

DATE

Municipal Official
Municipality
Address

VIA CERTIFIED MAIL

RE: Pedestrian Study Notice for [PROVIDE LOCATION]

Dear Municipal Official:

An engineering study evaluated the need for pedestrian accommodations at the signalized intersection(s) of [PROVIDE LOCATION].

The study has determined that there is no need to provide pedestrian accommodations at this intersection at this time. Therefore, the Department will not provide pedestrian accommodations at this intersection in conjunction with the [NAME OF PROJECT], and the traffic signal permit for this intersection will be modified accordingly.

In light of the study findings, the following pedestrian features are no longer needed at this intersection:

[LIST UNNEEDED PEDESTRIAN FEATURES]

The Department recommends, but does not require, the removal of these features. As an alternative, these features may remain in-place and be maintained until they are no longer functional, at which point they must promptly be removed.

Thank you for your attention to this matter. If you have any questions, please contact XXXXX at ________________.

Sincerely,

District Executive
Engineering District -0

Attachment

CHAPTER 5. LOCATION OF SUPPORTS

This chapter covers the placement of the traffic signal supports. The support system is the physical means whereby signal heads, signs, and luminaires are supported in a particular location. Structural supports are to be designed to carry the loads induced by attached signal heads, signs, luminaires, and related appurtenances.

Traffic signal support system designs, details and considerations do change on occasion. Given that Publication 149 is the official signal design manual for the Department, this chapter includes the entire Chapter 5 from the Pub. Be sure to check for updates to Publication 149 for up-to-date information.

5.1 Location of Support Additional Considerations

Included below is a list of considerations either not fully addressed in Pub. 149 require additional emphasis. Engineering judgment and experience directs the action and responses to these considerations.

- ✓ Check the cone of vision in the MUTCD.
- ✓ Do not obstruct oncoming traffic’s view of pole mounted indications.
- ✓ Review clearance to above ground utilities and review conflicts with underground structures (including hydraulic structures) and utilities.
- ✓ The structures should not block crosswalks, curb ramps or 4’ x 4’ landing area required at the top of a pedestrian ramp.
- ✓ The structure should be convenient to pedestrians if push buttons are installed.
- ✓ Consider placing poles at locations that account for future widening or construction projects that are being considered.
- ✓ Signal structures should be located at T-intersections to help define the stop line. For instance, the driver on the main road uses the structure as a guide as where to stop if the pavement markings are not visible.

5.2 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 4 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 5 - LOCATION OF SUPPORTS

The location of fixed traffic signal supports requires consideration of many factors, such as right-of-way lines, curb radii, roadway cross-section, existing pole locations (lighting, utility, signs, signals), sidewalk width, pedestrian curb ramps, pedestrian push buttons, driveways, pedestrian movements, overhead wiring, cost, etc. The guidelines provided below should be used as applicable to each specific situation and engineering judgment shall be used at all times to provide the most practical support placement taking into consideration the factors above.

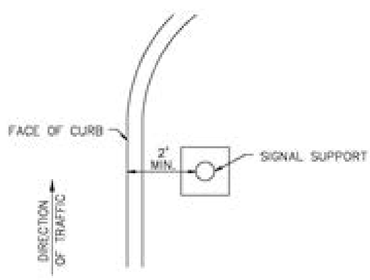
The potential hazard of fallen traffic signals, cables, or mast arms in the traveled roadway may present a safety problem equal to that of non-yielding roadside obstructions. Accordingly, supports for overhead signals should not be breakaway. Moreover, fixed overhead signal supports, base-mounted controller cabinets, and other rigidly-supported appurtenances should be located as far as practicable beyond the edge of the traveled roadway and outside the pedestrian accessible route. Traffic signal pedestals or poles of yielding or breakaway design may be used as supports for non-overhead signals and appurtenances.

5.1 Support Placement

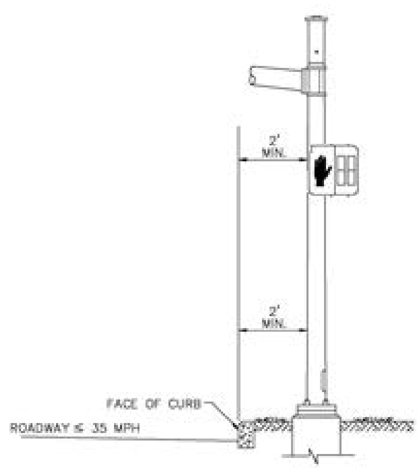
The scenarios discussed on the following pages should be followed for placement of mast arms and strain poles.

Scenario #1: Curbed Roadway and Speeds of 35 mph or Less

A minimum clearance of 2 feet shall be maintained between the face of full height barrier curb and the support itself or any signal equipment to be installed on the signal support, whichever is closer to the curb.



PLAN

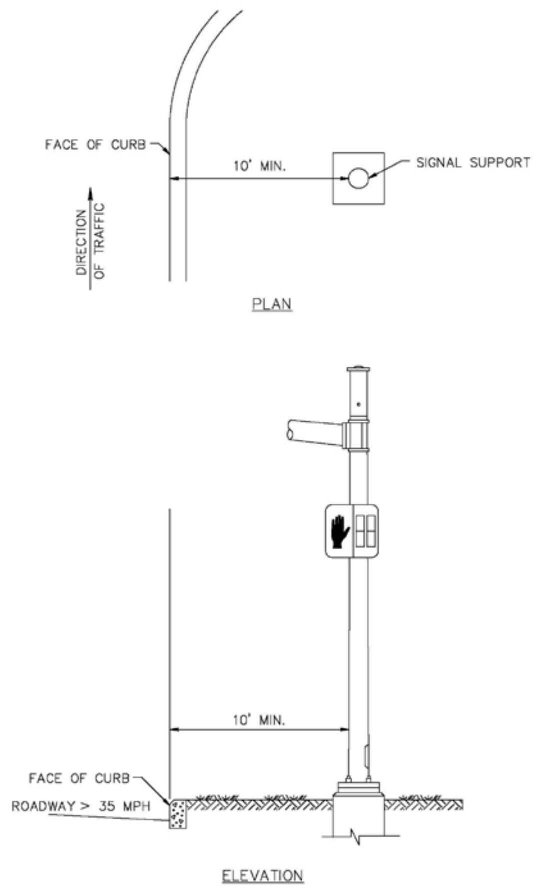


ELEVATION

Scenario #2: Curbed Roadway and Speeds Greater Than 35 mph

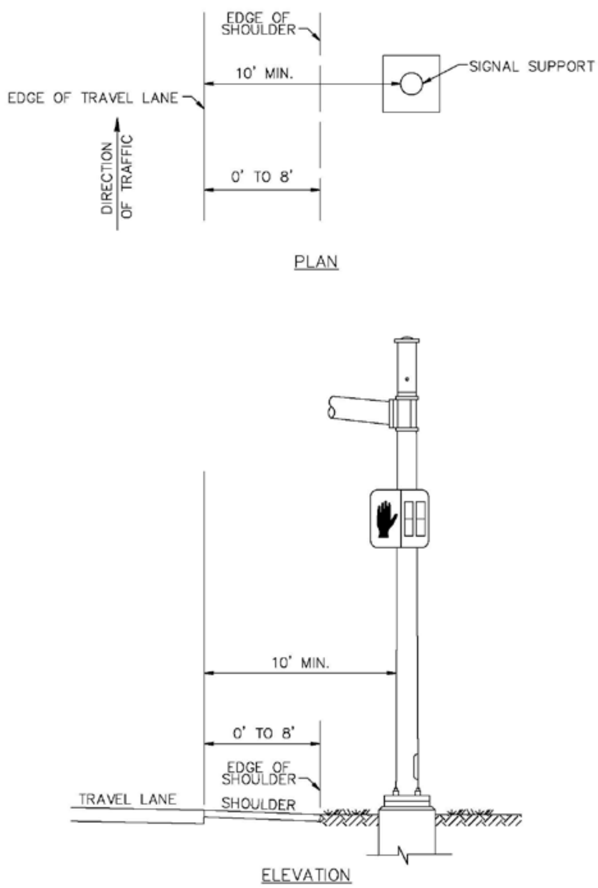
The signal support shall have a minimum clearance of 10 feet from the face of curb. On **rural** highways, every effort shall be made to attain the clear roadside concept that will not compromise vehicular safety.

On **urban** streets, every effort shall be made to obtain the 10 feet clearance, unless engineering judgment, other requirements (e.g. ADA, etc.), or documented extenuating circumstances dictate otherwise. For a roadway cross-section that includes curbed shoulder and speeds greater than 35 mph, the signal support shall have a minimum clearance of 10 feet from the travel lane and 2 feet from the face of curb.



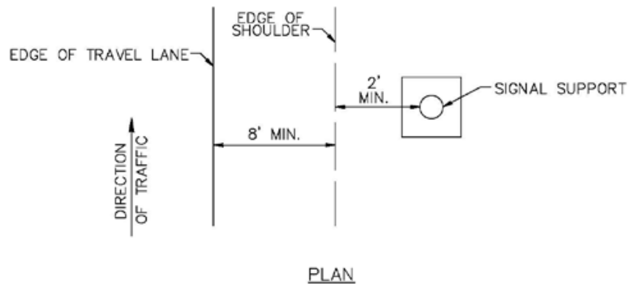
Scenario #3: No Curbs and Shoulder 0' to 8’

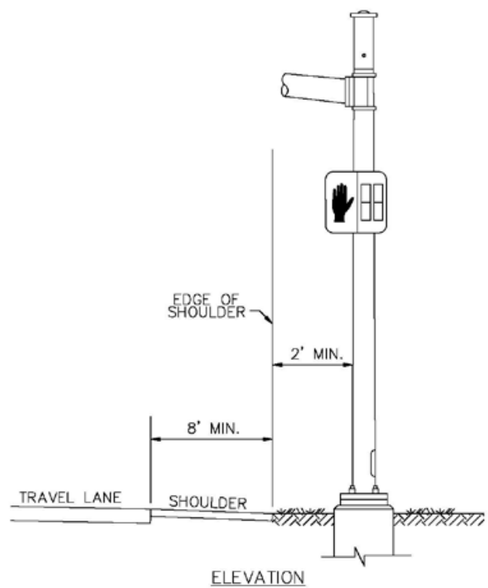
The signal support shall have a minimum clearance of 10 feet from the travel lane. On rural highways, every effort shall be made to attain the clear roadside concept that will not compromise vehicular safety.



Scenario #4: No Curbs and Shoulder Greater Than 8'

The signal support shall have a minimum clearance of 2 feet from the shoulder. On rural highways, every effort shall be made to attain the clear roadside concept that will not compromise vehicular safety.





Scenario #5: Islands and Medians

The installation of fixed supports for overhead traffic signals and pedestrian poles in islands and medians should be avoided, if possible. However, fixed supports or or any signal equipment to be installed on the signal support, whichever is closer to the curb, may be located in islands or medians when necessary to maintain the effectiveness of the signal display provided the designer can provide a set-back of 2 feet minimum from the face of curb on any roadway with speeds of less than 35 mph when the support is placed on a curbed (4 inches or greater) island or 10 feet set-back from the travel lane of any roadway with speeds less than 35 mph on an uncurbed island or island with mountable curb. Speeds less than 35 mph also need to consider vehicle turning patterns and roadway geometry.

On sides of islands or medians that have speed limits or prevailing travel speeds of 35 mph or greater, a set-back of 10 feet minimum from the travel lane of any roadway is required. For more information refer to the 2011 AASHTO Green Book.

CHAPTER 6. VEHICLE AND PEDESTRIAN SIGNAL HEADS

In this chapter, vehicle and pedestrian signal head placement is addressed. The primary consideration in head placement (vehicle and pedestrian) is clear visibility. Drivers approaching an intersection shall be given a clear and unmistakable indication of their right-of-way assignment. The number and placement of signal faces shall conform to the requirements of the MUTCD. The size of lenses shall be as stated in the MUTCD.

6.1 Signal Head Additional Considerations

Included below is a list of considerations either not fully addressed in Pub. 149 or require additional emphasis. Engineering judgment and experience directs the action and responses to these considerations.

In general, vehicle signal faces should be placed and aimed to have maximum effectiveness for an approaching driver. They should be located a distance from the stop line equal to the distance traveled while reacting to the signal and bringing the vehicle to a stop at an average approach speed. Visors, shields, or visual delimiting should be used to help in directing the signal indication to the approaching traffic, and to reduce sun phantom resulting from external light entering a signal lens.

A red ball or arrow indication is a directive to drivers that they must not enter the intersection. A yellow ball or arrow indication is a change interval and a notice to drivers that they may enter the intersection only if they are too close to safely/comfortably stop. A green arrow informs drivers that they have an unrestricted (by vehicles and pedestrians) movement and may enter the intersection. A green ball indication informs drivers that they may make a permitted left, through or right movement while yielding to conflicting vehicles and pedestrians.

An important update in the 2009 MUTCD, Section 4D.13 states:

> "For new or reconstructed signal installations, on an approach with an exclusive turn lane(s) for a left-turn (or U-turn to the left) movement and with opposing vehicular traffic, signal faces that display a CIRCULAR GREEN signal indication should not be post-mounted on the far-side median or mounted overhead above the exclusive turn lane(s) or the extension of the lane(s)."

An additional note from the 2009 MUTCD, Section 4D.06 state:

> "Strobes shall not be used within or adjacent to any signal indication."

6.2 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 6 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 6 - VEHICULAR AND PEDESTRIAN SIGNAL HEADS

6.1 Vehicular Signal Heads

Meaning of Vehicular Signal Indications

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.04.

Application of Steady Signal Indications

For additional information not provided in this publication, consult the Publication 46, Chapter 4 and the MUTCD, Section 4D.05.

At least one indication in each signal face shall be displayed at any given time when a traffic control signal is being operated in a steady (stop-and-go) mode. Signal face(s) that control a particular vehicular movement during any interval of a cycle shall control that same movement during all intervals of the cycle.

Signal Indications – Design, Illumination, Color, and Shape

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.06.

Vehicular signal indications shall be circular or arrow. The intensity and distribution of light from each illuminated signal lens should comply with the Department's Specifications for Circular and Arrow LED's.

Size of Vehicular Indications

For additional information not provided in this chapter, consult Section 4D.07 of the MUTCD.

12-inch signal indications should be used in all new signal faces. 8-inch signal indications may be permissible, refer to Section 4D.07 for guidance. Consult the appropriate local PennDOT engineering District if you have any questions regarding the use of 8-inch signal indications.

Positions of Signal Indications within a Signal Face – General

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.08.

Each signal face at a signalized location shall have three, four, or five signal sections (*unless otherwise provided in the MUTCD for a particular application*). Signal sections in a signal face shall be arranged in a vertical or horizontal straight line as specified in the Positions of Signal Indications within Vertical & Horizontal Faces.

Consult with the appropriate local PennDOT engineering district prior to implementing alternative applications of vehicular signal indications.

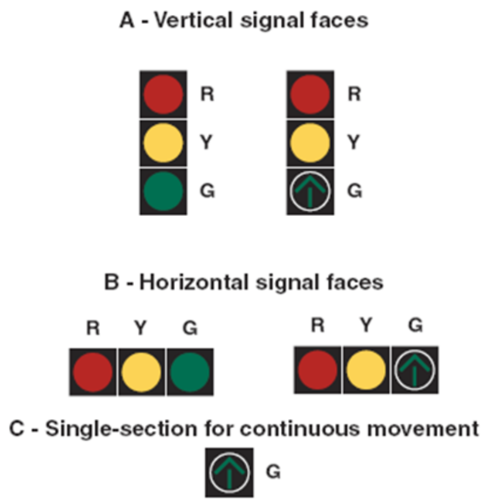
Positions of Signal Indications within a Vertical Signal Face

For additional information not provided in this publication, consult the MUTCD, Section 4D.09 .

Referenced below is Figure 4D-2 of the MUTCD, showing acceptable positions for signal indications.

Consult with the local PennDOT engineering district and/or central office prior to implementing alternative applications of vehicular signal indications.

Figure 4D-2. Typical Arrangements of Signal Sections in Signal Faces That Do Not Control Turning Movements



Note: Removed "DUAL RED" indications. (MUTCD, Figure 4D-2)

Positions of Signal Indications within a Horizontal Signal Face

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.10.

All red signal indications shall be located to the left of all signal sections that display yellow signal indications and green signal indications.

Consult with the local appropriate PennDOT engineering district prior to implementing alternative applications of vehicular signal indications.

Number of Signal Faces on an Approach

Two primary signal faces shall be provided.

For additional information not provided in this publication, consult the MUTCD, Section 4D.11.

Visibility, Aiming, and Shielding of Signal Faces

Road users approaching a signalized intersection or other signalized area shall be given a clear and unmistakable indication of their right-of-way assignment.

For additional information not provided in this publication, consult the MUTCD, Section 4D.12.

Optically Programmed Signal Heads/Louvers

Optically programmed signals/louvers are designed for applications where visibility of proper, non-conflicting signal indications is critical. The most common uses for these signals/louvers are for closely spaced intersections, offset intersections, sharply skewed intersections, or for internal clearances.

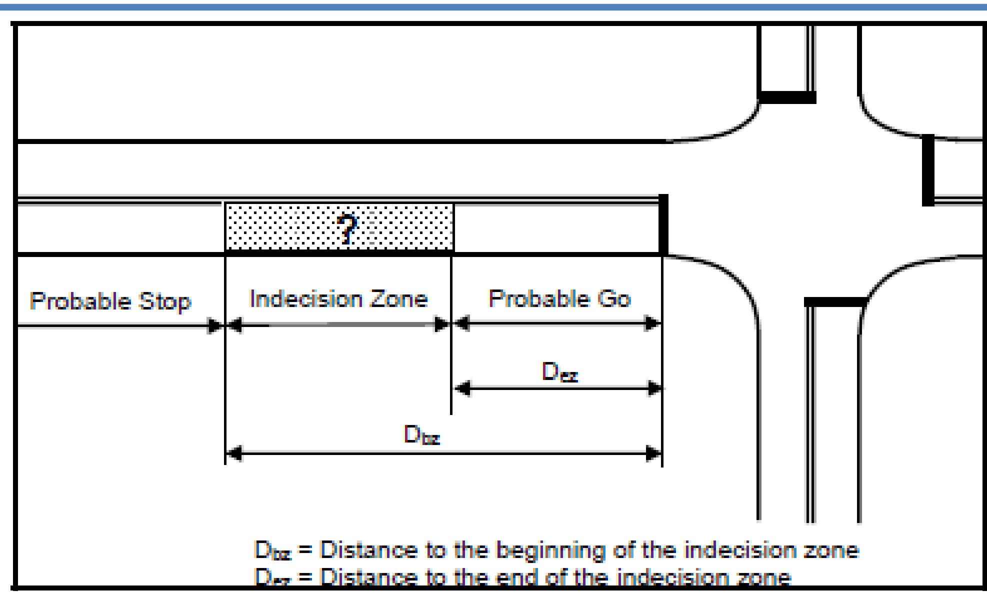
An overhead programmed signal/louver shall be rigidly mounted to retain the signal's effectiveness and desired area of visibility and non-visibility.

When intersections are less than 200 feet apart or very closely spaced, motorists may see upstream signal indications and become confused as to which signals control the intersection. This confusion may be greatest during the clearance interval of the intersection. Oftentimes, this results in motorists becoming trapped within the intersection area, thus potentially creating delays and hazards to other motorists.

The potential for such occurrences can be drastically reduced by the use of optically programmed signals/louvers and ***"distance limiting"*** their area of visibility. Distance limiting is the programming of the signal/louver so that motorists cannot see the signal display until they are beyond the point at which they have decided to proceed through the first set of signals. The second set of signal indications should be visible as far in advance as possible, but not prior to the ***"Probable Go"*** point as per **Exhibit 6-1**.

The distance limit point shown on the signal plan should generally correspond to the distance D_{ez} from the stop line of the first intersection. D_{ez} tends to be about 2.5 seconds travel time from the stop line (as per the FHWA Traffic Signal Retiming Manual) and can be calculated using prevailing vehicular speeds.

Exhibit 6-1 Indecision Zone Boundaries on a Typical Intersection Approach (*from FHWA's Traffic Signal Retiming Manual)*



<u>Internal Clearance</u>

The situation described above also occurs at intersections where the cross streets are offset or where a railroad is downstream of the cross street. In these situations, the far side signals are usually of such a distance from the stop line that the signals may draw and stop motorists within the intersection or across the tracks during the clearance interval. The provision of an ***"internal clearance"*** can help eliminate this situation.

To provide an internal clearance on an approach, it is necessary to furnish two separate, yet interrelated, signal installations. The first consists of an installation of standard signals placed in accordance with usual design practice. The second consists of optically programmed signals placed at the far side of the intersection. ***These signals shall be distance limited as per the procedure described above for a closely spaced intersection*.**

The internal clearance is provided in the controller phasing. The beginning of the green interval for both signals occurs simultaneously. However, the clearance interval of the programmed signals is delayed long enough to allow a vehicle which enters the intersection during the yellow interval of the standard signals to clear the intersection. The internal clearance allows motorists entering the intersection during the normal yellow interval to see the green indication of the programmed signal once they cross the stop line. Thus, the motorists are informed that they have the right-of-way to complete the movement.

Pedestrian Signals

Occasionally, there are locations where complex crosswalk patterns are necessary, split phasing is used, or vehicle demand for green time is such that pedestrians can only be allowed to cross a portion of an approach during one phase and complete the crossing in another phase. Programmed pedestrian signals, distance limited, may be provided in such cases.

Skewed Intersections

The use of programmed signals at skewed intersections is not mandatory but their use may be appropriate when the angle between two approaches is 35 degrees or less.

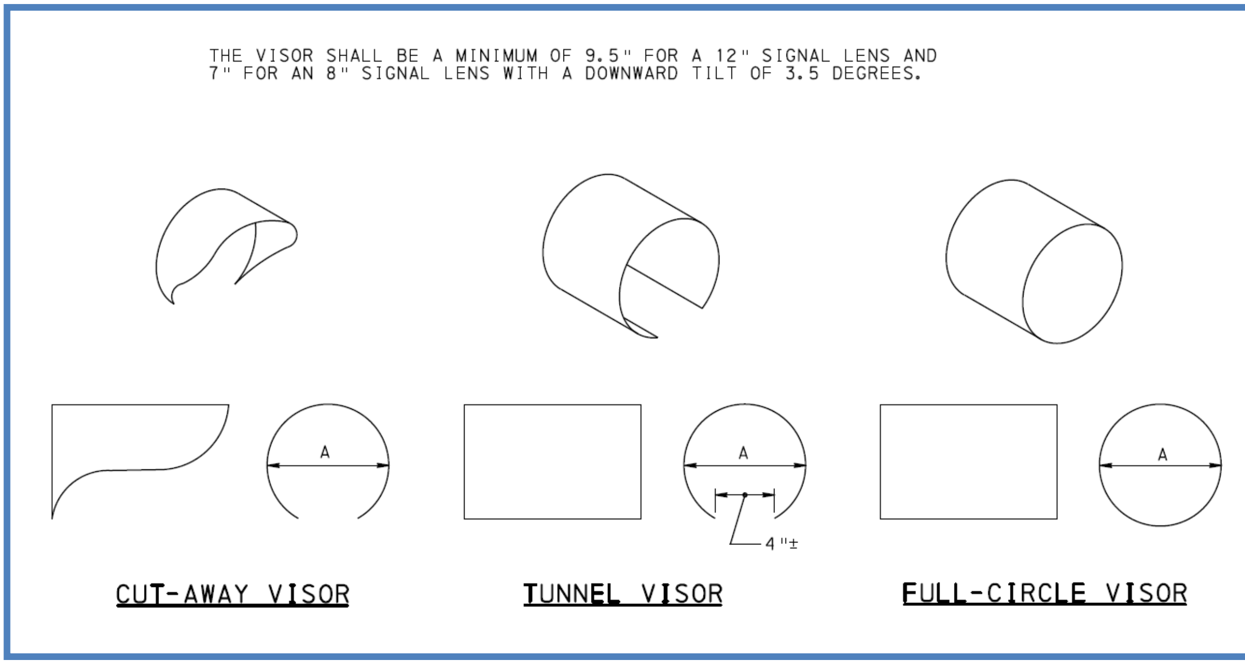
Three-Section Pedestrian Signal Heads

At intersections where pedestrian signals are not used and pedestrians may be present, the designer must verify that the pedestrian has adequate visibility of the vehicular signals. The pedestrian must be able to see an indication while walking from the curb to a point in the roadway where the pedestrian will then be able to walk to the center of the farthest travel lane during the vehicular change and clearance intervals at a walking speed of 3.5 ft/s.

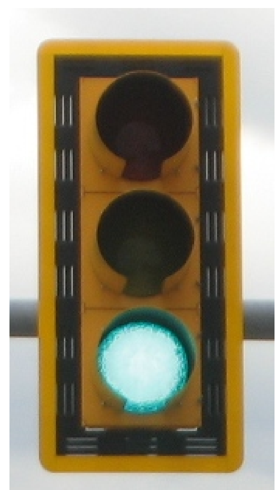
Visors

There are generally three types of visors; cut-away, tunnel, and full-circle visors. Cut-away visors should normally be used; however, the other types may be used where necessary to restrict the signal's visibility as discussed in Section 4D.12 of the MUTCD. The inside of signal visors must have a dull black finish. Refer to **Exhibit 6-2** for approved visors.

Exhibit 6-2 Approved Visor Drawings



Backplates



For additional information not provided in this chapter, consult Section 4D.12 of the MUTCD .

The front surface of backplates should have a dull black finish. A yellow retroreflective strip with a minimum width of 3 inches may be placed along the perimeter of the face of a signal backplate to project a rectangular appearance at night.

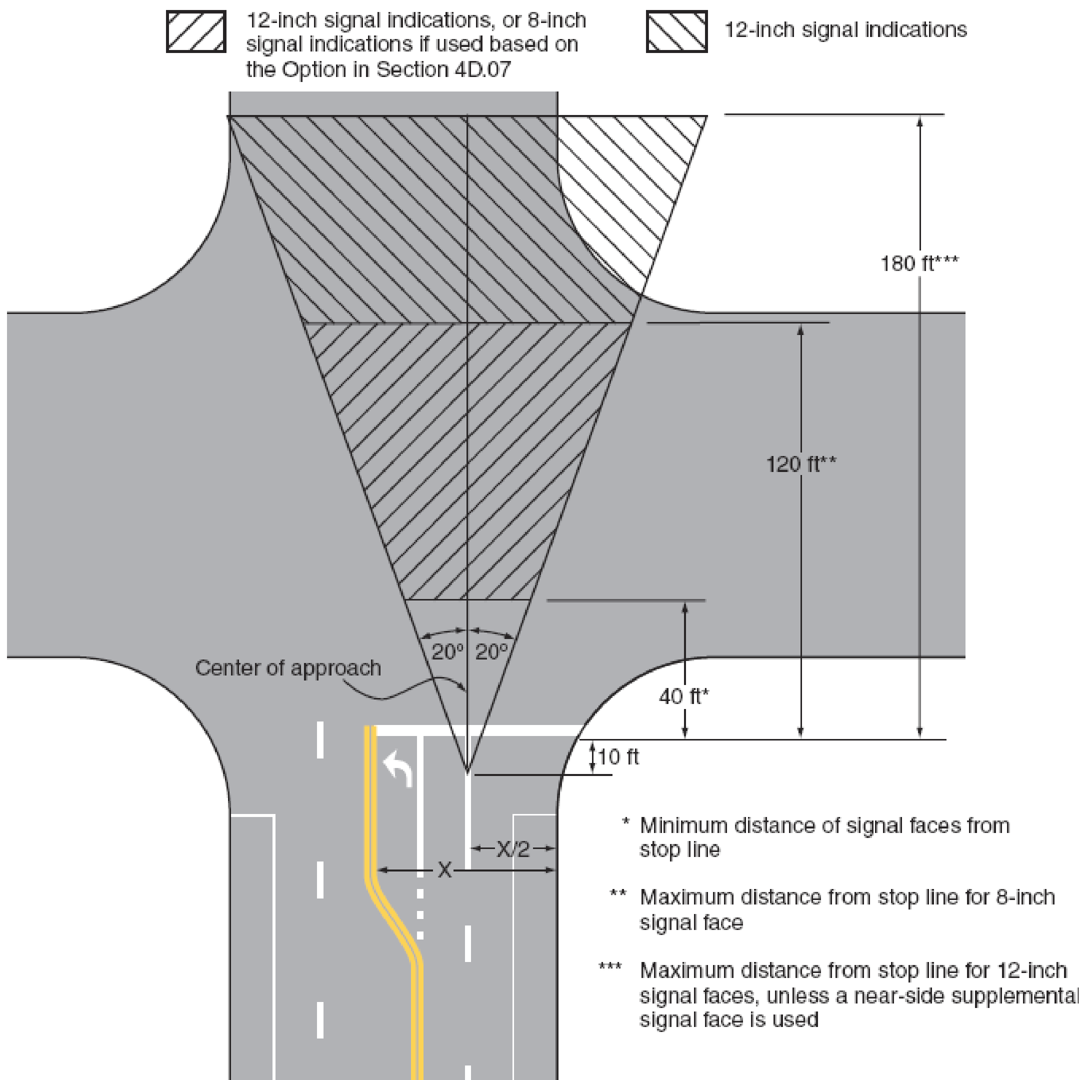
Louvers

Louvers are full-circle inserts with one or more built-in fins or vanes that restrict the viewing angle of the signal. When used, louvers should be installed with tunnel or full-circle visors. Louvers are used to decrease the possibility of motorists seeing signals which are not intended for them, especially at locations where roads intersect at acute angles. Louvers shall be considered for other special applications such as vehicular signals installed for pedestrians when their indication is in conflict with other vehicular signals. For the louvered signal, as viewed by the intended user, indicate the degree of cut-off and which side the cut-off is to occur, right or left.

Lateral Positioning of Signal Faces

For additional information not provided in this Publication, consult Publication 46, Chapter 4; and the MUTCD, Section 4D.13. Referenced below is Figure 4D-4 of the MUTCD.

Figure 4D-4. Lateral and Longitudinal Location of Primary Signal Faces



Notes:

1. See Section 4D.11 for approaches with posted, statutory, or 85th-percentile speeds of 45 mph or higher
2. See Section 4D.13 regarding location of signal faces that display a CIRCULAR GREEN signal indication for a permissive left-turn movement on approaches with an exclusive left-turn lane or lanes

Longitudinal Positioning of Signal Faces

Consult Publication 46, Chapter 4 and the MUTCD, Section 4D.14.

Mounting Height of Signal Faces

Refer to PennDOT TC-8801 standard drawings.

For additional information not provided in this publication, consult Publication 46, Chapter 4; Publication 191, Section 5.1.3; and the MUTCD, Section 4D.15.

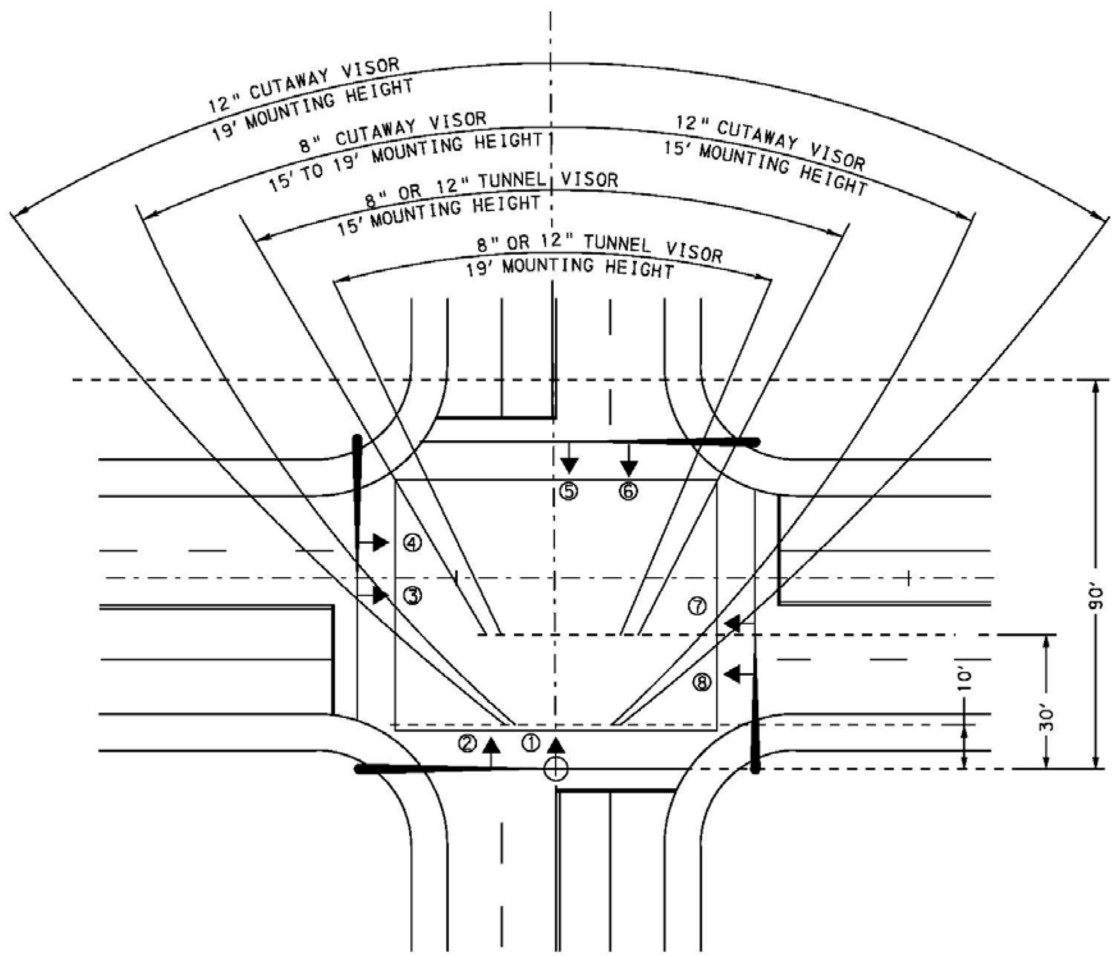
Lateral Offset (Clearance) of Signal Faces

Refer to PennDOT TC-8801 standard drawings.

Signal faces must have a horizontal offset of 2 feet or greater from the face of a vertical curb or edge of shoulder.

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.16.

Exhibit 6-3 Approved Visor Drawings



Procedure for Signal Visibility for Pedestrians:

(a) Place overlay such that the (+) point is directly over the location of the signal head nearest the crosswalk under consideration.

(b) The signal head must be visible at a point in the crosswalk which allows the pedestrian to have sufficient time to travel (at 3.5 ft/s) to the center of the farthest traveled lane before crossing vehicles receive a green.

(c) In this example signals with tunnel visors will not be visible to the pedestrians.

Signal Indications for Left Turn Movements

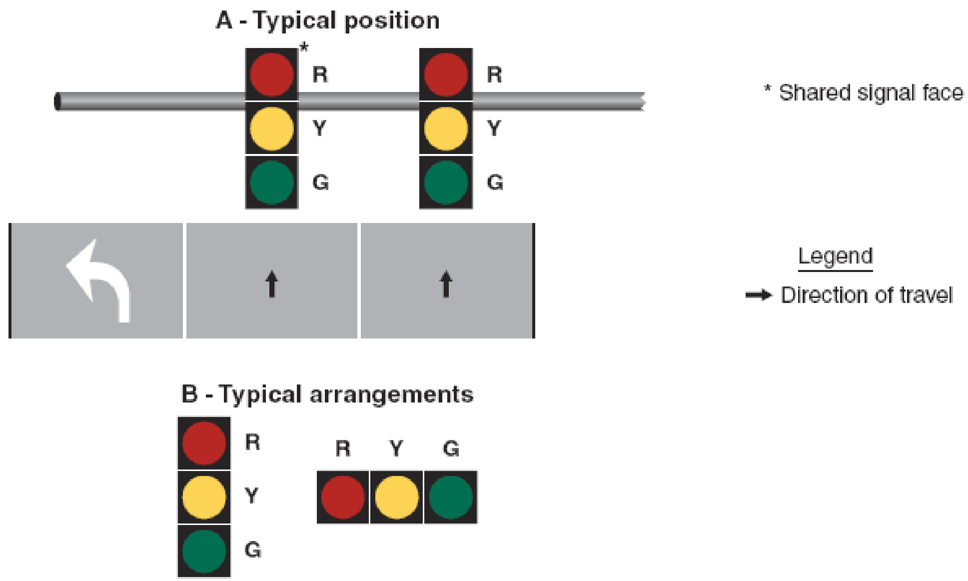
During a permissive left-turn movement signal faces for through traffic on the opposing approach shall simultaneously display green or steady yellow signal indications. During a protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display circular red indications and pedestrian signal heads shall display a steady DONT WALK.

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.17.

Signal Indications for Permissive Only Mode Left Turn Movements

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.18. Referenced below is Figure 4D-6 of the MUTCD.

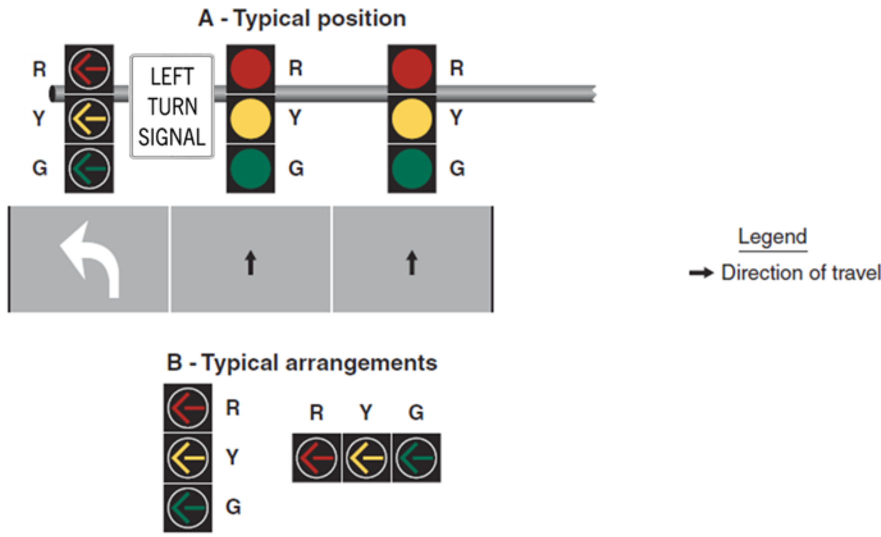
Figure 4D-6. Typical Position and Arrangements of Shared Signal Faces for Permissive Only Mode Left Turns



Signal Indications for Protected Only Mode Left Turn Movements

Signal indications should be capable of displaying only one of the three indications at any given time (steady red arrow, steady yellow arrow, and steady green arrow).

Figure 4D-10. Typical Position and Arrangements of Separate Signal Faces for Protected Only Mode Left Turns



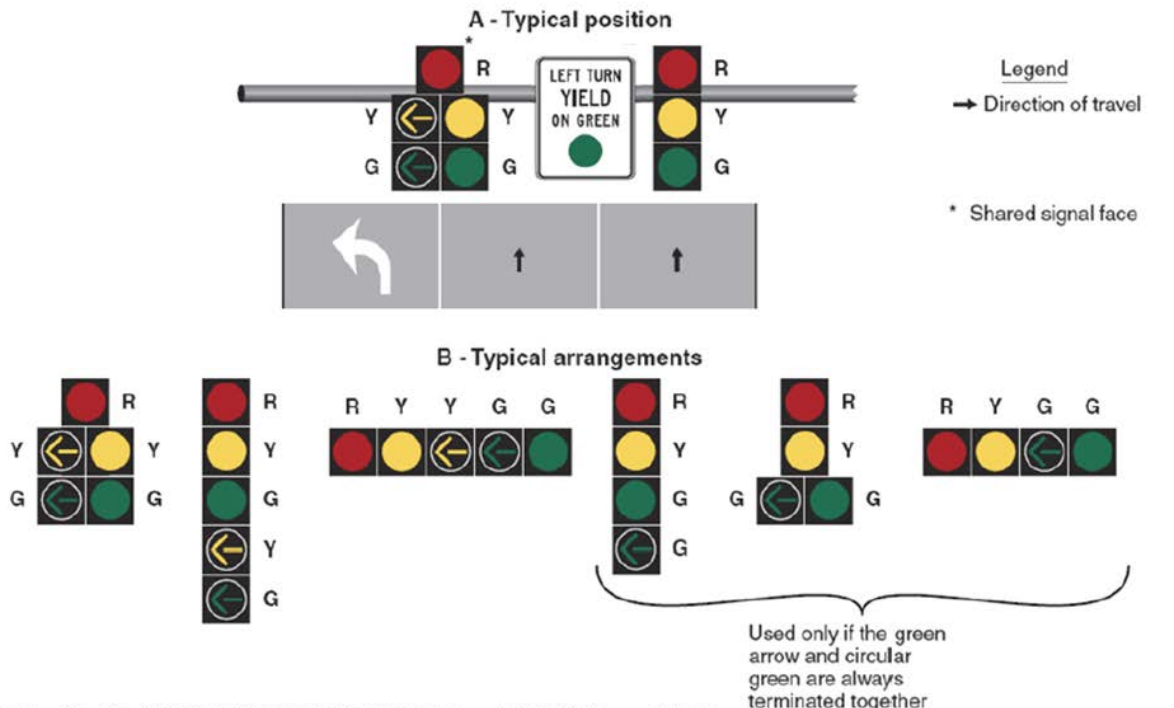
Note: Added "LEFT TURN SIGNAL" sign. (MUTCD, Figure 4D-10)

For additional information not provided in this publication, consult Publication 46, Chapter 4 and the MUTCD, Section 4D.19.

Signal Indications for Protected/Permissive Mode Left Turn Movements

Consult with the local PennDOT engineering district and/or central office prior to implementing alternative applications of vehicular signal indications. Referenced below is Figure 4D-11 of the MUTCD.

Figure 4D-11. Typical Position and Arrangements of Shared Signal Faces for Protected/Permissive Mode Left Turns



Note: Modified "LEFT TURN YIELD ON GREEN" sign. (MUTCD, Figure 4D-11)

For additional information not provided in this publication, consult the MUTCD, Section 4D.20.

Note: Under emergency conditions a 5-section head for left turns should flash the same color as the rest of the approach, while a 3-section head for left turns on the yellow flashing approach should go dark.

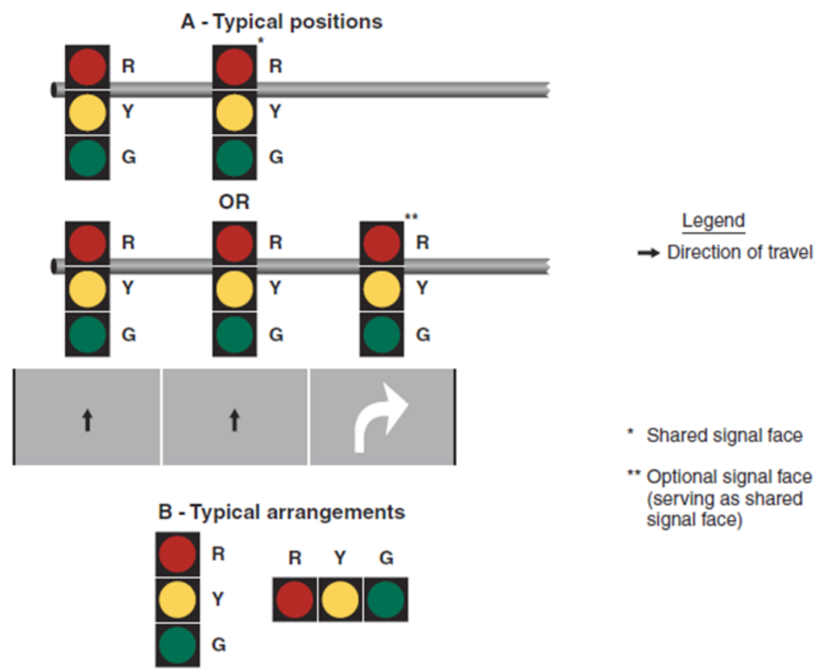
Signal Indications for Right Turn Movements – General

Consult Section 4D.21 of the MUTCD.

Signal Indications for Permissive Only Mode Right Turn Movements

Referenced below is Figure 4D-13 of the MUTCD.

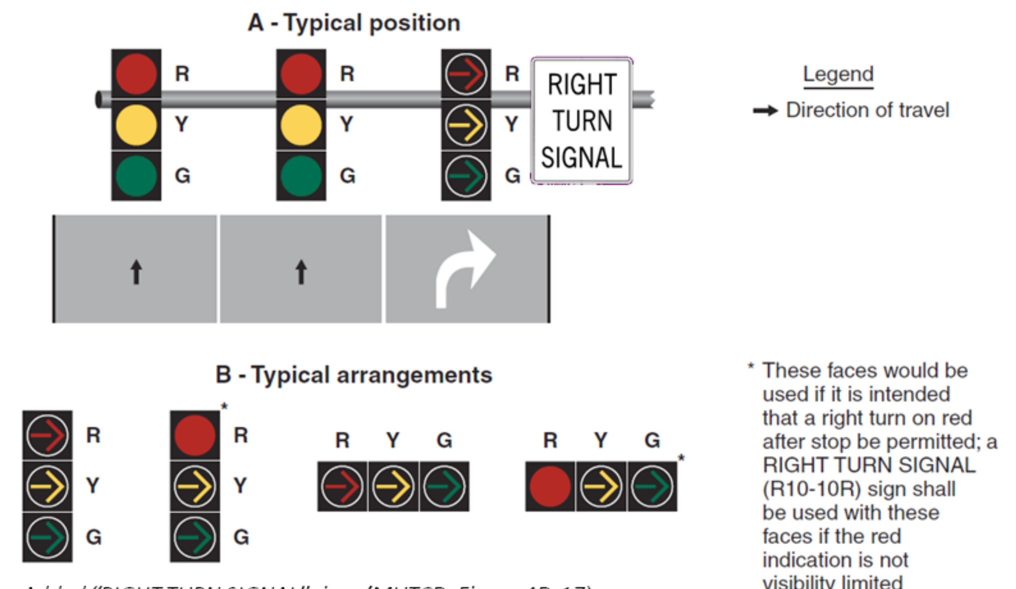
Figure 4D-13. Typical Positions and Arrangements of Shared Signal Faces for Permissive Only Mode Right Turns



Consult Section 4D.22 of the MUTCD.

Signal Indications for Protected Only Mode Right Turn Movements

Figure 4D-17. Typical Position and Arrangements of Separate Signal Faces for Protected Only Mode Right Turns

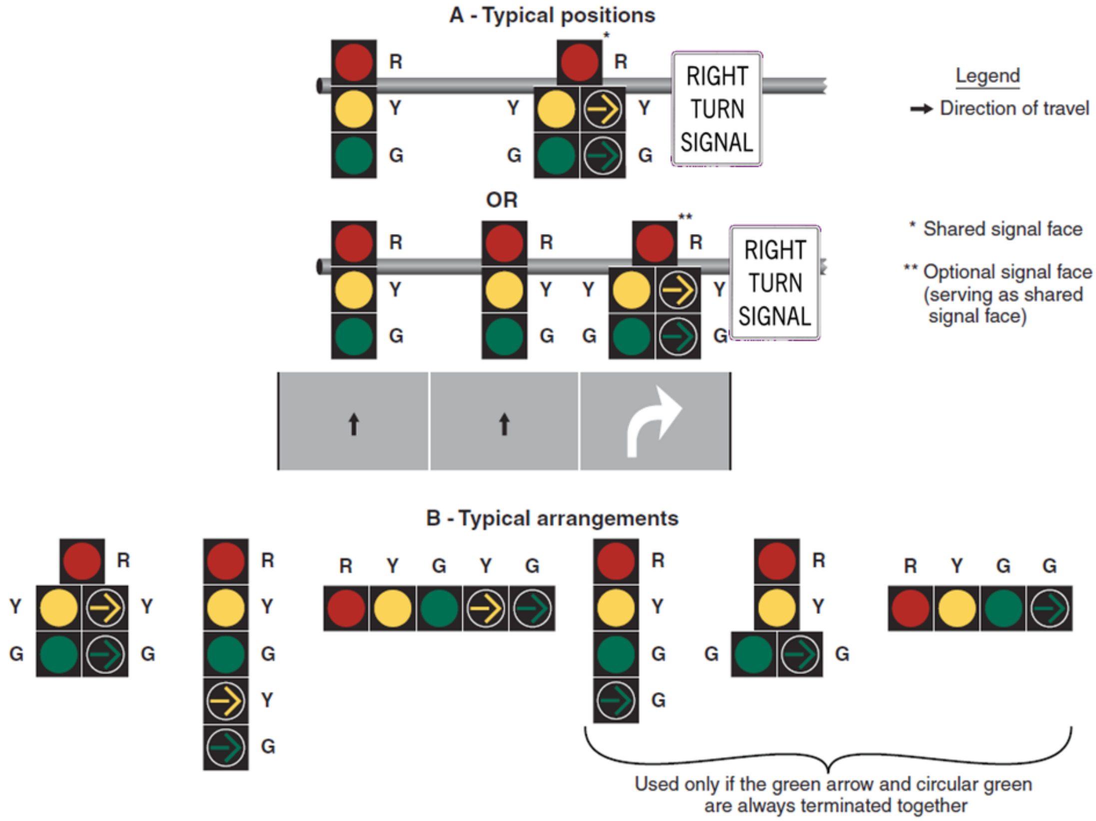


Note: Added "RIGHT TURN SIGNAL" sign. (MUTCD, Figure 4D-17)

Consult Section 4D.23 of the MUTCD.

Signal Indications for Protected/Permissive Mode Right Turn Movements

Figure 4D-18. Typical Positions and Arrangements of Shared Signal Faces for Protected/Permissive Mode Right Turns



Note: Added "RIGHT TURN SIGNAL" signs. (MUTCD, Figure 4D-18)

Consult Section 4D.24 of the MUTCD.

Signal Indications for Approaches with Shared Left Turn/Right Turn Lanes and No Through Movement

Shared lane for left-turn and right turn movements should use a circular red indication in each of the signal faces on the approach.

See Section 4D.25 of the MUTCD.

Signal Indications for Curve Approaches

When the location to be signalized involves horizontal or vertical curve approaches, there are three design issues that require special consideration. The first issue relates to the minimum visibility distances specified in the MUTCD, Section 4D.12 , the second issue involves driver expectancy with regard to the lateral placement of the signal displays, and the third issue involves accounting for the back of the queue length in case a curve obstructs sight distance to stopped vehicles. Referenced below is Table 4D-2 of the MUTCD.

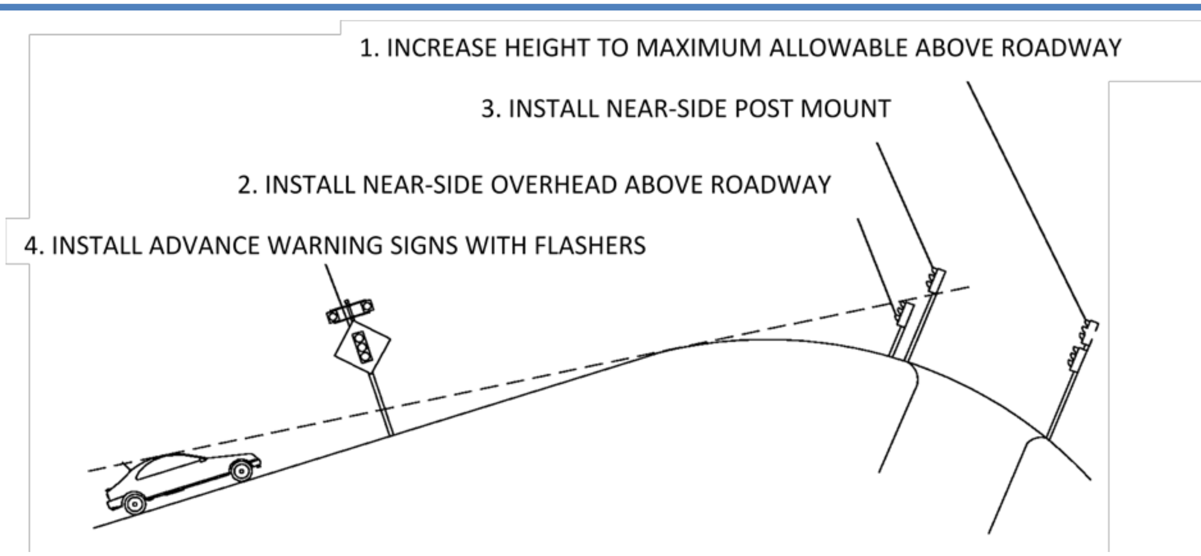
Table 4D-2. Minimum Sight Distance for Signal Visibility

85th-Percentile Speed	Minimum Sight Distance
20 mph	175 feet
25 mph	215 feet
30 mph	270 feet
35 mph	325 feet
40 mph	390 feet
45 mph	460 feet
50 mph	540 feet
55 mph	625 feet
60 mph	715 feet

Note: Distances in this table are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 seconds).

To resolve the minimum visibility issue on vertical curves, several techniques may be applied. Signal faces may be raised to their maximum heights and/or supplemented by near-side post-mounted or overhead signals. An advance warning sign, with or without flashers, may also be used at critical locations, as shown in **Exhibit 6-4**. On very high-speed approaches, overhead advance warning signs may also be considered.

Exhibit 6-4 Addressing Signal Visibility at Vertical Curves



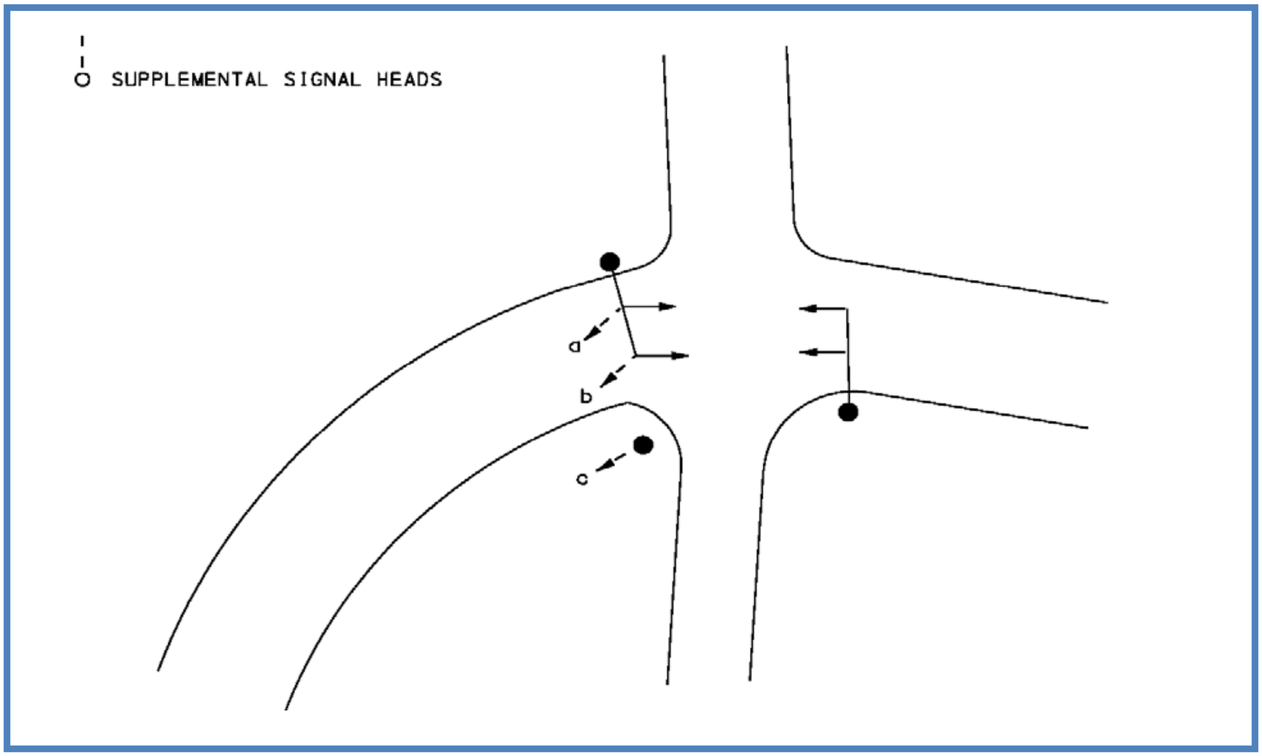
Similar techniques can also be applied to horizontal curve approaches. In this case, supplemental near-side signal indications may be placed on the left for right-hand curves or on the right for left-hand curves. These supplemental displays may be post-mounted or overhead as needed to provide adequate visibility. Advance warning devices similar to those suggested for vertical curves may be needed at locations where supplemental displays do not satisfy the minimum visibility distances.

Driver expectancy of the signal location is particularly critical at horizontal curve approaches. At unlighted locations at night, the driver may not always perceive the proper travel path to the intersection. Shifting a primary signal face and/or installing supplemental faces to guide the driver into the intersection may be considered.

There are no formal guidelines for locating signals in such diverse situations. One method for determining the most effective layout is to drive the approaches at night to identify the exact point where driver confusion may arise. A plan view of the intersection is then drafted showing the lines of sight in relation to alternate signal head placement. A design layout is then developed using the "best" alternative and is reviewed in the field.

Exhibit 6-5 illustrates a layout with three possible supplemental signal locations. In this illustration, *a and b represent additional signal head locations on a mast arm and c* is a post-mounted near-right signal. Although positions *a* and *b* are the most conspicuous, they might tend to draw the driver toward the left of the curve, since drivers are accustomed to seeing the first signal ***(primary signal)*** on the right. Position *c* might be preferable in that it would tend to lead the driver around the curve.

Exhibit 6-5 Supplemental Signal Placements for Horizontal Curves



Pedestrian Hybrid Beacons

The Department does not currently allow implementation of this device, refer to Publication 46.

Traffic Control Signals and Hybrid Beacons for Emergency Vehicle Access

An Emergency Vehicle sign with an emergency signal ahead supplemental plaque should be placed in advance of all emergency-vehicle traffic control signals. At least one of the two required signal faces for each approach on the major street should be located over the roadway. Also, it should be noted that hybrid beacons for emergency vehicle access are not permitted.

Section 4G of the MUTCD. Refer to Publication 46.

Traffic Control Signals for One-Lane, Two-Way Facilities

Section 4H of the MUTCD . Refer to Publication 46.

Traffic Control Signals for Freeway Entrance Ramp

Section 4I of the MUTCD . Refer to Publication 46.

Signals should be either a two-section signal face containing a red signal indication and a green signal indication or a three-section signal face containing a red signal indication, a yellow signal indication, and a green signal indication.

Traffic Control for Movable Bridges

The Department does not currently allow implementation of traffic control for movable bridges, refer to Publication 46.

Highway Traffic Signals at Toll Plazas

Please contact the Pennsylvania Turnpike Commission for these guidelines.

Lane-Use Control Signals

1) An engineering study should be conducted to determine whether static signs may be used or if control signals are necessary.
2) Pavement markings shall be used in conjunction with reversible-lane control signs.
3) Signal indications shall be in units with rectangular signal faces and have opaque backgrounds.
4) The color of signal indication shall be clearly visible for 2,300 feet.
5) Signal faces shall be located approximately over the center of the lane controlled, and shall be located in a straight line across the roadway approximately at right angle to the roadway alignment.
6) The bottom of the signal face shall be a minimum of 15 feet and a maximum of 19 feet above the pavement grade.
7) Signals shall be coordinated so that all the signal indications along the controlled section of roadway are operated uniformly and consistently and shall be designed to reliably guard against showing any prohibited combination of signal indications. (See MUTCD Section 4M.04 for list of prohibited combination signal indications.)

For further guidance refer to Section 4M of the MUTCD; Publication 46.

CHAPTER 7. DETECTION

The purpose of this chapter is to familiarize the designer with the various operational components of both vehicular and pedestrian detectors. The factors which determine appropriate detection for a given area are examined. Refer to Publication 149 (portions included as a handout at the end of this chapter), Publication 46 and the Introduction to Traffic Signals in Pennsylvania training manual for additional details.

7.1 Vehicle Detection

One of the advantages to actuated control is the ability to adjust timing parameters based on actual vehicle or pedestrian demand. Since this vehicle or pedestrian demand varies at different times of the day, a detector is placed in the path of approaching vehicles or at a convenient location for the use of pedestrians.

The actual operation of the signal is highly dependent on the operation of these detectors. The following sections identify some of the more common detector types and the various modes of operation employed.

7.1.1 Types of Detectors

Loop Detector

This is the most common detector type. It is a loop of wire imbedded in the pavement carrying a small electrical current. When a large mass of metal passes over the loop, it senses a change in inductance by the passage or presence of a vehicle near the sensor.

Microwave Radar Detector

A detector that is capable of sensing the passage of a vehicle through its field of emitted microwave energy. The principles of operation involve microwave energy being beamed on an area of roadway from an overhead antenna, and the vehicle's effect on the energy detected.

Video Detection

The process of using a video imaging system to analyze the feed from a video camera mounted above the roadway to determine the presence or passage of vehicles in one or more specific travel lanes on an approach to the intersection.

Infrared Detector

A detector that senses radiation in the infrared spectrum.

Ultrasonic Detector

A detector that is capable of sensing the passage or presence of a vehicle through its field of emitted ultrasonic energy.

7.2 Detector Definitions

Some of the more common detector definitions are defined below.

- ✓ **Actuation**: The operative response of any type of detector (call).
- ✓ **Call**: A registration of a demand for the right-of-way by traffic at a controller unit.
- ✓ **Calling Detector**: A registration of a demand during red interval for right-of-way by traffic (vehicles or pedestrians) to a controller unit.
- ✓ **Check**: An output from a controller unit that indicates the existence of unanswered call(s).
- ✓ **Continuous-Presence Mode**: This is a mode of operation where the detector output continues if any vehicle (first or last remaining) remains in the zone of detection.
- ✓ **Controlled Output**: This is the mode of operation where the detector has the ability to produce a pulse that has a predetermined duration regardless of the length of time a vehicle is in the zone of detection.
- ✓ **Detector**: A device for indicating the presence or passage of vehicles.
- ✓ **Extension Detector**: A detector that is arranged to register an actuation at the controller unit only during the green interval for that approach so as to extend the green time of the actuating vehicles.
- ✓ **Limited-Presence Mode**: This is a mode of operation where the detector output continues for a limited period of time if vehicles remain in zone of detection.
- ✓ **Locking and Non-Locking Mode of Operation**: Vehicle actuations (calls) can be received at the detector in either a locking or non-locking mode. For the locking mode, the call is retained until the phase receives its green interval. For non-locking mode, the call is retained only while vehicles are in the zone of detection.
- ✓ **Passage Detection**: The ability of a vehicle detector to detect the passage of a vehicle moving through the zone of detection and to ignore the presence of a vehicle stopped within the zone of detection.
- ✓ **Presence Detection**: The ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in its zone of detection.
- ✓ **Pulse Mode**: This is a mode of operation where the detector produces a short output pulse when detection occurs.
- ✓ **Zone of Detection**: The area or zone that a vehicle detector can detect a vehicle.

7.3 Detector Operations

Some of the more common detector operations are defined below.

- ✓ **Call and Extend**: Upon actuation the detector immediately places a call on its associated phases at all times. The detector shall also immediately cause the controller unit to extend the green time for the actuating vehicle only during the green interval of that phase. The controller unit may be in Lock or Non-Lock mode.
- ✓ **Extend Only**: The detector immediately registers actuation at the controller unit only during the green interval for that phase thus extending the green time before the actuating vehicles. The controller unit may be in Lock or Non-Lock mode.
- ✓ **Call Only**: Upon actuation the detector immediately places a call on its associated phase only during the red interval of that phase. This call remains active as long as the detector is actuated. The controller unit may be in Lock or Non-Lock mode.
- ✓ **Call Only Density**: Upon actuation the detector immediately places a call on its associated phase only during the red interval of that phase. This call is inactivated when the controller unit outputs a check. This allows the use of density functions on this phase but necessitates the use of detector memory (lock) on the controller unit.
- ✓ **Delay Call Density Only**: When actuated during the red interval of its associated phase, the detector delays its output call for a pre-determined length of time during the extended actuation. This call is inactivated when the controller unit outputs a check and the time delay unit is not reset until after that phase has been served. This allows the use of density functions on this phase but necessitates the use of detector memory (lock).
- ✓ **Carry-Over Call and Extend**: Upon actuation the detector immediately places a call on its associated phase at all times and continues to output the call for a pre-determined length of time. The detector shall also immediately cause the controller unit to extend the green time for the actuating vehicle during the green interval of that phase and shall continue its output for a pre-determined length of time following an actuation. The controller unit may be in Lock or Non-Lock mode.
- ✓ **Delay Call Only**: When actuated during the red interval of its associated phase, the detector delays its output call for a pre-determined length of time during the extended actuation. After the time delay expires, the call remains active at the controller unit as long as the detector remains actuated. The controller unit may be in Lock or Non-Lock mode.
- ✓ **Type-3**: These are detectors at the stop bar that place a call while the phase is red. These type-3 detectors also place extension calls for the first 4 to 10 seconds of green time. After this initial green time, the type-3 detectors are disabled.

7.4 Pedestrian Detection

Pedestrian detectors are devices that notify the controller of the presence of pedestrians.

7.4.1 Push Buttons

The pedestrian push button is the typical detection device used for actuation of pedestrian timings. The device consists of a housing of high visibility with a 2-inch minimum diameter button. Optional features can include a latching LED confirmation light and confirmation tone. Push buttons should be located horizontally and vertically on a traffic signal support nearest to the crosswalk in accordance with the MUTCD Chapter 4E, and TC-8803 of Publication 148. If a history of visually impaired pedestrians is documented, the use of Accessible Pedestrian Systems (APS) should be provided. An APS can include locator tones, spoken WALK messages, and/or vibrotactile indications to assist the impaired pedestrians in safely traversing the intersection. Consult the MUTCD sections 4E.09 to 4E.13 for guidance on APS.

7.4.2 Passive Pedestrian Detection

Detection systems that passively sense the presence and walking speed of pedestrians may be considered. Ensure that these systems have been approved by PennDOT before proceeding with their use.

7.5 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 7 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 7 - DETECTION

7.1 Vehicular Detection

Vehicular detectors are devices that provide information such as the presence, occupancy, volume, and speed of vehicles to the controller.

Types and Functions of Vehicular Detectors

The designer should be careful to consider all manufacturer recommendations for detection equipment. Ensure that the specified equipment can accommodate the full function of the design and operational intent in all roadside environments.

Inductive Loop

Inductive loop detection involves the placement of a continuous length of wire in the pavement, a lead-in cable, and an amplifier to provide an input to the controller.

When a current is placed on the wire, the loop becomes a large inductor, creating a magnetic field around it. When a ferrous object, such as a car, passes over the loop, eddy currents, induced in the frame of the vehicle, cause a decrease in the inductance of the loop. The detector amplifier senses this decrease and translates it to a vehicle demand. There are two modes of operation for detectors: pulse and presence.

When the mode selection switch on the loop amplifier is set to the PULSE position, the detector provides one output pulse having a pulse width of 75 milliseconds to 150 milliseconds for each vehicle passing over a detection area. The pulse mode provides a locking call on the controller until serviced. Since long detection areas are of little advantage when pulse detection is used, pulse detection is typically associated with the less expensive short detection areas.

When the mode selection switch is set to the PRESENCE position, the detector provides one output pulse for each vehicle passing over the detection area, or an output for a minimum of 180 seconds for a vehicle stopped over the detection area. Presence detection is typically associated with long, stop line detection areas and non-locking operation, such as volume density.

Magnetic/Microloop

Magnetic detectors detect vehicles inductively by installing a transducer (microloop) under the pavement. Operation is similar to inductive loops.

Video

Video detection systems use video cameras rigidly mounted on traffic supports to detect vehicles. One video camera is capable of providing detection to several lanes of traffic for one approach and of providing demand and volume, simultaneously. Video detection systems require video detection cards in lieu of loop amplifiers.

Accurate detection requires that the system be able to operate successfully in all kinds of weather and under a variety of ambient light conditions. Although the capabilities of these systems have increased, certain conditions (such as heavy fog) and (washout caused from the sun aligned directly with the approach) may still produce detection problems. Proper configurations shall be drawn through the video detection software to establish the detection zones. These detection zones may be removed, replaced, or redrawn using the video detection software.

Video detection can be used successfully for actuation detection on any approach as long as the camera can be located to meet the following criteria:

1) The camera is mounted at a height of approximately 30 feet; a lower height where the camera is mounted on a mast arm is acceptable for stop line detection, and up to 100 feet upstream detection for approaches of 30 MPH or less.
2) At a mounting height of 30 feet, a detection zone may be placed as far as 300 feet from the camera. This horizontal to vertical ratio of 10 to 1 defines the maximum limit for reliable detection at lower mounting heights. Vertical curvature of the approach should also be considered.

   Note: Trucks may block vehicles causing inefficiency in working as volume-density detector.
3) The camera is mounted such that the zone of detection is in view and the horizon is NOT in the view.
4) The camera is aligned with the lanes that are being detected with a head-on view of traffic as much as practical.
5) The selected zone of detection is not affected by occlusion.
6) The intersection should have adequate street lighting levels to assure that whole vehicles, not just their headlights, are detected at night.

Video detectors have a number of distinct advantages over traditional loop detectors. Among these advantages are:

1) The potential of rapid deployment.
2) Feasible to use as temporary detectors.
3) Can be used in locations when there is pavement deterioration.
4) Can be used for approaches that are on bridge decks or other structures.
5) Can be installed in construction zones when lane changes require detector reconfigurations.
6) Can be installed with minimum disruption to existing traffic (short-term or no lane closures).
7) Can be used for detecting vehicles that are not within right-of-way.
8) Cost may be lower than conventional loop detection, particularly on multi-lane approaches.

Video detection can also be characterized with some distinct limitations:

1) Good operation with video detection demands proper camera placement.
2) Good camera placement requires proper support structure.
3) Vision-based systems can be limited in poor lighting conditions and also by changing shadows casued by trees near an intersection.
4) Severe fog or precipitation and wind gusts can result in poor performance.
5) Cameras require periodic lens cleaning to maintain proper performance.
6) Routine maintenance for checking camera views and inspecting mounting connections.
7) Detection over extended distances may be substandard and should be considered when evaluating the product.

Microwave / Radar

Microwave/radar systems use sensors rigidly mounted on traffic supports to detect approaching vehicles based on the frequency of emitted microwaves. Microwave sensors can detect vehicles in pulse and presence mode. Microwave systems require interface boards/modules in lieu of loop amplifiers. This type of detection may be desirable to track vehicles through the intersection. Digital wave radar systems allow for contiuous tracking of vehicles at an intersection and perform well under all weather and light conditions.

Other

Various other types of vehicle detection systems exist. Ensure that these systems have been approved by PennDOT before proceeding with their use.

Selection

Each detection type has advantages and disadvantages. Factors, such as size of detection area, number of approach lanes, pavement conditions, and average modes of travel (vehicles, trucks, bicycles), must be identified before design. Radar/microwave and video systems may have higher upfront costs but potentially need less maintenance and replacement.

Inductive loops have been the preferred method of detection due to its lower cost of installation, greater reliability, and flexibility in design.

Microloops may be used in lieu of inductance loops in situations such as limited right of way and poor pavement conditions. The field of one microloop is typically 6'x6' but up to four can typically be wired in series per lead-in cable.

Video detection should be considered at larger intersections where it can be cost-prohibitive to install multiple inductive loops. The initial installation cost may be higher than loops but most video cameras are capable of multiple zones of detection.

Design and Placement of Detection Zones

There are two basic configurations of zones of detection which may be utilized:

a) Short zone

b) Long zone

Refer to TC-8806 (Detectors) of Publication 148 for inductive loop layout details and installation. The discussion below is generally relative to inductive loop detectors but may be considered for other types.

Short Zones

The short zone may be installed either alone, or in conjunction with other short zones to create a large detection area (*see* **Exhibit 7-1**). Sizing and layout criteria are as follows:

a) The length shall be 6 feet.

b) The minimum width shall be 5 feet.

c) The sides of the zone should be 3 feet from either edge of the travel lane.

d) For detection in advance of the stop bar, the location from the stop line is determined by the speed of approaching vehicles.

e) For sequential short zones, the detection area shall be comprised of four zones and shall be approximately 70 feet long. The first zone shall be placed so that it extends 3 feet beyond the stop line. Additional distance beyond 3 feet would require district traffic engineer approval. The second, third, and fourth zones shall be sequentially spaced at 10 feet, 15 feet and 20 feet, respectively.

Short zones may operate in either the pulse mode or the presence mode.

Long Zones

The long zone is used to provide a large detection area with one zone. Each lane of a detectorized approach shall have a separate zone (*see* **Exhibit 7-1**, **Exhibit 7-2**, *and* **Exhibit 7-3** *of this publication*). Sizing and layout criteria are as follows:

a) The maximum length shall be 50 feet.

b) The maximum width shall be 8 feet and the minimum 5 feet.

c) The sides of the zone should be a minimum of 2 feet from either edge of the travel lane.

d) The front edge of the zone may extend 3 feet beyond the stop line. Additional distance beyond 3 feet would require district traffic engineer approval.

e) Long zones shall operate in the presence mode only.

Modified Long Inductive Loop

The modified long inductive loop was devised to address the problem of adjacent lane detection in very high sensitivity inductive loop systems. The outer configuration of the loop is identical to conventional loops, but has a saw cut down the center. The loop consists of wire laid in a figure eight pattern in the saw cut, thus creating two narrow loops laid side by side (*see* **Exhibit 7-1** *of this publication*). This winding pattern creates fields that cancel outside the perimeter of the loop and are enhanced within it. Modified long loops are more effective than conventional loops in the detection of small vehicles such as bicycles and small motorcycles. The procedures for sizing and layout shall be identical to those for both short and long conventional loops. Refer to TC-8806 (Detectors) of Publication 148 for additional loop patterns for small vehicles.

Detector Zone Design

The following represents various inductive loop sensor design options available to the designer. Note that zones of detection for other types of detectors should be designed in a similar fashion.

Option 1: Consists of sequential short loops for individual lane detection in either the pulse or presence mode. They may be wired either in series or parallel; however, best results are achieved when alternate loops are paired and wired in parallel to separate input channels. There is an added safety feature inherent to this option as, should one loop fail, detection is not completely lost. Although the initial cost is higher than that for long loops, maintenance is easier, as in case of damage, only a small loop need be replaced.

The short loops, like the long ones, are susceptible to detecting vehicles in adjacent lanes; however, they are more sensitive and are better suited for sensing small vehicles.

Option 2: Consists of a long loop 6 feet by 50 feet maximum for each approach lane. This enables individual lane detection in the presence mode. Although this loop is larger than the other options, its initial cost is the lowest as less lead wire and fewer junction boxes are required. Construction cost is lowest of all options. The disadvantages are that, should the loop break, all detection for that lane is lost, and long loops are the least sensitive of all. When the sensitivity is increased, the loop becomes more susceptible to detecting vehicles in adjacent lanes.

Option 3: Consists of a modified long loop for each approach lane. Its operation is identical to that of Option 2. The major advantage of this option is that it is usually sensitive enough to detect bicycles and small motorcycles, yet it does not detect vehicles in adjacent lanes. Like Option 2, detection for an entire lane is lost should the loop be severed.

Option 4: Consists of one short loop per lane located in advance of the intersection based on normal approach speeds. This option, which operates in pulse mode only, is best suited for providing extension intervals on roads with higher travel speeds. They can also be used for individual lane counting and gap determination.

Option 5: Is basically the same as Option 4, except one intermediate loop is used for multilane detection instead of individual lane detectors. Construction is less expensive than Option 4; however, should breakage occur, detection on that approach would be completely lost.

Option 6: Is a single short loop per approach lane for use where a driveway is located between the intersection and the area of detection for Options 4 or 5. Traffic generated by the driveway would be unable to actuate its phase without the additional detectors placed near the stop line. A 6 feet x 6 feet calling detector shall be used in these cases.

Exhibit 7-1 Detection Options for Various Types of Detection

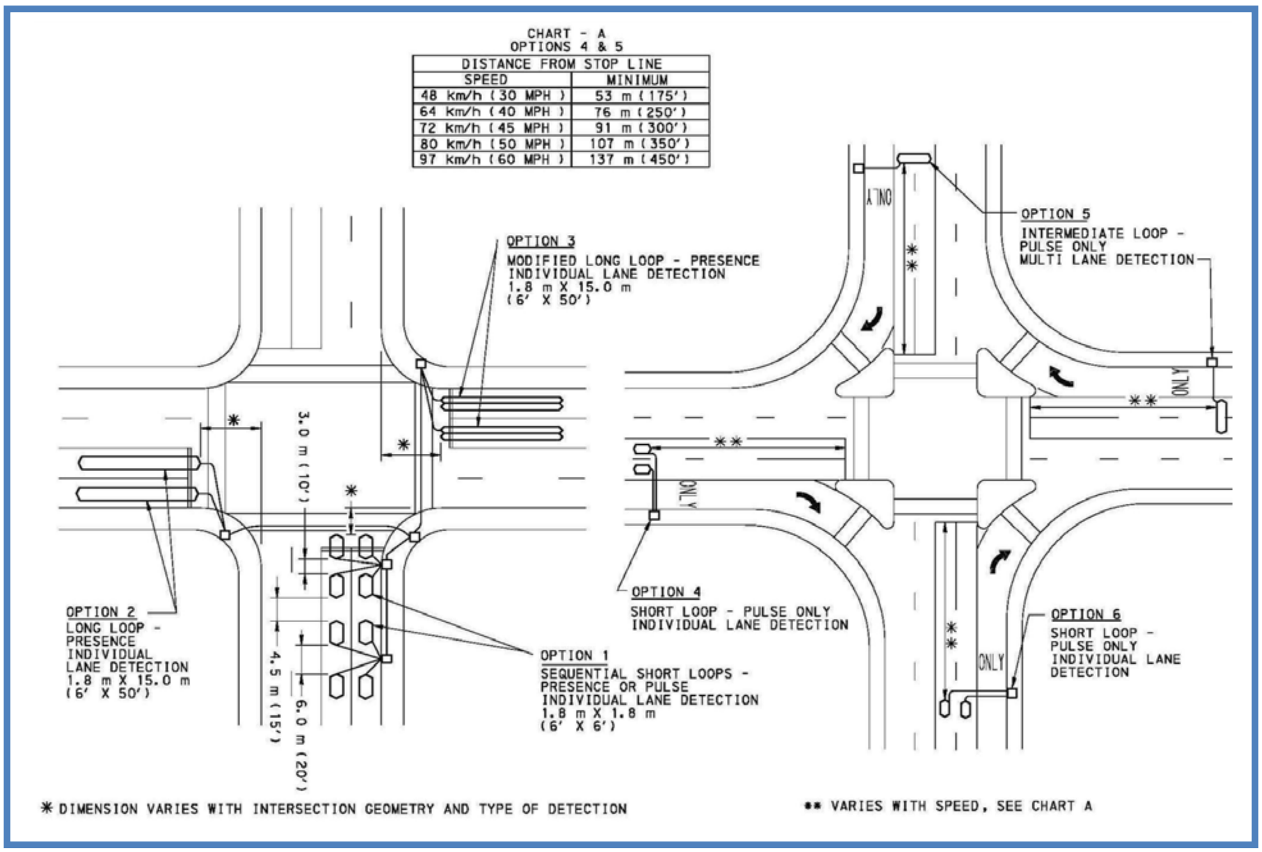
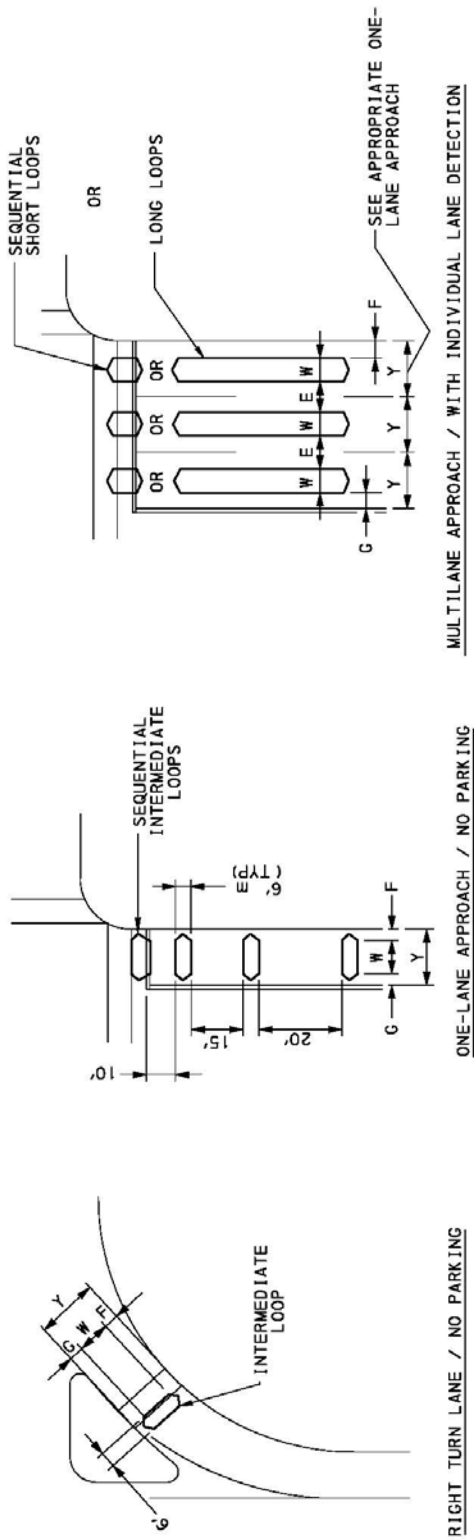


Exhibit 7-2 Detection Location Details for Various Approach Widths



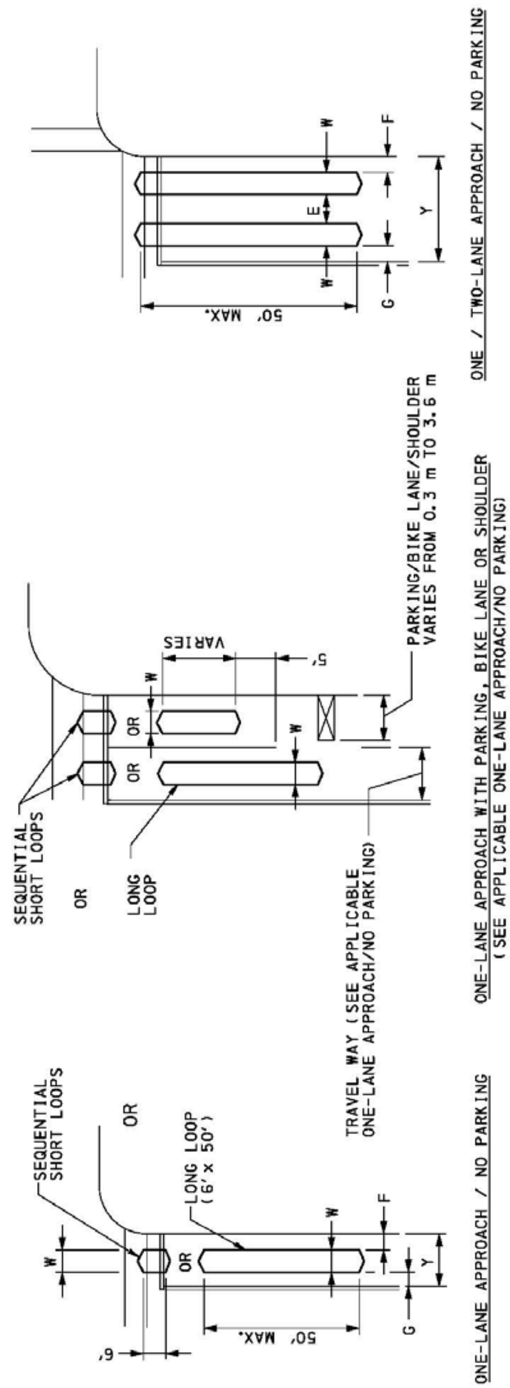
RIGHT TURN LANE / NO PARKING
ONE LANE APPROACH / NO PARKING

Y	G	W	F
APPROACH WIDTH	DISTANCE FROM LANE LINE OR ISLAND CURB TO LOOP	WIDTH OF LOOP	DIST. FROM CURB OR EDGE OF PAVEMENT TO LOOP
14'	4'	6'	4'
15'	4'	7'	4'
16'	4'	8'	4'
17'	4'	9'	4'
18'	4'	10'	4'
19'	4'	11'	4'
20'	4'	12'	4'
21'	4'	13'	4'
22'	4'	14'	4'
23'	4'	15'	4'
24'	4'	16'	4'
25'	4'	17'	4'
26'	4'	18'	4'

MULTILANE APPROACH / WITH INDIVIDUAL LANE DETECTION

Y	G	E	W	F
APPROACH WIDTH	DIST. FROM CENTERLINE TO LOOP	DIST. BETWEEN LOOPS	WIDTH OF LOOP	DIST. FROM LOOP TO CURB OR EDGE EDGE OF ROAD
10+10+10 = 30'	3'	5'	5'	2'
11+11+11 = 33'	3'	5'	6'	2'
12+12+12 = 36'	3'	6'	6'	3'

Exhibit 7-3 Detector Location Details for Various Approach Widths



ONE / TWO-LANE APPROACH / NO PARKING

Y	G	E	W	F
18'	2'	2'	6'	2'
19'	3'	2'	6'	2'
20'	3'	2'	6'	3'
21'	3'	3'	6'	3'
22'	3'	4'	6'	3'
23'	3'	5'	6'	3'
24'	3'	6'	6'	3'
25'	3'	6'	6'	4'

FOR 26' LANES, THREE 6' LOOPS SHOULD BE USED WITH 2' SPACING BETWEEN THEM AND KEEPING 2' BETWEEN THE LOOP AND CURB OR EDGE OF PAVEMENT AND 2' BETWEEN THE LOOP AND LANE LINE OR ISLAND CURB.

ONE-LANE APPROACH / NO PARKING

Y APPROACH WIDTH	G DISTANCE FROM CENTERLINE TO LOOP	W WIDTH OF LOOP	F DIST. FROM CURB OR EDGE OF PAVEMENT TO LOOP
9'	3'	4'	2'
10'	3'	5'	2'
11'	3'	6'	2'
12'	3'	6'	3'
13'	3'	7'	3'

Loop Sensor and Saw Cut

Before design of the sensor, a field investigation should be made to determine the condition of the roadway pavement. If the pavement is badly damaged (rutted, cracked, broken, etc.), the pavement should be reconstructed prior to installing a sensor.

Junction Boxes

An inductive loop sensor should have a junction box located in its immediate vicinity out of the roadway area. Sensors shall be provided with a length of 1-inch diameter rigid conduit from the junction box or pole base just beyond the curb or edge of roadway under the finished pavement. The conduit carries the sensor wires from the saw slot in the roadway to the junction box or pole base, where the sensor wires are spliced to the lead in wires. Refer to TC-8806 (Detectors) of Publication 148 for more details on junction box and conduit use with inductive loop detectors.

7.2 Pedestrian Detection

Pedestrian detectors are devices that notify the controller of the presence of pedestrians.

Push Buttons

The pedestrian push button is the typical detection device used for actuation of pedestrian timings. The device consists of a housing of high visibility with a 2-inch minimum diameter button. Optional features can include a latching LED confirmation light and confirmation tone. Push buttons should be located horizontally and vertical on a traffic signal support or an exclusive push button pole nearest to the crosswalk in accordance with the MUTCD, Chapter 4E, and TC-8803 of Publication 148.

If a history of visually impaired pedestrians is documented, the use of Accessible Pedestrian Signals (APS) should be provided. An APS can include locator tones, spoken WALK messages, and/or vibrotactile indications to assist the impaired pedestrians in safely traversing the intersection.

Consult the MUTCD sections 4E.09 to 4E.13 for guidance on APS.

Passive Pedestrian Detection

Detection systems that passively sense the presence and walking speed of pedestrians may be considered. Ensure that these systems have been approved by PennDOT before proceeding with their use.

CHAPTER 8. ELECTRICAL DISTRIBUTION

The purpose of this chapter is to familiarize the designer with the standard practices for electrical distribution above and below ground for signal systems. Publication 149, Chapter 8 discusses many of the items particular to signal design in Pennsylvania. The remainder of this chapter is a handout from Chapter 8 of Publication of 149.

8.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 8 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 8 - ELECTRICAL DISTRIBUTION

8.1 Controller Placement

Of prime importance is the prevention of potential damage or knockdown of controllers by vehicular traffic. Controllers should not be located near the curb return or on channelization islands. Consider the position of the controllers door, it should not open into traffic. Additional considerations, such as the location of electrical service or communications lines and visibility of signal operations from the controller, should be taken into account. Ideally, maintenance personnel should be able to view at least one of the traffic signal indications for all operating phases while setting the timing or performing other tasks in the controller cabinet. Contact with the utility companies shall be made to determine how electric service will be provided, and field verification should be made to determine the design aspects of the electric service at the intersection location. Controller configuration shall be in compliance with Publications 148 and 408.

8.2 Conduit

Conduit Layout

The conduit layout should be designed to minimize difficulty in construction as well as maintenance of the traffic signal. Conduit runs should be run as straight as possible to minimize material and construction costs and to ease pulling the cables. The runs should also be routed around utilities. Since portions of the roadway may need to be closed during trenching for the conduit, major streets should be crossed by conduit only once, when possible.

A conduit shall be provided from each pole or pedestal foundation to another foundation or junction box. Conduits passing beneath the roadway shall have a junction box at each terminus except at the last point of a cable run where the conduit may terminate in the pole base.

The conduit shall be laid out so that the traffic signal controller is located at or near the center of the conduit layout. This enables the creation of two separate wiring systems, each handling about half of the signals at the intersection.

A separate conduit shall be installed for the electrical service cable and for street lighting.

Size

In general, conduit sizes of 2-inch diameter or greater are to be used for purposes of signalization or interconnection. Use of 1-inch diameter conduits will be allowed for the routing of detector leads through the curb into a junction box and for detector lead-in runs of two or less to the controller cabinet. 1-inch diameter conduit also may be used for service leads. The required conduit size is determined by the number and sizes of cable to be contained in the conduit. In no case during the traffic signal design should a conduit be filled to more than 40 percent. The fill areas are determined by adding the cross sectional areas of all cables to be contained in the conduit and comparing it to the 40 percent fill areas of the conduit. See **Exhibit 8-1** and **Exhibit 8-2** of this publication for an example of this analysis.

Note: When conduit is to be placed beneath the roadway, consider using either conduit of a larger diamter or placement of a spare conduit for future expansion.

Exhibit 8-1 Conduit Fill Areas

	Conduit --- 40% fill areas, in^2			
Type	1 in	2 in	3 in	4 in
Non-metallic*	0.29	1.18	2.64	4.65
Metallic	0.34	1.34	2.95	5.09
Note: * use these values for design purposes				

Exhibit 8-2 Cable Areas

Number of Cables	Signal Cable Areas, in^2							
	#12 AWG				#14 AWG			
	3/c	5/c	7/c	Lead-in	3/c	5/c	7/c	Lead-in
1	0.145	0.212	0.273	0.116	0.107	0.152	0.180	0.093
2	0.290	0.424	0.546	0.232	0.214	0.304	0.360	0.186
3	0.435	0.636	0.819	0.348	0.321	0.456	0.540	0.279
4	0.580	0.848	1.092	0.464	0.428	0.608	0.720	0.372
5	0.725	1.060	1.365	0.580	0.535	0.760	0.900	0.465
Bare Copper Ground Wire - #8 AWG 1/c = 0.017 in^2								
Luminaire Cable #8 AWG 1/c = 0.058 in^2								
Coaxial Cable (RG-59/U) = 0.012 in^2								
Video Camera Power Cable - #16 AWG 3/c = 0.389 in^2								

Method of Installation

a) **Trench -** Conduits to be installed in developed areas may be installed by the open trench method. The trench shall be deep enough to provide a minimum depth of cover of 24 inches; a minimum depth of cover of 36 inches is recommended if conduit carries communications cable. Trenching shall meet the provisions of Publication 148 and Publication 408.

b) **Jacking -** In highly developed areas, under new pavements, or under major highways where the interruption of traffic is a critical concern, a jacking method (pre-approved by the Department) may be considered for the installation of conduit.

c) **Boring.** Directional boring may be considered as an alternative to "trench and backfill" and "jacking". The depth of borings should be below the existing roadway subgrade and should not cause any deformation of the roadway. For more information refer to Publication 14M, Section 954.3 (b).

8.3 Junction Boxes

Junction boxes are located at the juncture of two or more conduit lines. These boxes provide a point from where cables may be pulled through the conduit. All junction boxes shall meet the provisions of Publication 148 and Publication 408.

Description

All junction box installations of the various types consist of three basic components: box, cover, and coarse aggregate drain.

In paved areas, the cover shall be set flush with the finished grade of the sidewalk. In earth areas, it should be 1-inch above the surrounding grade.

Location

A junction box should be provided at the following locations:

a) On intersection corners where traffic signal poles are to be situated and underground cable runs continue to other supports.

b) Where detector sensors are spliced to lead-in wire.

c) In extremely long conduit runs, greater than 330 feet.

The facilitation of maintenance should be kept in mind when locating junction boxes. To this end, junction boxes in roadway areas and in driveway areas should be avoided.

Types

Several types of junction boxes are detailed in Publication 148 and Publication 72M (RC Standards). Publication 148 contains details for Type JB-26 and Type JB-27 junction boxes that are commonly used for traffic signals. The junction boxes detailed in the Publication 72M (RC Standards) [Type JB-1, Type JB-2, Type JB-11, Type JB-12] are used in general for highway lighting, but can be used for traffic signals if needed.

The following are guidelines to assist in the selection of junction boxes:

a) Type JB-26: Used for detector lead-in, only in areas not subject to vehicular traffic.

b) Type JB-27: Used for all other system distribution other than for detector lead-in, only in areas not subject to vehicular traffic.

c) Types JB-1 and JB-2: Used for all system distribution, only in areas not subject to vehicular traffic.

d) Types JB-11 and JB-12: Used for all system distribution in areas subject to vehicular traffic.

As a general rule, the total cross sectional area of conduit entering a junction box should not exceed 15% of the area of the junction box. When this amount is exceeded a larger box should be considered.

8.4 Wiring

Conductors

The size of all signal wire shall be determined utilizing the method shown in **Exhibit 8-1** and **Exhibit 8-2** of this publication; #14 AWG shall be the minimum size.

Cable Selection

The number of conductors to be used for signal head wiring is determined by the number of indications to be displayed by the signal.

Each indication requires two conductors: an ungrounded conductor and a grounded conductor (neutral). Neutral returns in a signal head may be spliced together, thus the total number of conductors required equals the number of signal sections plus one. For example, a three-section signal head requires five conductors; a pedestrian signal requires three conductors, etc.

Cables should be selected such that the various sizes are reserved for specific applications. The following wiring applications shall be adhered to:

Use	Minimum Conductor Size
Preemption Detector	3/c
Preemption Confirmation Light	3/c
Pedestrian Pushbutton	3/c
Pedestrian Signal	5/c
Three-Section Traffic Signal	5/c
Four-Section Traffic Signal	7/c
Five-Section Traffic Signal	7/c

Standardizing cable sizes for signal heads will yield at least one spare conductor for each signal. This will:

a) Reduce the number of different size cables to be purchased, which should result in reduced construction cost.

b) It allows for future expansion of the signal system to accommodate separate movements.

Consider providing a larger number of conductors to signal heads that may need to be replaced in the future with a signal head having more indications. For example, the left-most signal head on a mast arm may require a five-section signal head if a left-turn phase is anticipated in the future.

Wiring Method

Prior to determining the wiring required for a traffic signal design, the following must be prepared and completed:

a) Traffic signal layout with all signal heads numbered;

b) Traffic signal operation chart; and

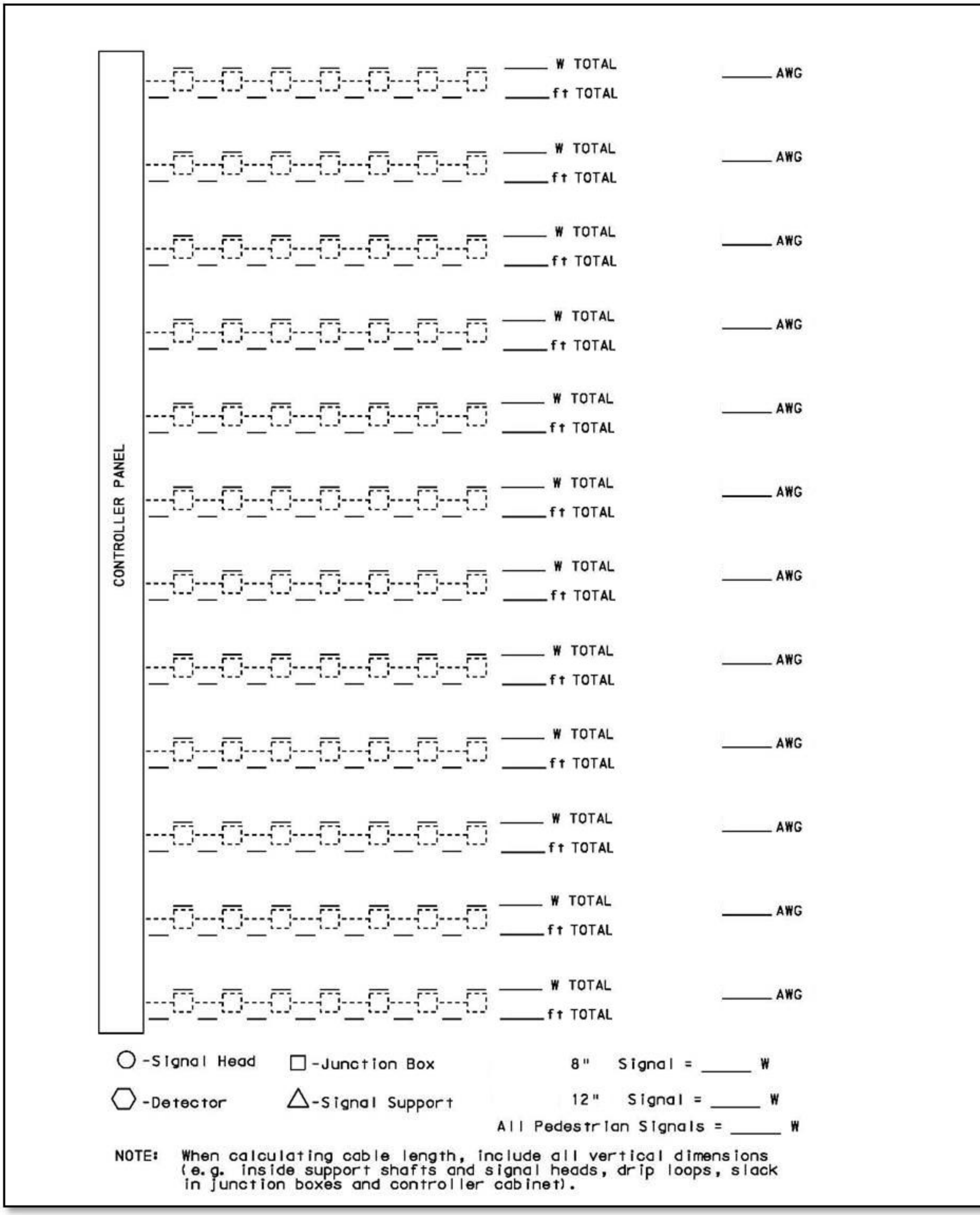
c) Conduit and junction box layout.

The following rules shall be adhered to when determining the required wiring:

a) Phase neutrals shall not be mixed;

b) Only those signals that display identical indications throughout the sequence of operations may have their wires terminated together.

Exhibit 8-3 Conductor Size Worksheet



Wiring Diagram

A schematic wiring diagram shall be prepared for each traffic signalization design location. This diagram shall show the controller, signal heads, detectors, pushbuttons, junction boxes as well as the required number, size, and types of wiring, and splices. An example of the diagram is illustrated in **Exhibit 8-5** of this publication.

Color Codes

The individual conductors in a signal cable shall be color coded. These codes, for up to a seven conductor cable, shall be used as follows:

Conductor	Color	Application
1	Black	Green Ball/Arrow, "WALKING PERSON" or WALK indication
2	White	Neutral
3	Red	Red, "UPRAISED HAND" or DONT WALK indication
4	Green	Reserved
5	Orange	Yellow Ball/Arrow
6	Blue	Green Arrow
7	White/Tracer	Yellow Arrow/Spare

Detector Wiring

Loop detectors are wired through two cables – a loop sensor and a lead-in cable.

The loop sensor is installed in pavement surfaces through a saw-cut and covered with a sealant. The sensor must also lead to the junction box via a trench through a 1-inch conduit. The size of the loop detector determines the number of turns in the pavement.

The lead-in cable is spliced to the leads of the loop sensor and routed, via conduit, to the controller cabinet. Three splicing alternatives are approved by the Department.

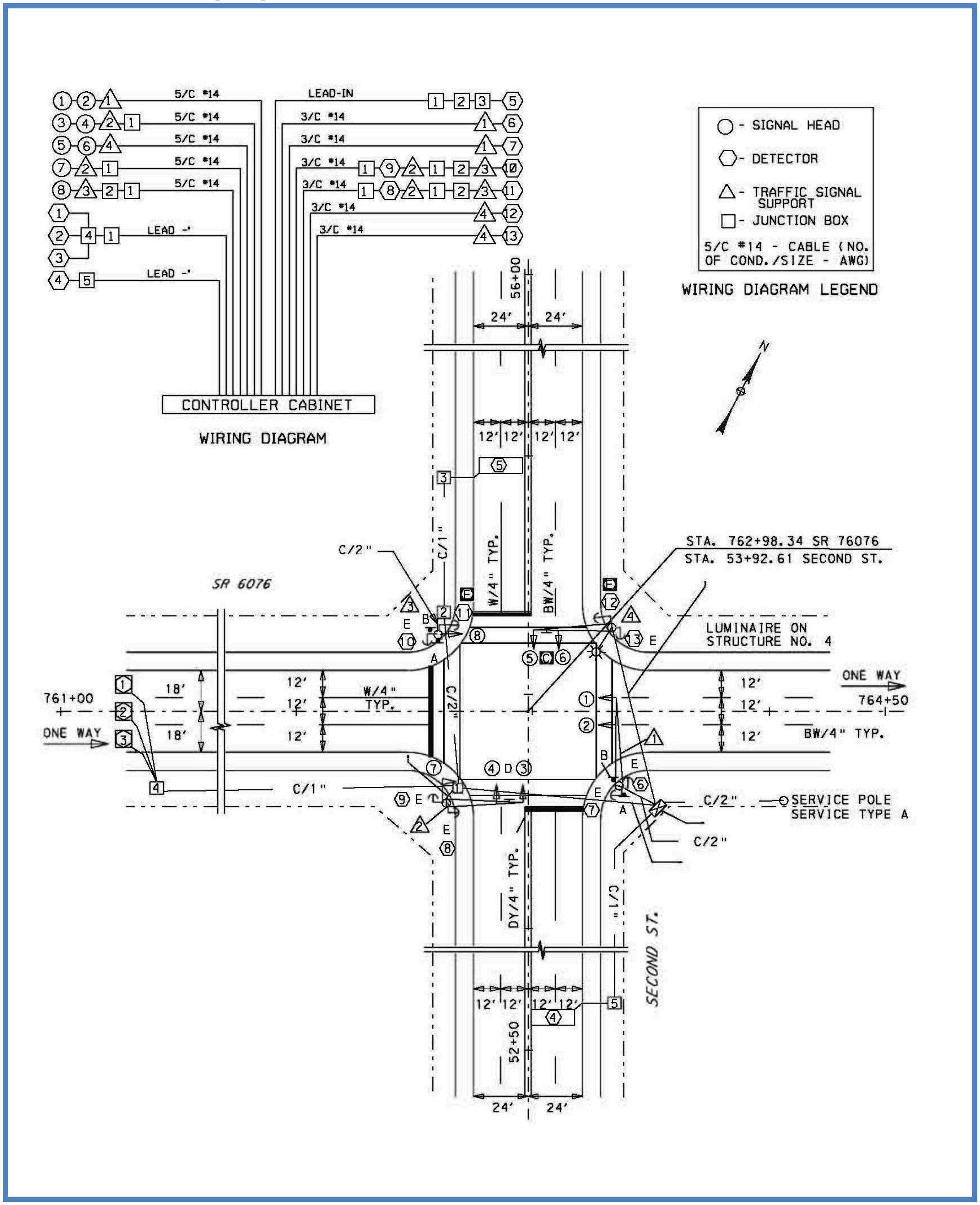
a) Alternative A: The sensor cables and the lead-in cable are soldered together then covered first with wire nuts then immersed in an epoxy sealant.

b) Alternative B: The sensor cables and the lead-in cable are connected via insulated compression connectors then covered in two alternating layers of electrical tape and sealant.

c) Alternative C: The sensor cables and the lead-in cable are connected via insulated compression connectors then covered in a moisture-proof splicing kit.

Refer to Publication 148, TC-8806 for standard Detector drawings. For video or other methods of detection, follow the manufacturer's recommended installation procedures.

Exhibit 8-4 Wiring Diagram



8.5 Electric Service

Three methods of providing electricity to the intersection are available.

a) Type A. Service is initially provided to a service (utility) pole. From the service pole, the service cable is routed through a 2-inch (minimum) conduit to the controller cabinet.

b) Type B. Applicable for both pole mounted or base mounted cabinets. Service is initially provided to a traffic signal support. From the signal support, the service cable is routed through a 2-inch (minimum) conduit to the controller cabinet.

c) Type C. Service is provided directly from the utility to the controller cabinet via a 2-inch (minimum) conduit.

The selection of type should consider several factors such as area (urban, suburban, rural), right of way, and the proximity of controller cabinet to utility. Verify with the utility whether the intersection needs to be metered or unmetered. Refer to Publication 148, TC-8804 for standard Electrical Distribution drawings.

CHAPTER 9. INTERSECTION LIGHTING

The purpose of this chapter is to provide guidance as appropriate for intersection lighting when installing traffic signals. Each proposed signalized intersection should be evaluated to determine whether intersection lighting is needed. Once a determination to install intersection lighting has been made, the appropriate lighting level should be established by referring to the design value tables in the latest American Association of State Highway Transportation Official's (AASHTOs) Roadway Lighting Design Guide. The design value should be the sum of the recommended values for the two intersecting roadways. Additionally, Publication 13M (Design Manual 2), Chapter 5, Lighting should be evaluated appropriately. For complicated intersections, a qualified lighting engineer should design and/or review the intersection lighting to ensure adequate lighting levels are provided.

9.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 9 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

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CHAPTER 10. PREEMPTION AND PRIORITY CONTROL

This chapter relates to preemption and priority control at signalized intersections. Preemption and priority control is the transfer of the normal control of signals to a special signal control mode, i.e., to accommodate emergency vehicles.

Publication 149 is the official signal design manual for the Department. This chapter includes the entire Chapter 10 from the Pub. Be sure to check for updates to Publication 149 for up-to-date information.

10.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 10 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

In addition to the materials indicated throughout this chapter, please consult the MUTCD, Section 4D.27.

CHAPTER 10 - PREEMPTION AND PRIORITY CONTROL

In addition to the materials indicated throughout this chapter, please consult the MUTCD, Section 4D.27.

Systems in which traffic control signals are preempted by an approaching emergency vehicle shall be designed and installed to provide a fail-safe indication to the driver of the approaching emergency vehicle when the equipment has preempted the traffic signal at that intersection. The fail-safe indication shall be a flashing white light on the street or approach on which the emergency vehicle is approaching.

Traffic signals operating during preemption conditions should be operated in a manner designed to keep traffic moving. The stopping of all traffic by the display of a steady All-Red is prohibited, except during normal clearance intervals.

10.1 Emergency Vehicle Preemption (EVP)

Types

Currently, emergency vehicle preemption systems use either optical, acoustic, or radio with global positioning system (GPS) technologies. When considering emergency vehicle preemption systems, it is important to evaluate the pros and cons of the various types of PennDOT-approved systems. Since emergency vehicles may cross municipal borders, it is also important to determine the type of preemption systems that adjacent municipalities use or plan to use in order to ensure the desired regional interoperability.

Optical Preemption Systems

Optical preemption systems have three basic components: 1) emitters that send the signal from the emergency vehicle to request the preemption; 2) detectors that receive the signal and send it to the controller; and 3) controller cards that process the signal, determine its validity, and initiate the preemption of all other signal functions. The emitters used in optical systems use light to inform the detector that a call has been placed at the signalized intersection.

Acoustic Preemption Systems

Acoustic preemption systems detect the sound from the siren of an emergency vehicle. Acoustic preemption systems do not require an optical emitter on the emergency vehicle, but it is desirable that all the types of sirens used by emergency vehicles be tested and the system be calibrated to help ensure that the desired performance is achieved.

Radio with Global Positioning System (GPS) Preemption Systems

Radio with GPS preemption systems have three basic components: 1) emitters that send the signal via radio from the emergency vehicle to request the preemption; 2) detectors that receive the signal and send it to the controller; and 3) controller cards that process the signal, determine its validity, and initiate the preemption of all other signal functions. The GPS feature monitors the movement of the approaching emergency vehicle and initiates the preemption phasing accordingly.

Operation

Emergency vehicle preemption may occur during any interval of the normal controller operation. Depending upon the direction of travel of the emergency vehicle, one of the following phases (using NEMA phases) will be displayed: Phase 1+6, 2+5, 3+8, or 4+7. The system shall provide service on a first-come, first-serve basis. Once the first priority vehicle calls the system, it shall prevent other preemptive vehicles from entering calls until the first emergency vehicle releases control and clears the intersection.

The transition into and out of preemption as a result of a preemptive call being received during any interval of traffic signal operation shall be clearly defined in the Movement, Phasing, and Sequence Diagram; Emergency Preemption Phasing Diagram; and associated notes on the traffic signal permit. Care should be taken to avoid yellow traps, if practical. During the transition to preemption, the controller unit may stay in a normal sequence phase if that phase is also defined as a preemption phase. For example, if the traffic signal is in phase 1+6 green and that phase is the direction from which the preempting vehicle is approaching, the controller may stay in phase 1+6 without going through selective clearances.

Upon termination of the preemption phase, the controller goes to the pre-designated post preemption phase, then to normal "Phase Next" operation. Four options are available within most controllers in determining the post preemption phase:

a) Go to Exit Phase: The preemption phase and the post preemption phase may be as follows:

Preemption Phase	Post Preemption Phase
1+6	2+6
2+5	2+6
4+8	2+6
2+6	4+8
3+8	4+8
4+7	4+8

As an alternative, the post preemption phase would be the major street green.

b) Go to Next Demand: The post preemption phase may be the phase immediately after the preemption phase during normal operation.

c) Resume Interrupted Sequence: The post preemption phase will be the phase that occurred before the preemption phase.

d) Exit to Coordination: The post preemption phase will be the phase that would have occurred to keep the signal in coordination within the system.

10.2 Preemption Systems

Rail

Consult chapter 19 of this publication and the MUTCD, Chapter 8.

Where the distance between a traffic signal and a highway-rail grade crossing is less than 300 feet, rail preemption should be utilized to help avoid a potential collision between a vehicle which is queued on the tracks and the rail utility. An interconnection between the rail utility and the controller cabinet will be necessary. Rail preemption shall supersede emergency preemption.

Design of the rail preemption system involves determining the amount of time a queue of vehicles needs to clear the tracks before transferring right-of-way to the rail. The "Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings," (*see Appendix D*) adopted by PennDOT from the Texas Department of Transportation, should be utilized to calculate the proper clearances and to provide the rail utility with the correct distance for placing its actuators on its tracks. Typically, while the signalized intersection is preempted by the railroad, a non-conflicting phase is active. As provided within Publication 46, PUC coordination is required for all railroad preemption systems.

Transit

Transit priority preemption may be used for buses or light-rail services where the traffic signal can truncate opposing phases or extend phases concurrent with the bus/light-rail vehicle at a traffic signalized intersection. A predetermined amount of time, typically 5-15 seconds, shall be established. Transit priority shall not supersede emergency preemption. The effectiveness of transit priority should be evaluated and recommended in an engineering study and approved by the appropriate District Traffic Engineer prior to considering deployment.

Queue

Where queue spillback is a concern and deemed necessary to address with signal operations, queue preemption may be utilized. A detection zone should be utilized between the stop bar and the theoretical gore. If the detector is continuously occupied for a predetermined amount of time the signal may be preempted and the phase of concern will be activated. The detection zone location and occupancy actuation time should be approximated by factoring in the estimated queue discharge rate, vehicle headways, and average vehicle arrival rate so as to avoid the back of queue reaching the point of conflict. Typically, queue preemption systems are used at the end of limited access ramp sections where a concern with queue vehicles affecting the limit access facility exists.

CHAPTER 11. SYSTEMS

This chapter discusses a traffic signal and its design within a traffic signal system. A traffic signal system is defined as two or more traffic control signals operating in coordination with each other.

Refer to Publication 149 (portions included as a handout at the end of this chapter), Publication 46 and the Introduction to Traffic Signals in Pennsylvania training manual for additional details.

11.1 Coordinated Systems

11.1.1 Cycle Length

The cycle length is the total time to complete one sequence of signalization around an intersection. In an actuated controller unit, a complete cycle depends on the presence of calls on all phases. In a pre-timed controller unit (see Chapter 3), it is a complete sequence of signal indications.

A detailed network analysis should be performed using a software package such as Synchro or TRANSYT for cycle length determination in a coordinated system. The use of computer models allows for multiple iterations of varying cycle combinations to determine the optimum signal timing parameters.

11.1.2 Signal Timing Intervals and Splits

The sum of the green, yellow, and all red intervals typically defines an individual phase **split**. A split is the segment of the cycle length allocated to each phase that may occur (expressed in percent or seconds).

The primary considerations that must be given to vehicle split times are as follows:

- ✓ The phase duration must be no shorter than some absolute **minimum time**, such as 5 to 7 seconds of green plus the required clearance interval. If pedestrians may be crossing with this phase, their crossing time must also be considered and included in the minimum phase length.
- ✓ A phase must be long enough to avoid over saturating any approach associated with it. Too short a time causes frequent **cycle failures** where some traffic fails to clear during its phase.
- ✓ A phase length must not be so long that green time is wasted and vehicles on other approaches are delayed needlessly.
- ✓ Phase lengths should be properly designed to efficiently balance the cycle time available among the several phases, not just "equitably" between, say, north-south and east-west.

11.1.3 Offset

The **offset** is the time relationship, expressed in seconds or percent of cycle length, determined by the difference between a fixed point in the cycle length and a system reference point.

Proper determination and application of intersection offsets provide for the efficient movement of platoons through multiple intersections during the green indication. Properly timed offsets can significantly reduce delay and improve driver satisfaction with the system timing.

11.1.4 System Concept

A system may be defined as an arrangement or combination of interacting or interdependent parts which form a unified whole serving a common purpose. The system concept as related to traffic signal control includes the methods, equipment, and techniques required to coordinate traffic flow along an arterial or throughout an area.

System Objective

The major objective of a traffic control system is to permit continuous movement and/or minimize delay along an arterial or throughout a network of major streets. This involves the selection, implementation, and monitoring of the most appropriate operational plan. Basically, a traffic signal system provides the appropriate and necessary timing plans for each intersection in terms of individual needs as well as the combined needs of a series of intersections.

Relationship of Timing Plans to Traffic Control

In the system concept, a timing plan is defined by a combination of control parameters for one or more intersections based upon an analysis of demand. Timing plans can be provided as a function of equipment at the local intersection, the central control point, or both. Timing plans consist of:

1. *A system cycle*. A specific cycle length is imposed throughout the system covered by the timing plan.
2. *Split*. All intersections in the system have defined splits which are the apportionment of the cycle to the various phases present at that intersection.
3. *Offset*. Each intersection has a unique offset. The offset is the relationship of the beginning of the main street green at this intersection to a master system base time. Offsets are generally expressed in seconds. Properly established offsets along a street can potentially provide for smooth traffic flow without stopping.

Basis of Selecting Timing Plans

The selection parameters which define timing plans include:

1. *Historic Data.* Time of day information compiled from traffic counts to reflect traffic volumes for a specified time of day (morning peak, midday, afternoon peak, etc.) and day of week.
2. *Current Data.* Real time, on-street volumes from traffic detection equipment.
3. *Special Data.* Special events, emergency route assignment, special right-of-way pre-emption (fire equipment, ambulances, buses, etc.).

11.1.5 Types of Traffic Signal Control Systems

Many combinations of methods, equipment, and techniques can comprise a traffic signal control system. Generally, these systems fall into the following basic types.

Time-Based Coordinated (TBC) System

This form of coordination uses non-interconnected controllers with auxiliary devices called time-based coordinators. These devices use the power company supplied frequency to keep time very accurately. Various timing plans can be established with time of day and day of week plan changes. Since all intersections use the same power source, the time-based coordinators provide coordination without physical interconnection.

Global Positioning System (GPS) receivers have been used for several years to provide a clock sync to ensure the TBC is maintained.

Interconnected Pre-Timed System

This type of system was originally developed for electromechanical controllers, but can also be used with some of the newer controllers. Local intersections are physically interconnected (usually by a 7-wire cable) to ensure coordinated operation. The system provides automatic re-synchronization should a signal go “out of step.” The number of timing plans is a function of the number of dials and the number of offsets and splits per dial; the most common system consists of a three-dial, three-offset, one-split combination. Timing plans are normally selected by a time clock or time dependent programming device. The local controller for one intersection may act as master controller for the system.

Traffic Responsive System

Basically, this is an interconnected system using a master controller for pattern (cycle/offset/splits) selection. Traffic detectors are used to sample directional volumes and detector occupancy. Volume and occupancy metrics determine which of the available patterns is selected (i.e., inbound, outbound, or average) based on predetermined thresholds. The master controller may be an analog or a digital computer.

Interconnected Actuated Systems

Generally, a small system with a master-slave relationship (i.e., two or more fully- or semi-actuated local controllers with one acting as a system master and controlling cycle length for the other controllers). Offset capability is limited. A variation of this system uses a system master, coordinating units, and local actuated controllers. The master may be traffic responsive or a combination of time clocks.

Traffic Adaptive System

Traffic adaptive systems perform "real-time" adjustments to the cycle length, splits and offsets in response to traffic demand. Traffic adaptive systems require extensive detection inputs. Complete and accurate traffic flow data must be gathered, processed and communicated to the central computer.

11.2 Traffic Signal Timing Software

Chapter 12 of Publication 46 provides details on the accepted software tools used by PennDOT.

11.3 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 11 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 11 - SYSTEMS

The 2001 Traffic Control Devices Handbook published by the Institute of Transportation Engineers states:

"A traffic signal control system exists whenever two or more signals operate in a synchronous manner. The objective of a traffic signal control system is to improve the flow of traffic along a major street or throughout a network of streets. A traffic signal control major system consists of an appropriate signal-timing plan and the hardware components to implement that signal-timing plan. The signal-timing plan must satisfy traffic demand, traffic flow patterns and the geometrics that exist at each intersection and in the network as a whole.

Traffic signal control systems may be relatively small and simple or fairly large and complex. A system may merely consist of a series of intersections along a major street whose controller units are interconnected. Such a system's purpose is to move platoons of traffic without interruption along the major street. On the other hand, a system may consist of a network of streets whose intersection controller units are centrally controlled by a digital computer with two-way communication between the computer and the intersection controllers. The purpose of this type of system is to reduce the total amount of delay and the total number of stops occurring to all traffic in the network."

Refer to Chapter 3, Operational Requirements and Publication 46, Section 4.6, for information regarding traffic signal coordination, proper timing, and progression analysis procedures. Where the proximity between signalized intersections is such that traffic signal coordination is deemed appropriate and necessary, a system of traffic signals may be implemented. Historically, and currently, a reliable coordinated system can be achieved using a physical method of interconnection via some type of wiring or cable. More recently, technologies have become available that allow for the implementation of a system without physical means. The provision of traffic signals into a system is the focus of this chapter. Each type of system has its advantages and disadvantages that should be weighed by the designer while factoring in reliability, cost, and functionality.

11.1 Types

Time-Based Coordination (TBC)

The simplest form of coordination is the use of time-based coordination. The controller at each traffic signal must be equipped with an internal or external time clock to provide a point of reference (controller brands do not need to match). The primary disadvantage of TBC is that the time clocks may "drift" if not properly maintained. Over time small changes at each controller accumulate. Periodic resynchronization will be necessary. The use of GPS time clocks will generally eliminate this drift.

Interconnect

A communication link between two or more intersections has more long-term reliability for maintaining the coordination and efficiency of a system than TBC. Interconnect typically requires the use of a master controller, which can either act as a time clock synchronizer for all of the traffic signals in a system or send time-of-day patterns to each local controller. Methods of communication are discussed in *Section 11.3*.

Centralized/Closed Loop System

There are various types of centralized traffic signal systems that may be implemented. Types may range from large scale city grid systems that have proprietary customized software to smaller scale "off-the-shelf" PC-based arterial systems. A centralized system offers the capability to remotely monitor the individual intersection controllers, or groups of controllers. These systems are capable of communicating through a land line telephone drop or direct connection via fiber optic cable or wireless methods. The software is typically capable of viewing and editing timing patterns, viewing and storing traffic volumes, monitoring communication status, receiving maintenance alarms, etc.

Certain systems may offer traffic responsive program selections based on traffic demand. A group of pre-determined timing patterns may be stored in the system which can be selected based on traffic volume and occupancy thresholds.

Adaptive Signal Control

Adaptive signal control (ASC) is a type of traffic signal system that continually adjusts based on real-time traffic data in an attempt to provide the optimal traffic signal operation. Parameters, such as splits, permissives, and force-offs are adaptable within common controller brands; however, more advanced controllers are available. The use of ASC requires an extensive amount of detection to measure volume, occupancy, and/or queue lengths.

11.2 Design Considerations

Several factors should be considered when determining which type of system to use, including but not limited to:

a) Cost
b) Desired Functions
c) Operation and Maintenance
d) Corridor classification

TBC or a simple interconnect may be sufficient for isolated corridors with predictable traffic patterns. A centralized or closed loop system should be considered for major arterials and densely-populated areas that experience heavy volumes and daily volume fluctuations that may occur due to non-recurring congestion. Interconnected systems need to be monitored periodically to ensure that communications are operational. ASC should be considered as well for areas that experience major fluctuations in traffic demand, such as near interstates, shopping malls, sporting venues, etc. Buy-in and a financial commitment of operations and maintenance from the lead municipality must be obtained before proposing any type of system that requires periodic operations and maintenance.

11.3 Communications

Three modes of communications are typically used to interconnect signals within a system. Refer to *Section 953* (Traffic Signal Systems and Communications) of Publication 408 for specifics on the materials and construction methods.

Hard-wire Interconnect

Twisted-pair cable is generally installed in conduit between intersections.

a) **Advantages**

Least expensive method of physical interconnection, no additional equipment is required beyond the controller unit

b) **Disadvantages**

Conducts electricity which may cause lightning or power surge damage at multiple signal controllers

Fiber Optic Cable

Fiber optic cable can be installed aerially or in conduit between intersections. Care must be taken during design to specify the correct accompanying equipment as different types of fiber optic cable are available, i.e., single-mode vs. multi-mode, loose tube vs. tight buffered.

a) **Advantages**

Non-conductive (not susceptible to lightning strike travel), able to carry large amounts of data

b) **Disadvantages**

Cable difficult and exspensive to repair, accompanying equipment, and installation more expensive

Spread Spectrum Radio (SSR)

Communications between intersections is provided by a wide bandwidth frequency signal. Two frequency ranges are allowed, 902-928 MHz and 2.4 GHz, which do not require FCC licensing. An implementation survey will be required during design to determine if obstructions and/or roadway curvatures would require repeaters.

a) **Advantages**

No physical connection between intersections, lower cost

b) **Disadvantages**

Limited bandwidth compared to fiber, repeaters may be necessary.

Methods may be mixed within a system. For example, three intersections can be interconnected by fiber optic cable but a fourth may be interconnected by SSR due to an obstruction, such as a railroad overpass.

CHAPTER 12. UTILITIES

Coordination with utilities is essential for traffic signal construction projects. Aerial (overhead) utilities, such as electric, telephone, and cable lines, are typically attached to wooden utility poles. Underground utilities, such as gas, sewer, and water lines, can vary greatly in depth. All aerial and underground utilities must be verified and shown on the construction plans, and the location and depth of all traffic signal support foundations and conduit must be designed accordingly. Additional utilities, such as railroad crossings, must also be considered. Any time traffic signal equipment is installed under a crossing or attached to an overpass owned by a railroad, the PA Public Utilities Commission (PUC) must be contacted.

During design, any impact on existing utilities must be assessed. Relocation can be expensive and time-consuming. For major projects with utility relocation, it is strongly recommended that the new utility locations be identified during the design phase. Refer to Publication 16M (Design Manual Part 5 – Utility Relocation) for information on utility relocation procedures.

12.1 Handout from Publication 149

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CHAPTER 12 - UTILITIES

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12.1 Pennsylvania ONE-CALL System

PA Act 121 of 2008 as amended requires designers to contact the PA One Call System whenever excavation is expected. To contact the system, dial 8-1-1. The signal designer must follow the PA One Call System regulations and policies. The system's User's Guide states "The designer shall make a reasonable effort to prepare the construction drawings to avoid damage to and minimize interference with a facility owner's facilities in a proposed construction area." Consult the system's User's Guide and other information related to designer responsibilities at www.pa1call.org.

When utilities are marked in the field they should follow ANSI Standard Z535.1 (Common Ground Alliance Best Practices for Temporary Marking). The colors and designations of the markings will be as follows:

Color	Designation(s)
White	Proposed excavation
Pink	Temporary survey markings
Red	Electric power lines, cables, conduit and lighting cables
Yellow	Gas, oil, steam, petroleum, or gaseous materials
Orange	Communication, alarm or signal lines, cables or conduit and traffic loops
Blue	Potable water
Purple	Reclaimed water, irrigation and slurry lines
Green	Sewer and drain lines

12.2 PennDOT Utility Contacts

For Department projects that require utility clearances, **Exhibit 12-1** provides contact information for each district.

Exhibit 12-1 District Utility Contact List

District Utility Coordinator	Phone
District 1 Utility Coordinator	(814) 678-7088
District 2 Utility Coordinator	(814) 765-0449
District 3 Utility Coordinator	(570)368-4254
District 4 Utility Coordinator	(570) 963-4068
District 5 Utility Coordinator	(610) 871-4437
District 6 Utility Coordinator	(610) 205-6530
District 8 Utility Coordinator	(717)705-2681
District 9 Utility Coordinator	(814) 696-7214
District 10 Utility Coordinator	(724) 357-2827
District 11 Utility Coordinator	(412) 429-4949
District 12 Utility Coordinator	(724) 439-7142
Central Office Utility Coordinator	(717) 787-9661

12.3 Utility Information

Designers shall include utility locations on traffic signal construction plans. The presentation format shall follow Publication 14M (Design Manual Part 3 – Plans Presentation).

Utilities can be transmitted either aerially or underground. The lateral location as well as the height/depth is of importance when designing a traffic signal to avoid damage to the utility and the potential for interference.

Aerial

Overhead (aerial) cables are typically carried on wooden utility poles, which are owned and maintained by utility companies. Utility pole locations should be surveyed and shown on construction plans. It should be noted whether a pole is a joint pole or a non-joint pole. A joint pole will carry more than one facility (i.e., electric, telephone, and cable) while a non-joint pole is a dedicated pole with only one facility.

The utility pole carrying electrical service closest to the controller cabinet location should be selected for the electrical service point.

Underground

Several types of utilities, such as electric, potable water, and sanitary sewer, can be carried through conduit and pipes underground. A survey of manholes and junction boxes, as well as a PA One Call, is necessary to determine the location of all underground utilities. The depths of each utility will vary. Some projects may require Subsurface Utility Engineering (SUE).

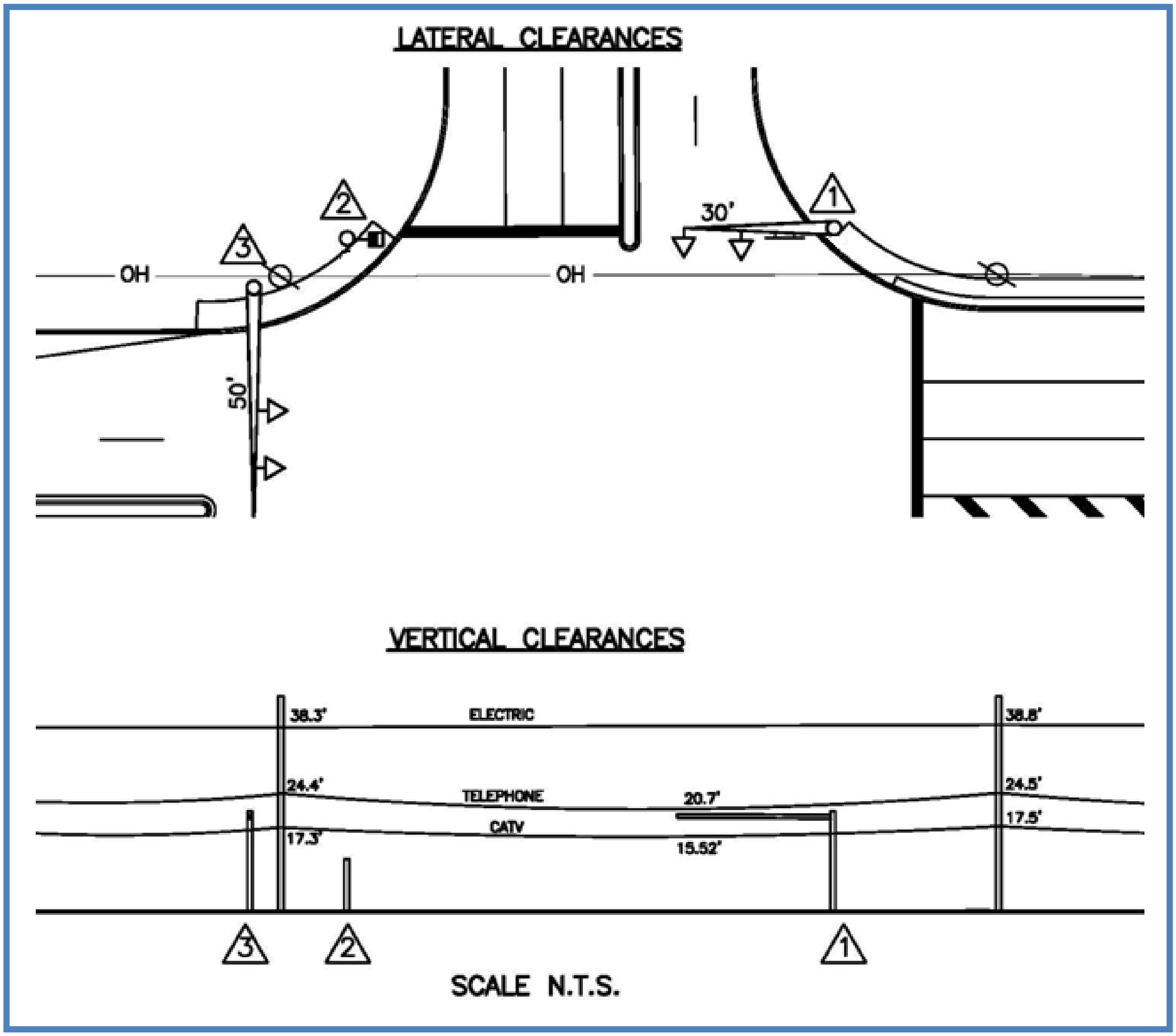
12.4 Required Clearances

Refer to the National Electrical Safety Code (NESC), dated 2007 or as amended, for national clearance and installation standards. The standards of the local utilities present should also be referred to as they may be more stringent than the NESC. The lateral clearances from the utility lines to any traffic signal equipment must be met as well as vertical clearances between utility lines and mast arms and luminaries.

12.5 Overhead Clearances

Clearance requirements are established in regards to equipment installed near overhead utilities. An Overhead Wire Clearance Plan of the lateral and vertical clearances may be prepared as an optional design tool. Refer to Exhibit 12-2 for an example.

Exhibit 12-2 Overhead Wire Clearance Plan



CHAPTER 13. PAVEMENT MARKINGS AND SIGNS

Pavement markings are an integral part of the traffic signal control system.

13.1 Handout from Publication 149

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CHAPTER 13 - PAVEMENT MARKINGS AND SIGNS

13.1 Pavement Markings

Provide pavement markings (such as centerline, channelization, stop lines, crosswalk lines, and lane control markings) as may be required to properly direct and control the flow of vehicular and pedestrian traffic through the signalized intersection.

Pavement markings shall meet the provisions of Publication 35 (a.k.a. Bulletin 15), Publication 46, Publication 111 (TC-8600 Series), Publication 212, and Publication 408.

For additional information consult the MUTCD Part 3, Markings.

13.2 Signs

Signs provide proper direction and control the flow of vehicular and pedestrian traffic through the signalized intersection. Examples of such direction or control include turn prohibition, lane control, one-way, overhead street name, and pedestrian control. Refer to the MUTCD, Part 2, Signs for guidance on selection and placement of signs. All signs shall also meet the provisions of Publication 35 (a.k.a. Bulletin 15), Publication 46, Publication 111 (TC-8700 Series), Publication 212, Publication 236, and Publication 408. Note that the series numbers in Publication 236 supersede those of the MUTCD.

13.3 Illuminated Signs

Illuminated signs may be used where an engineering study shows that reflectorized signs will not provide effective performance or where extraneous light makes it difficult to read reflectorized signs.

The traffic control signal shall be given dominant position and brightness to assure its target priority in the overall display.

Changeable message or blank-out signs may be installed where the message is applicable at specific times.

Internally illuminated street name signs may be used as preferred by the local municipality. Please refer to Publication 408, sections 936 and 1103.

For more information consult the MUTCD, Section 2A.07, Retroreflectivity and Illumination.

CHAPTER 14. TEMPORARY TRAFFIC SIGNALS

Temporary traffic signals should only be used in situations where temporary traffic control signals are preferable. Refer to the MUTCD, Section 6F.84, Temporary Traffic Control Signals and Publication 213 for further guidance on when temporary traffic control signals are preferable to other means of traffic control.

14.1 Handout from Publication 149

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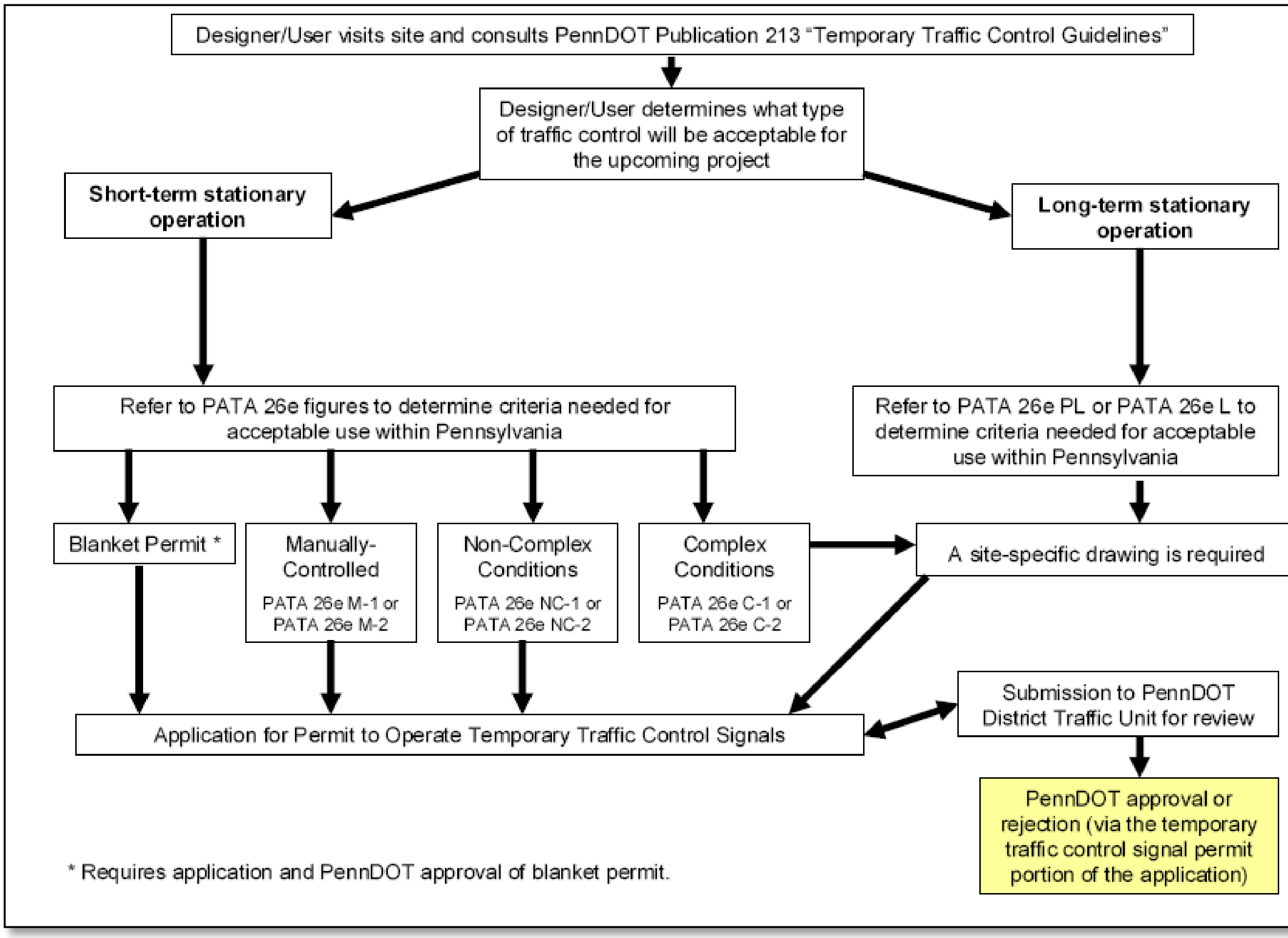
14.1 Temporary Traffic Control Signal Requirements and Timeframes

Exhibit 14-1 Temporary Traffic Control Signal Requirements and Timeframes *(from PATA 26e PL)*

Type of Application	Publication 213 Figure	PennDOT Approval Required Prior to Use	Advance Site Visit Required by User	Application Required	Site-Specific Drawing Required	Deadline for District Receipt of All Required Materials
Long-Term Stationary Operation Fixed Supports	PATA 26e L	X	X	X	X	At least 15 working days prior to desired usage
Long-Term Stationary Operation Trailer-Mounted Portable Traffic Control Signals	PATA 26e L	X	X	X	X	At least 15 working days prior to desired usage
Short –Term Stationary Operation Pedestal-Mounted Portable Traffic Control Signals Manually -Controlled	PATA 26e M-1	X	X	X		At least 3 full working days prior to desired usage
Short –Term Stationary Operation Trailer-Mounted Portable Traffic Control Signals Manually -Controlled	PATA 26e M-2	X	X	X		At least 3 full working days prior to desired usage
Short –Term Stationary Operation Pedestal-Mounted Portable Traffic Control Signals Non-Complex Conditions	PATA 26e NC-1	X	X	X		At least 3 full working days prior to desired usage
Short –Term Stationary Operation Trailer-Mounted Portable Traffic Control Signals Non-Complex Conditions	PATA 26e NC-2	X	X	X		At least 3 full working days prior to desired usage
Short –Term Stationary Operation Pedestal-Mounted Portable Traffic Control Signals Complex Conditions	PATA 26e C-1	X	X	X	X	At least 15 working days prior to desired usage
Short –Term Stationary Operation Trailer-Mounted Portable Traffic Control Signals Complex Conditions	PATA 26e C-2	X	X	X	X	At least 15 working days prior to desired usage
Short –Term Stationary Operation Pedestal-Mounted Portable Traffic Control Signals Blanket Permit		X	X	X		At least 15 working days for initial blanket permit request; at least 3 full working days prior to each usage under the blanket permit
Short –Term Stationary Operation Trailer-Mounted Portable Traffic Control Signals Blanket Permit		X	X	X		At least 15 working days for initial blanket permit request; at least 3 full working days prior to each usage under the blanket permit

14.2 Process for Obtaining PennDOT Approval to Use Temporary Traffic Control Signals



14.3 Blanket Permits

What is a blanket permit?

a) For repeat users of portable traffic control signals, PennDOT's appropriate Engineering District Office may issue a blanket temporary traffic control signal permit covering multiple locations and dates of operation for up to a one-year period. This action will only be considered by PennDOT if that user has properly used portable traffic control signals in a safe and efficient manner on three or more past deployments without problems and in compliance with PennDOT requirements.

b) PennDOT's Bureau of Maintenance and Operations (BOMO) will be involved in the blanket permit process. Although permits are issued by the appropriate Engineering District Office, BOMO will participate in the evaluation process to determine whether a particular portable traffic control signal user can be issued their initial blanket permit in each Engineering District. BOMO will provide the overall blanket permit approval number, participate in any blanket permit revocation proceedings, and will keep track of users who have been issued blanket permits statewide.

What types of operations can be covered by a blanket permit?

a) Blanket permits can only be issued for short-term stationary operations (manual control or non-complex conditions) that satisfy the criteria and provisions of PATA 26e M-1, PATA 26e M-2, PATA 26e NC-1, or PATA 26e NC-2, except for emergency work as defined in PennDOT Publication 212. See Note 2 of each figure.

b) Blanket permits **cannot** be used for portable traffic control signal usage involving either long-term operations or short-term operations with complex conditions that are governed by PATA 26e PL, PATA 26e C-1, or PATA 26e C-2.

Who can apply for a blanket permit?

a) Any repeat user of portable traffic control signals who agrees to the responsibilities, terms, and conditions as outlined herein.

b) The blanket permit will be issued to up to two specific individuals (representing a company), and not to companies in general.

What are the roles and responsibilities of the blanket permittee?

a) Responsible for the proper installation, maintenance, and operation of the portable traffic control signal system as specified in Publication 213 and the temporary traffic control signal permit.

b) Work closely with the work crew to provide safe and proper operations as specified in Publication 213 and the temporary traffic control signal permit. Safety will be strictly enforced, and will not be compromised when using the devices.

c) Assist the work crew with Publication 213 and temporary traffic control signal permit requirements for portable traffic control signal usage.

d) Provide technical and expert assistance on the use of the devices before, during, and after deployments to the contractors' personnel.

e) Take responsibility to ensure that the devices are working properly.

f) Approved products as specified in Publication 35 (Bulletin 15) must be used.

g) Ensure the upkeep of the devices to PennDOT specifications and requirements maintained by the Bureau of Maintenance and Operations (BOMO).

h) Provide documentation, satisfactory to PennDOT, showing that the individual successfully completed a training course given by the manufacturer on the operation of the portable traffic control signal system that is being deployed under the blanket permit.

i) Ensure proper all-red clearance intervals and yellow change intervals are used as specified in Publication 213 and the temporary traffic control signal permit.

j) Ensure appropriate green intervals are used based on traffic conditions. Ensure this is evaluated several times a day, and all changes should be documented.

k) Ensure that good records are kept of any changes during the operation of the devices.

l) Ensure that proper documentation is maintained on-site (including the temporary traffic control signal permit, Publication 213, etc.).

m) Develop and document a contingency plan by the permittee prior to the deployment of the devices to establish procedures in the event of device failure or malfunction, or in the event of changing conditions or unforeseen circumstances.

n) Provide the initial programming and the initial monitoring of the portable traffic control signals each day. All changes during the day should be made under the direction of the permittee and documented.

o) Be on-site at the start of signal usage each day. Provide emergency protocols and a contingency plan to address situations involving device malfunctions or changing conditions. Also, provide a direct number whereby the blanket permittee can be contacted at all times during signal usage.

p) Provide instructions to the work crew about proper removal procedures and how to place devices into a flash mode before going dark.

q) Visit the site in advance to ensure that proper usage can be achieved at the location of the upcoming deployment.

r) Continue to follow the appropriate processes outlined in Publication 213 for obtaining PennDOT approval to use portable traffic control signals. The deadline for PennDOT District Office receipt of all required materials for the blanket permit request is at least 15 working days prior to the first desired usage date. Thereafter, required materials must be received by the appropriate District Office at least 3 full working days prior to each usage under an established blanket permit.

s) Coordinate yearly with PennDOT's Central Office and District Offices to ensure proper installations are occurring. Also, this will allow for a working relationship where the blanket permittee will be up-to-date with respect to the latest requirements and guidance documents.

What is the process/procedure to follow if an individual wants to be considered as a future blanket permittee?

a) Submit a written request to BOMO and the appropriate Engineering District(s) identifying the individuals seeking to be evaluated for future blanket permit consideration. Indicate the Engineering Districts where blanket permit consideration is being sought. Clearly indicate acceptance of the blanket permittee roles and responsibilities as outlined herein. Provide written documentation from the manufacturer of each portable traffic control signal system that will be deployed indicating that each individual seeking a blanket permit has successfully completed a training course given by the manufacturer on the operation of that signal system.

b) After receipt of the written request, PennDOT will contact the applicant to discuss the evaluation process and associated expectations. A series of successful trial deployments will need to be completed.

c) The appropriate processes outlined in Publication 213 for obtaining PennDOT approval to use portable traffic control signals must be followed for the trial deployments. Failure to do so may result in rejection of the trial deployment.

How many successful trial deployments must be completed before obtaining a blanket permit?

a) The initial application will begin the evaluation of the trial deployments. Previous deployments will not be considered during the blanket permit evaluation.

b) A minimum of three proper deployments by the individual desiring to be a future blanket permittee, with at least one proper deployment in each Engineering District where a blanket permit is desired.

c) PennDOT will allow a maximum of two individuals from the same company to be evaluated on each trial deployment for the purposes of being considered as a future blanket permittee.

d) BOMO will be actively involved in monitoring the trial deployments, and feedback received from District Office personnel, the work crew, the supplier/manufacturer, and others will be considered.

Upon successful completion of the trial deployments, what are the next steps?

a) PennDOT will document all comments and advise the applicant of successful completion of the trial deployments.

b) BOMO will work with District Office personnel to ensure that a blanket permit is issued to applicants that fulfill requirements.

What about blanket permit revocation?

a) A blanket permit must be renewed each year.

b) A blanket permit can be revoked at any time for poor performance by the Engineering District. BOMO will be involved in any revocation proceedings.

c) If a blanket permit is revoked, that individual will not be allowed to submit for a blanket permit application for at least one year. Future submissions should follow the same procedures as a first-time applicant.

14.4 Guidelines for the Selection of Temporary Traffic Control Signals in Work Zones

For information consult the [MUTCD Section 4D.32, Temporary Traffic Control Signals](#).

For all construction projects, a temporary traffic-control (TTC) plan must be included or referenced within the scope of the construction project plans. A TTC plan outlines the temporary traffic control measures which will be used for facilitating motorist or pedestrians through a work zone, incident, or other event which causes temporary interruption of normal road usage.

Key Terms and Definitions

Portable Traffic Control Signal- as defined in the MUTCD is a temporary traffic control signal that is designed so that it can be easily transported and reused at different locations. Types of portable signals are trailer-mounted and pedestal-mounted.

Temporary Traffic Control Signal on Fixed Supports – as defined in the MUTCD is a temporary traffic control signal that is temporarily mounted on fixed supports. They are typically constructed with span wires mounted on temporarily-installed poles.

Trailer-Mounted Portable Traffic Control Signal System – The system consists of two trailers, with each trailer having a vertical upright and a horizontal arm to accommodate the mounting of at least two signal heads.

Pedestal-Mounted Portable Traffic Control Signal System – The system consists of four units, with a pedestal-mounted signal head on each unit.

Automated Flagger Assistance Device (AFAD) – is a manually-controlled device operated by one or more individuals to safely stop and control traffic through a work zone.

Long-Term Stationary Operation – As defined in Publication 213 is work that occupies a location more than 24 hours.

Short-Term Stationary Operation – As defined in Publication 213 is work that occupies a location up to 24 hours.

Short-Term Stationary Operation for Temporary Traffic Control Signals – is defined as daylight work areas with work in active progress, emergency nighttime work areas with work in active progress, or work areas of relatively short duration where work begins during daylight and continues in active progress during hours of darkness.

Long-Term Stationary Operation for Temporary Traffic Control Signals - is defined as all other stationary operations that do not meet the short-term stationary operation for temporary traffic control signals criteria.

Signal Phase – the right-of-way, yellow change, and red clearance intervals in a cycle that are assigned to an independent traffic movement or combination of movements.

Two-Phase Traffic Signal Operation – is defined as an operation when two different vehicle movements occur during the signal cycle. One-lane, two-way traffic control is often a two-phase operation assuming that additional phases are not needed for driveways and intersecting roads.

Multiple Phase Traffic Signal Operation – is defined as an operation when more than two vehicle movements occur during the signal cycle.

Traffic Signal Timing – the amount of time allocated for the display of a signal indication.

Yellow Change Interval – is the first interval following the green interval during which the yellow signal indication is displayed. It is used to warn traffic of an impending change in the right-of-way assignment. The duration of a yellow change interval shall be predetermined.

Red Clearance Interval – is an interval that follows a yellow change interval and precedes the next conflicting green interval. It provides additional time before conflicting traffic movements, including pedestrians, are released. The duration of a red clearance interval shall be predetermined.

Temporary Traffic Control Signal Permit – is the PennDOT Engineering District Office acceptance that the proper documentation was received to ensure safe and effective use of temporary traffic control signals. This permit will allow proper use of the device in accordance with the provisions of the permit and Publication 213.

Temporary Traffic Control Signal Application – is an application that allows the PennDOT Engineering District Office to obtain the minimum required information to ensure safe and efficient operation of the temporary traffic control signal.

Site-Specific Drawing – A drawing that clearly depicts the work zone and the anticipated operations. Typically, this is part of the Traffic Control Plan (TCP). Performance Specification – Is the required product performance, which may include but is not limited to equipment, physical requirements, operational requirements, etc...

Manually-Controlled Portable Traffic Control Signal Operation – when a portable traffic control signal is being controlled manually.

Short-Term Portable Traffic Control Signal Operation under Blanket Permit – this allows a successful past user of portable signals to obtain an agreement with PennDOT to provide notice of the placement of the portable signals with minimal documentation. Verification of the agreement between the user and PennDOT will be evaluated prior to approval of a blanket permit request.

Short-Term Stationary Portable Traffic Control Signal Operation for Non-Complex Conditions– the "non-complex" application will be verified through a number of physical and operational requirements that the site must meet to be considered. These checks allow PennDOT to verify safe and efficient use if installed properly.

Short-Term Stationary Portable Traffic Control Signal Operation for Complex Conditions– the "complex" application would be any short-term portable signal installation that does not met the requirements for "non-complex" applications.

Short-Term Emergency Operation – An emergency application defined in Pennsylvania Code Title 67, Chapter 212.

Long-Term Portable Traffic Control Signal Operation – All physical and operational requirements should be part of the Traffic Control Plan.

Temporary Traffic Control Signal – as defined in the MUTCD is a traffic control signal that is installed for a limited time period. Temporary traffic control signals may be portable or temporarily mounted on fixed supports. Common types of temporary traffic control signals are signals mounted on span wire with temporary supports and trailer mounted portable signals.

Work in Active Progress – Workers, other than flaggers, are present and are actively engaged in performing the necessary work

14.5 Temporary Traffic Control Signal - Documents

Refer to Publication 213, Appendix A for the following documents related to the Temporary Traffic Control Signal application, compliance, operation, and approval:

a) Temporary Traffic Control Signal Permit or Temporary Traffic Control Signal Permit (fillable form)

b) Example Problem: Application For Permit to Operate Temporary Traffic Control Signals

c) Temporary Traffic Control Signals Non-Compliance Documentation Form

d) Temporary Traffic Control Signals User Comment Form

14.6 Operations

In the design phase of every project that will have temporary traffic control signals, it is required that both installations on fixed supports and trailer-mounted portable traffic control signals always be considered before completing the design of the Traffic Control Plan (TCP). In some instances, trailer-mounted portable signals or installations on fixed supports can be used. On the other hand, in certain instances, installations on fixed supports may be preferable to trailer-mounted signals, or vice-versa, depending on the nature of the project, site conditions, traffic conditions, and other specific factors.

Before developing a TCP with temporary traffic signals, it is absolutely essential that the designer visit the proposed worksite beforehand. The site visit will enable the designer to evaluate various factors that will help in the determination of whether the TCP should permit both temporary signal design options, or one or the other. These factors include lateral clearance, trailer or pole placement, signal operation (phasing and timing), and others. Please also note that pedestal-mounted portable traffic control signals will not be considered for long-term stationary operations.

Good management principles should always be practiced by agencies administering roadway construction, maintenance, and utility operations. The application of the following good management principles outlined in Pennsylvania Code Title 67, Chapter 212, § 212.418 should be practiced:

a) Keep the temporary traffic-control zones as short as practical to avoid long stretches with no work activity.

b) Minimize lane restrictions.

c) Remove all traffic-control devices as soon as practical after the construction, maintenance or utility operation is complete.

d) Ensure structural adequacy of the temporary traffic control signal.

Long – Term Stationary Operations Using Temporary Traffic Control Signals on Fixed Supports:

Pros:

a) Desirable signal head placement can be achieved.

b) More than two overhead signals can be erected.

c) Less susceptible to vandalism.

d) Pole placement sometimes may be easier to accommodate than trailers due to physical features.

e) Fixed supports may be more desirable for long duration deployments.

f) More appropriate for multilane approaches.

g) Employs common traffic signal control equipment and operational features.

Cons:

a) Inability to set up and take down each day.

b) Less appealing for short-duration jobs or jobs with short-duration, multiple set-ups.

c) Equipment and material availability is sometimes an issue.

d) Less cost savings potential.

If the designer determines that only one temporary signal design option is justified for a particular project, then the TCP shall be prepared accordingly, and written documentation shall be maintained in the project file outlining the reasons for this determination. It would also be desirable to clearly indicate on the TCP that the other option will not be permitted for the project.

If the designer determines that trailer-mounted portable signals or installations on fixed supports would be acceptable, then the TCP should clearly show the exact design and operation of both alternatives so that additional plans from the contractor would not be necessary. The TCP should include the design of all anticipated needed features. For example, if platforms or other special features will be needed, their design and placement should be in the TCP. Engineering judgment should be used and documented to determine the safest and most efficient operation for the work zone.

Long – Term Stationary Operations Using Trailer-Mounted Portable Traffic Control Signals:

Pros:

a) Systems can be deployed quickly.

b) Especially conducive to deployments for emergencies.

c) Systems can be easily set up and taken down each day, or for multiple construction phases.

d) Equipment can be reused on future projects.

e) Equipment capable of being leased.

f) Cost savings potential.

g) Capable of wireless radio or hardwire interconnect.

h) Commonly equipped with monitoring system for location, low battery status, and conflicts using website and/or cell phone paging.

i) Commonly equipped with batteries that are solar recharging.

j) Commonly equipped with solar panels, rechargeable batteries, and ability to run via commercial power.

k) Wireless remote commonly available.

Cons:

a) Arm length can sometimes affect signal head placement.

b) Arm length affects number of signal heads that can be placed overhead.

c) Trailer size and/or arm length in conjunction with physical features can sometimes limit adequate placement.

d) Manufacturers have different operating systems.

e) More susceptible to vandalism.

f) Less appropriate for long-duration jobs on multilane, high-speed roadways.

Temporary Traffic Control Signals for Short-Term Stationary Operations

Before developing and/or determining your traffic control plan (TCP) using Publication 213, it is absolutely essential that the user visit the proposed worksite beforehand. The site visit will enable the user to evaluate various factors that will help in the determination of whether the TCP should permit temporary signal (portable signal) options, or other traffic control methods such as flaggers. These factors include lateral clearance, trailer or pedestal placement, signal operation (phasing and timing), and others. Please also note that installations on fixed supports are not considered viable for short-term stationary operations because of the amount of time and materials needed for installation.

If the user determines that portable traffic control signals will be an option and would like to pursue that option, then a completed application shall be submitted to PennDOT's appropriate Engineering District Office. If the Engineering District Office agrees with the proposed usage, they will issue a temporary traffic control signal permit.

14.7 Exceptions

Exempt Work

The use of temporary traffic control signals is not required for certain types of work. Common examples include: winter control operations, trash collection, street cleaning, traffic data collection, and etc. For more information on exempted types of work refer to Pennsylvania Code Title 67, Chapter 212, § 212.402.

Grade Crossings

Temporary traffic control signals should not be located within 300 feet of a grade crossing unless the temporary traffic control signal is in accordance with the MUTCD,Section 4D.27, Preemption and Priority Control of Traffic Control Signals or a uniformed flagger is provided at the crossing to eliminate vehicles form stopping within the crossing boundaries.

CHAPTER 15. FLASHING WARNING DEVICES

The purpose of this chapter is to discuss the various flashing warning devices used.

15.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 15 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 15 - FLASHING WARNING DEVICES

For information not provided in this chapter consult the MUTCD, Chapter 4L, Flashing Beacons and Publication 46, Chapter 4, Flashing Beacons Guidance.

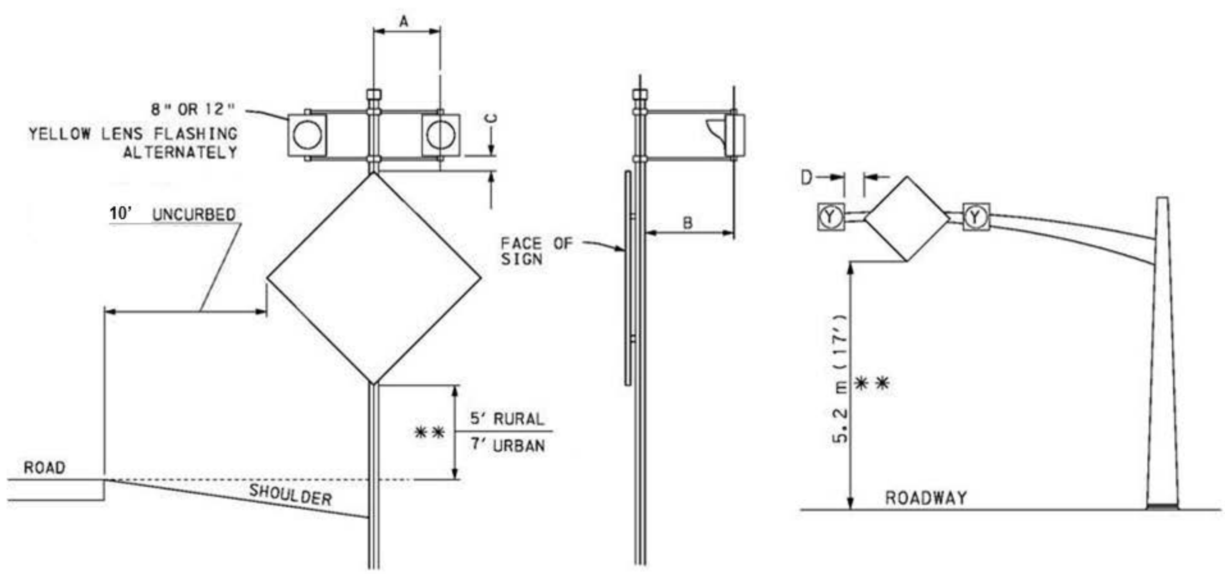
15.1 Intersection Control Beacon

Intersection control beacons are typically installed at stop-controlled intersections with a documented history of crashes. Each approach to the intersection has one or more signal sections that flash either yellow or red as needed for proper control of the intersection, (i.e., the major street approaches generally flash yellow unless a multi-way stop is used).

15.2 Warning Beacon

Warning beacons may be used for several types of applications as discussed in the MUTCD. Refer to **Exhibit 15-1** for an installation detail. When using the configuration shown in **Exhibit 15-1**, the indications shall flash alternately. These indications may also be actuated so as to only flash when conflicting activity (pedestrians, bicycles, etc.) is present.

Exhibit 15-1 Flashing Warning Device Detail



SIGN SIZE	A	B	C	D
30" x 30"	16"	15"	6"	12"
36" x 36"	* 20"	15"	6"	12"
48" x 48"	28"	15"	6"	12"
60" x 60"	37"	15"	6"	12"

* DIMENSION A FOR S1-1 SIGNS IS 16" AND THE 36" x 36" IS THE MINIMUM SIZE SIGN USED.

** CLEARANCE BETWEEN ROADWAY AND LOWEST SIGN OR SIGNAL HEAD.

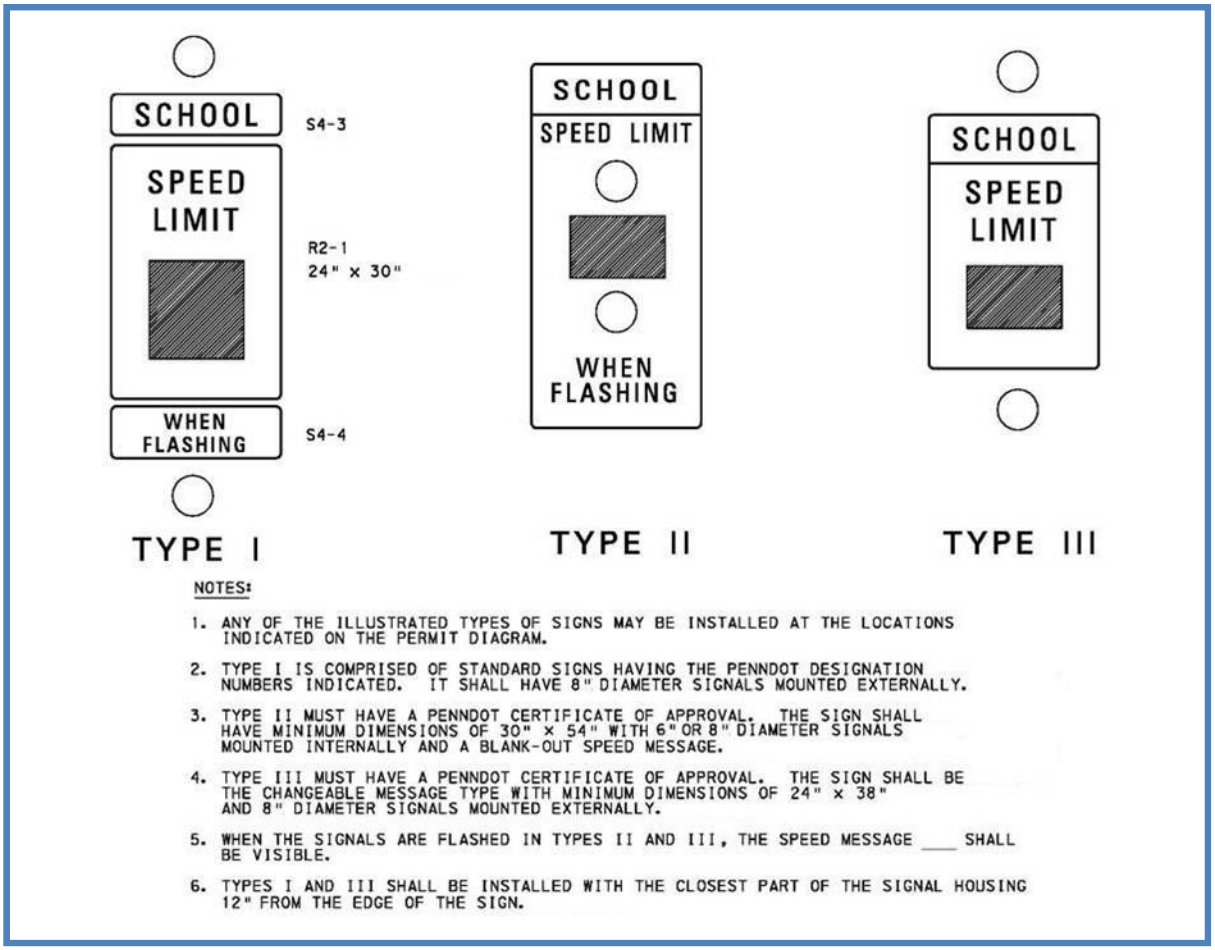
Note: Foundations are required for all Flashing Warning Device structures, in compliance with Publication 148.

15.3 Speed Limit Sign Beacon

For speed limit sign beacons in proximity to school zones also consult the MUTCD,Section 7B.15, School Speed Limit Assembly (S4-1P, S4-2P, S4-3P, S4-4P, S4-6P, S5-1) and

END SCHOOL SPEED LIMIT Sign (S5-3). Speed Limit Sign Beacons are typically installed with regulatory speed limit signs or school zone signs to command added attention. The beacons shall consist of two one-section signal heads with yellow circular indications aligned vertically on a speed limit sign and shall flash alternately. Refer to **Exhibit 15-2** for the three options allowable for School Zone Speed Limit signs.

Exhibit 15-2 School Zone Speed Limit Signs



15.4 Stop Beacon

Refer to the MUTCD, Section 4L.05, Stop Beacon.

CHAPTER 16. TRAFFIC SIGNAL PLAN DEVELOPMENT

In this chapter, the traffic signal plan development is discovered. This, as the name of the chapter implies, is an essential part of the signal design process. Publication 149 covers this process in detail.

16.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 16 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

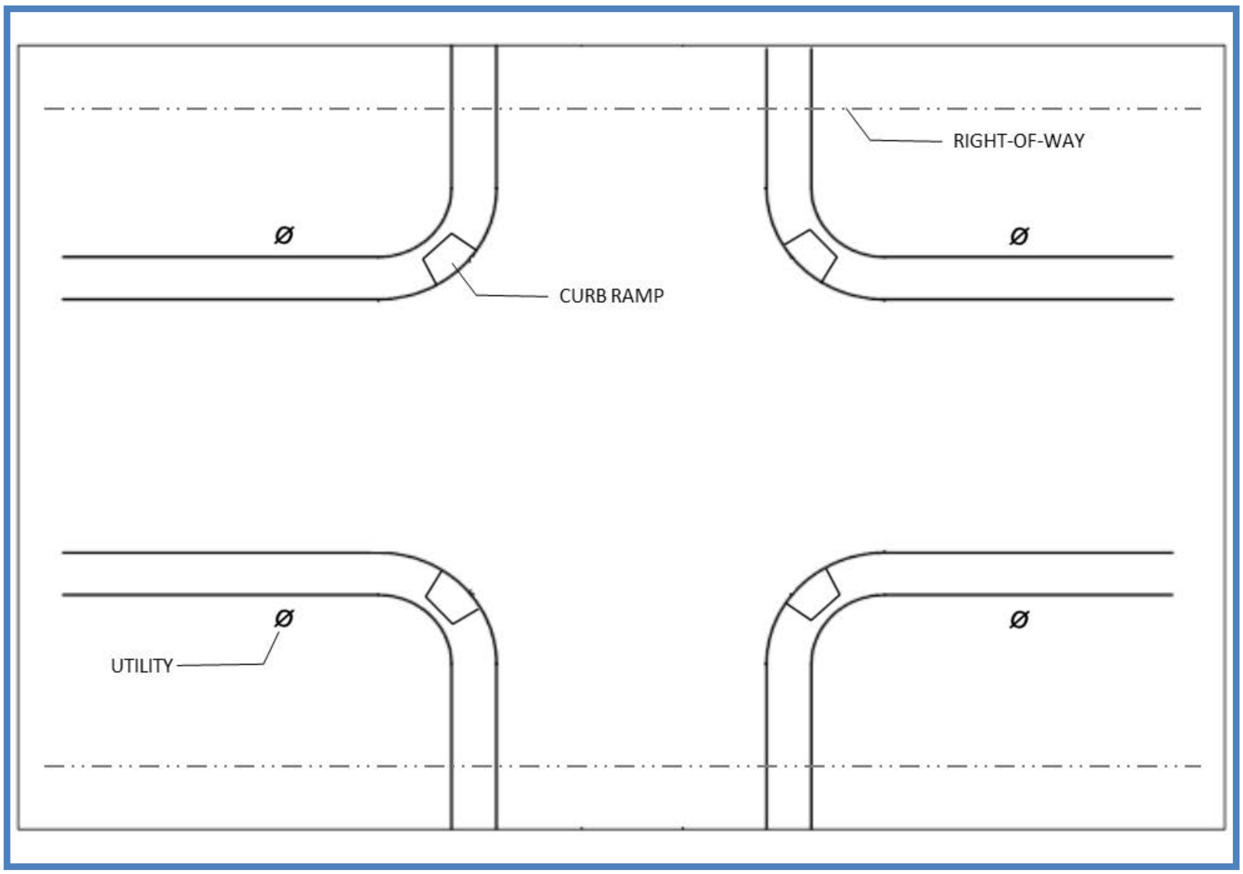
CHAPTER 16 - PLAN DEVELOPMENT

This chapter provides a basic guide for the development of traffic signal plans in Pennsylvania. First, a basic sequence of steps is provided for the designer to gain a general sense of the information needed and items to be considered while designing a traffic signal installation. The chapter will also present information related to traffic signal permit plans versus construction plans as well as tabulation sheets and computer aided drafting requirements.

16.1 Signal Plan Preparation Guide

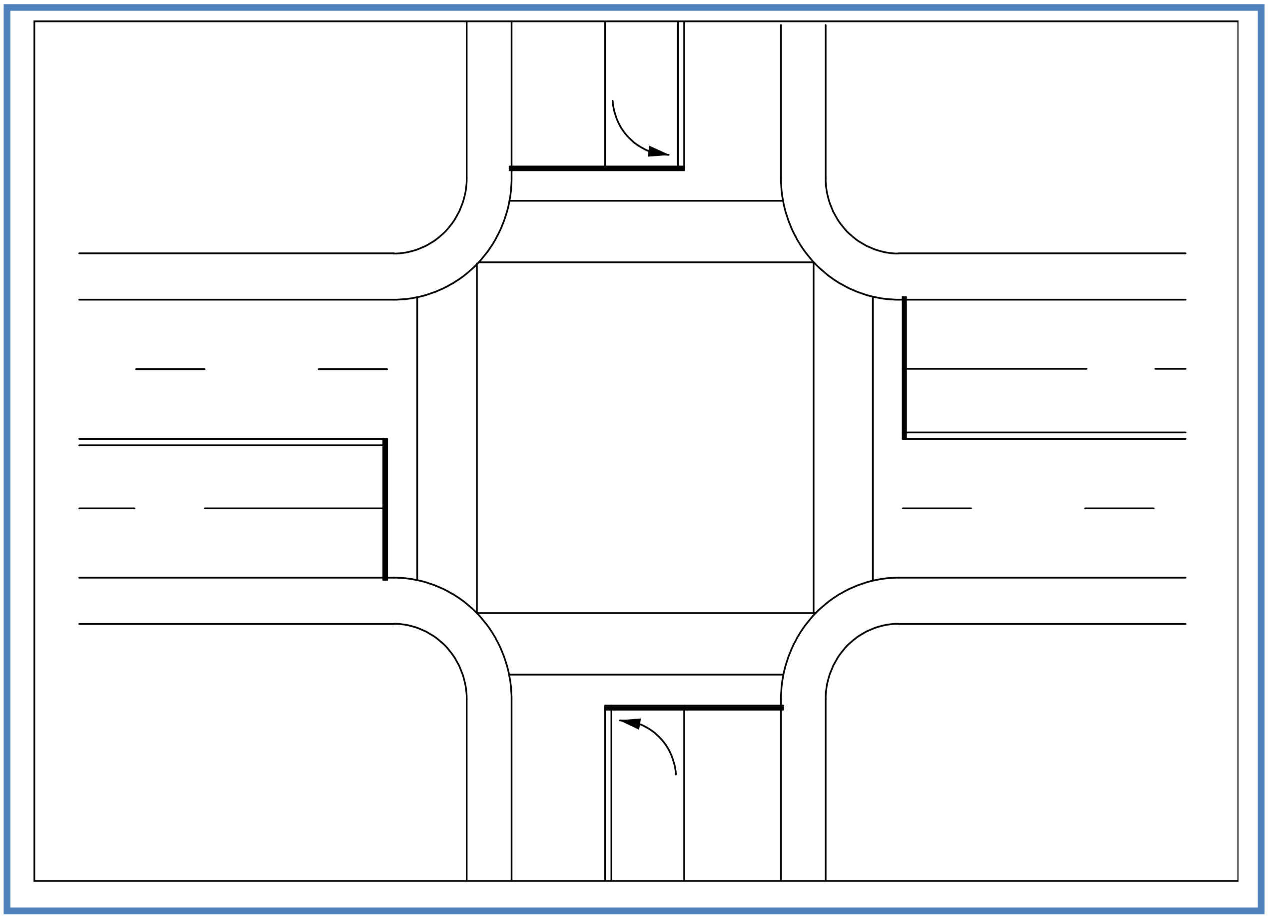
Although it may not be possible to strictly comply with the sequence indicated, this chapter will provide a systematic method to be used in preparing a plan. All critical design features and characteristics should be determined through an engineering study and engineering judgment. The preparation guide is a tool and should not supersede design features developed from the engineering study and engineering judgment. This procedure, when used in conjunction with the plan format checklists provided in this chapter and engineering study findings, helps ensure that the final product is a complete and concise plan for the installation of traffic signals. All designs should follow the general plan presentation requirements in Publication 14M (Design Manual 3).

Exhibit 16-1 STEP 1: Base Plan Preparation



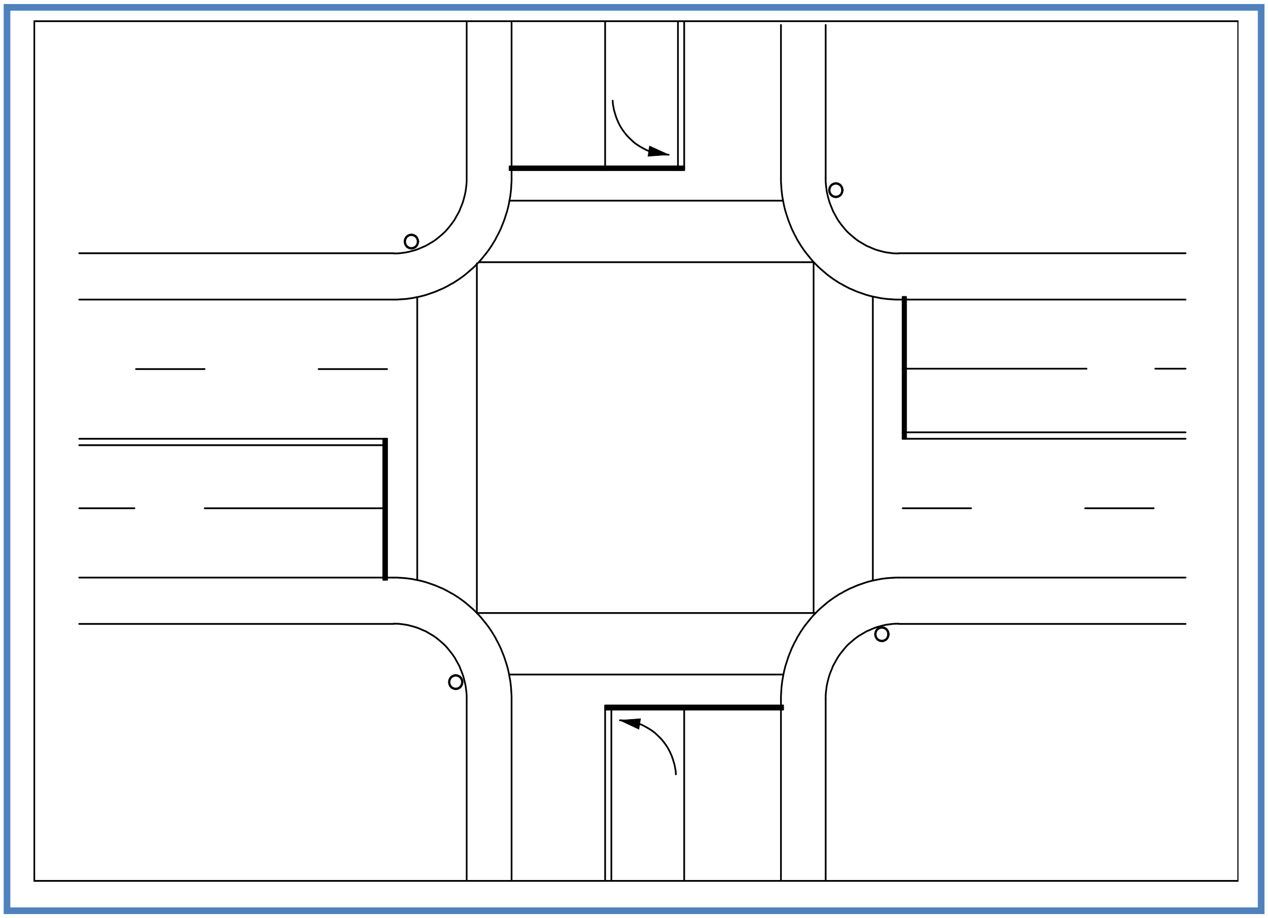
Show curbing, shoulders, curb ramps, sidewalks, islands, pavement markings, and inlets on the base plan. The development of an accurate base plan should include a field survey performed by a surveyor so that the most accurate design can be made. Field verification of the site is strongly suggested prior to continuing the design elements. If the project involves new construction, use care to ensure that the geometrics match those shown on the roadway plan.

Exhibit 16-2 STEP 2: Pavement Marking Layout



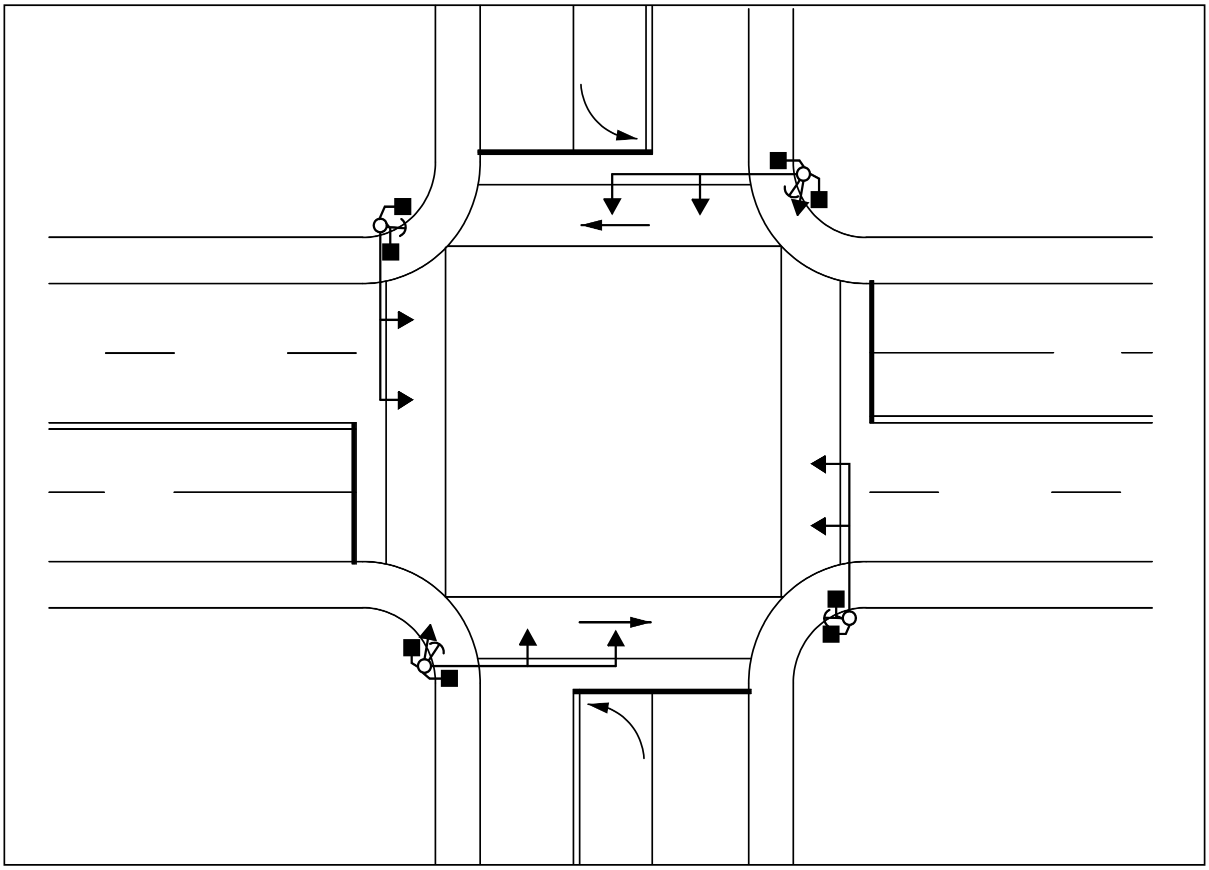
The roadway geometrics and lane configurations will either be based on existing conditions or proposed improvements that are based on previously completed capacity analysis and roadway design. Stop lines should be placed considering vehicular (truck or appropriate design vehicle) turning movements. The need for curb ramps and crosswalks should be determined through the engineering study taking into account *Chapter 4* of this publication, Publication 13M (DM2) Chapter 6, and Publication 72M (RC Standards). Layout of crosswalks and curb ramps should be developed in concert with one another to provide the safe and efficient movement of pedestrians and vehicles through the intersection. The pedestrian accessible route should not be obstructed by poles, signs, hydrants, or other street hardware. The crosswalk should be a minimum 2 feet from the adjacent travel lanes. Pavement marking details shall follow Publications 46, Publication 111, Publication 408, and Pennsylvania Code Title 67, Chapter 212.

Exhibit 16-3 STEP 3: Location of Traffic Signal Supports



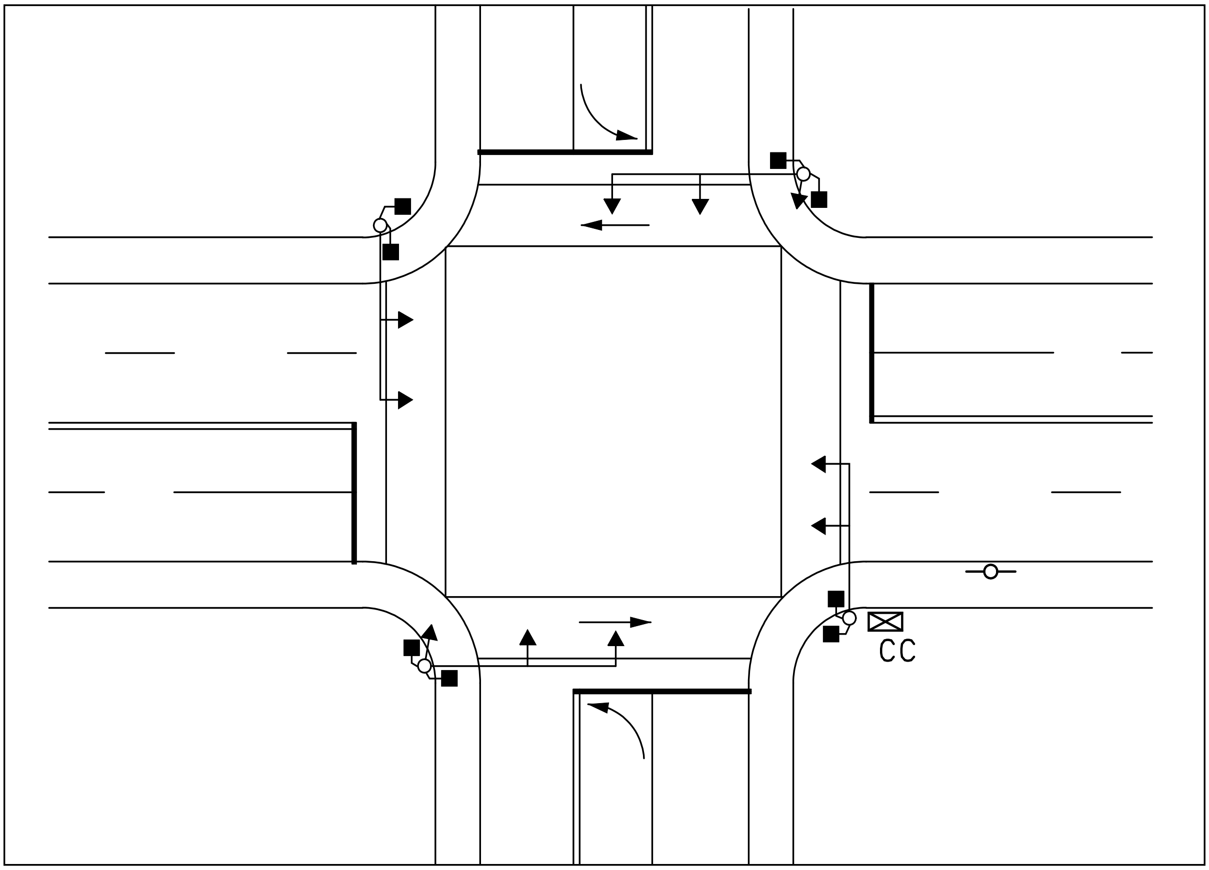
Follow the provisions of *Chapter 5* of this publication while designing the location of supports. Signal supports should, whenever possible, be located behind the sidewalk area to minimize obstructions to pedestrians and vehicular traffic. Consider right-of-way lines, and select sites that will yield optimum visibility of signals to drivers and pedestrians, and are free from conflicts with utilities and drainage facilities. Supports shall also be provided in accordance with Publication 13M (DM2), Chapter 6 and Publication 72M (RC Standards) provisions.

Exhibit 16-4 STEP 4: Signal Heads and Pedestrian Accommodations



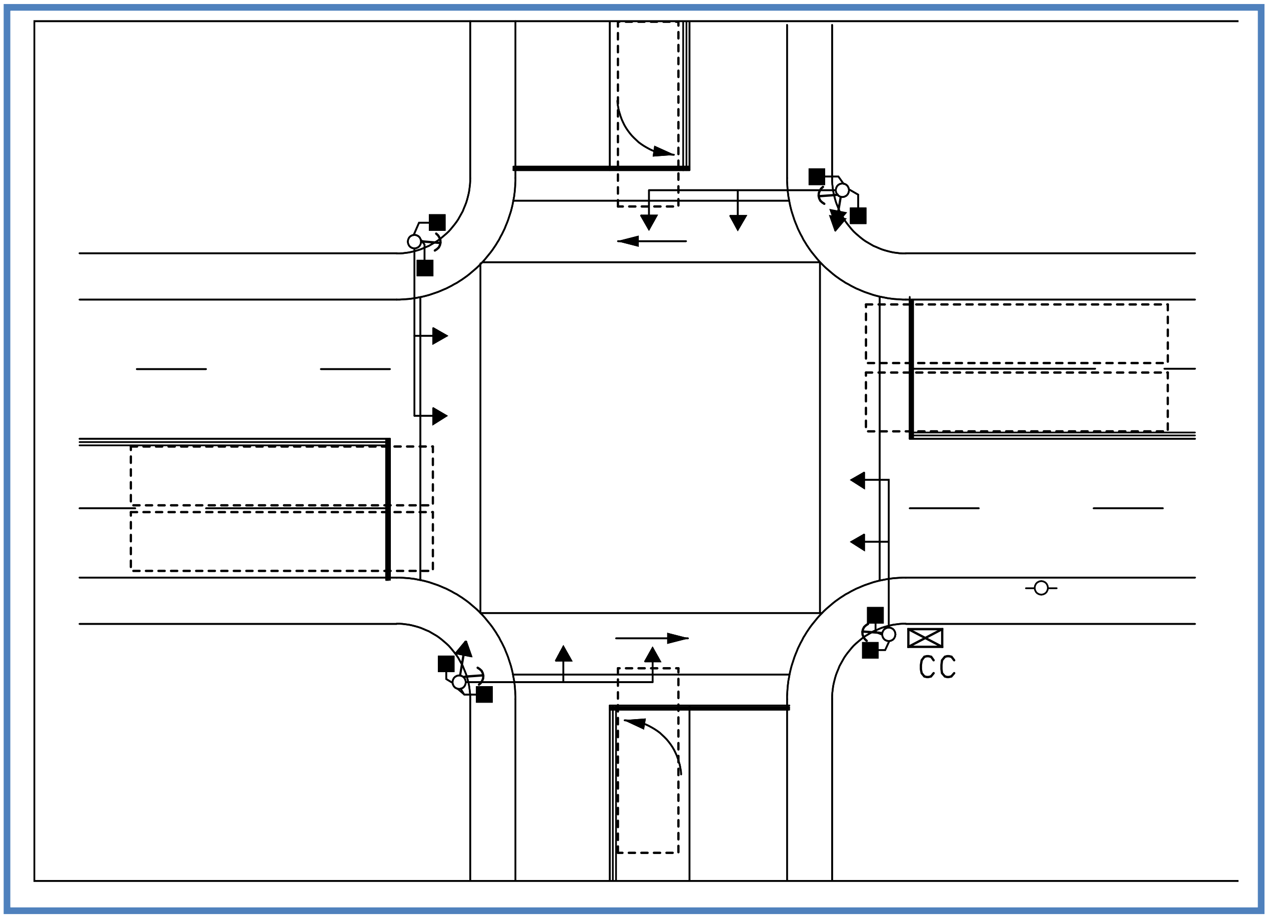
Locate the required positions of traffic signals in conformance with the provisions of the MUTCD and this publication. Provide mast arms, span wire, or pedestals for proper location of the signals. Using the signal templates, make sure the signals fall within the motorist's cone of vision. Adjust the locations or add supplemental signals, if necessary. Based on the engineering study and engineering judgment, pedestrian signals, pushbutton locations, and additional accommodations shall meet the provisions of Publication 13M (DM2), Publication 72M (RC Standards), Publication 148, the MUTCD, and this publication. Also, if preemption was determined to be placed at the location, proper placement and capabilities should be determined prior to the device location finalization.

Exhibit 16-5 STEP 5: Location of the Traffic Signal Controller



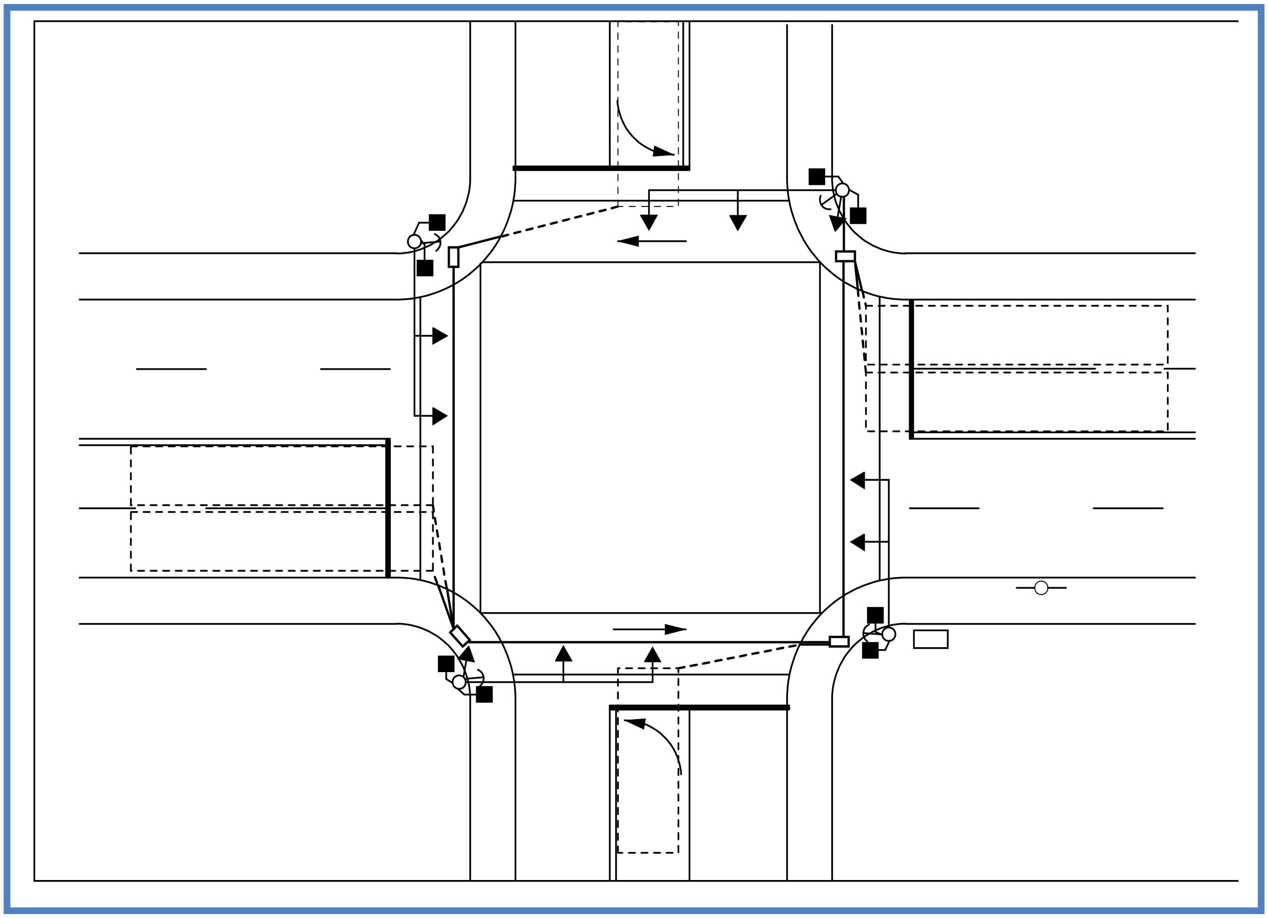
Select a location for the controller. Of prime importance is the prevention of potential damage or knockdown by vehicular traffic. Controllers should not be located near the curb return or on channelization islands. Additional considerations, such as the location of electrical service or communications lines and visibility of signal operations from the controller, should be taken into account. Ideally, maintenance personnel should be able to view at least one of the traffic signal indications for all operating phases while setting the timing or performing other tasks in the controller cabinet. Contact with the utility companies shall be made to determine how electric service will be provided, and field verification should be made to determine the design aspects of the electric service at the intersection location. Controller configuration shall be in compliance with Publication 148 and Publication 408.

Exhibit 16-6 STEP 6: Location of Detection Areas



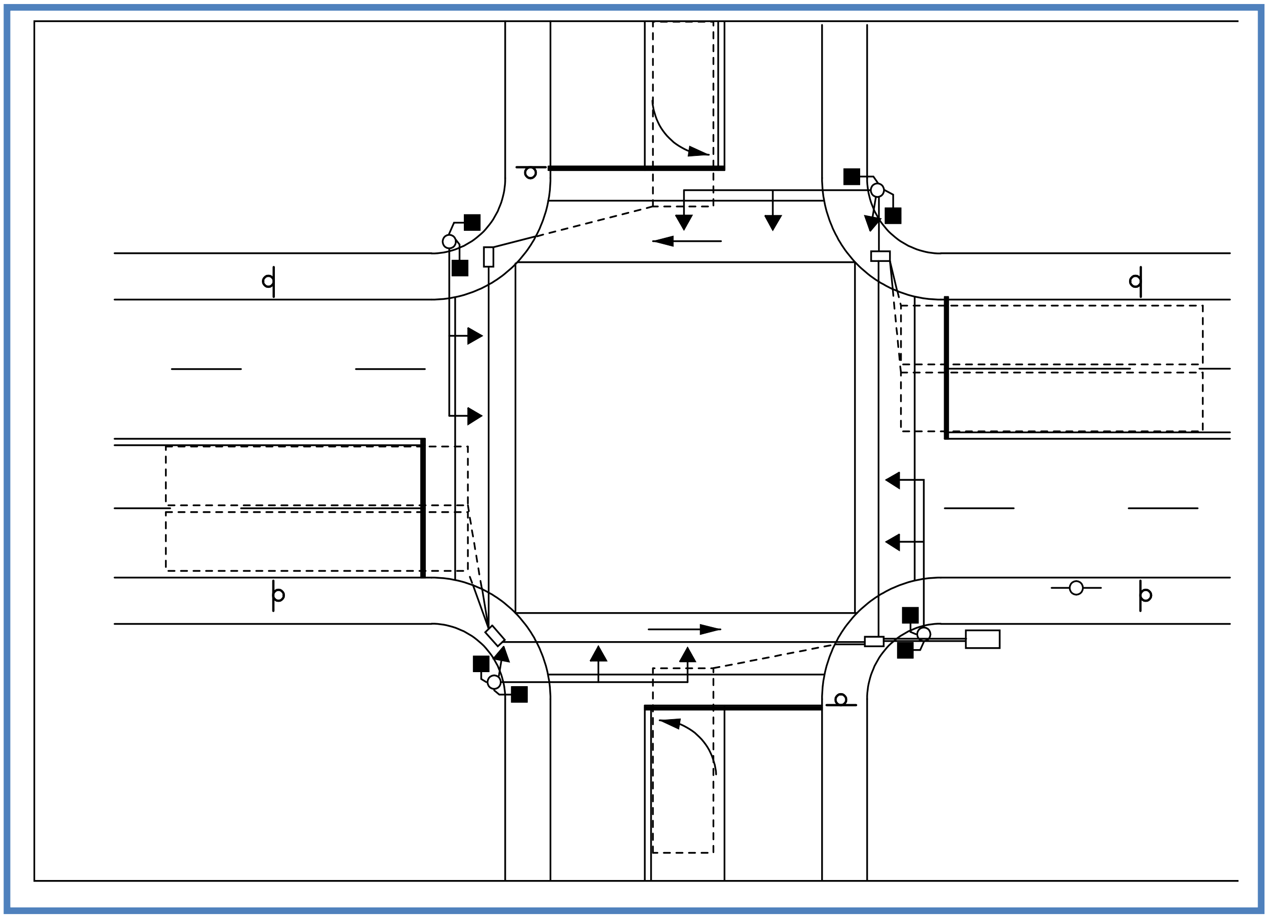
If the traffic signal installation under design is to be actuated, add detection of the sizes and types required in conformance with Publication 148, Publication 408, and this publication. For example, the detection zone should extend a minimum of 3 feet beyond the stop line. Detectors should be located a minimum of 3 feet from the centerline to minimize the possible detection of opposing or adjacent traffic. Avoid locating detectors where vehicles may park over them or near driveways to avoid false detections. Manholes or other subsurface structures which may affect the operation of the detectors must not be within the area of a loop detector. A series of smaller detection areas may be used to avoid subsurface structures and to provide the required area of detection.

Exhibit 16-7 STEP 7: Addition of the Electrical Distribution



Consult this publication for guidelines regarding the location of junction boxes, conduit, and electrical service conduit. Junction boxes should not be placed in curb ramps. Generally, there should be at least one junction box at each support where wiring runs continue to another location. Connect the junction boxes with a conduit system so the controller is near the center of the system, not at an end. To minimize obstructions to traffic during construction and to reduce costs, avoid placing conduit across both approaches of the major street. For detector leads, provide a conduit from the nearest junction box to the curb face. Add the conduit for electrical service. Prepare the wiring diagrams to indicate the size and number of conductors in each cable run.

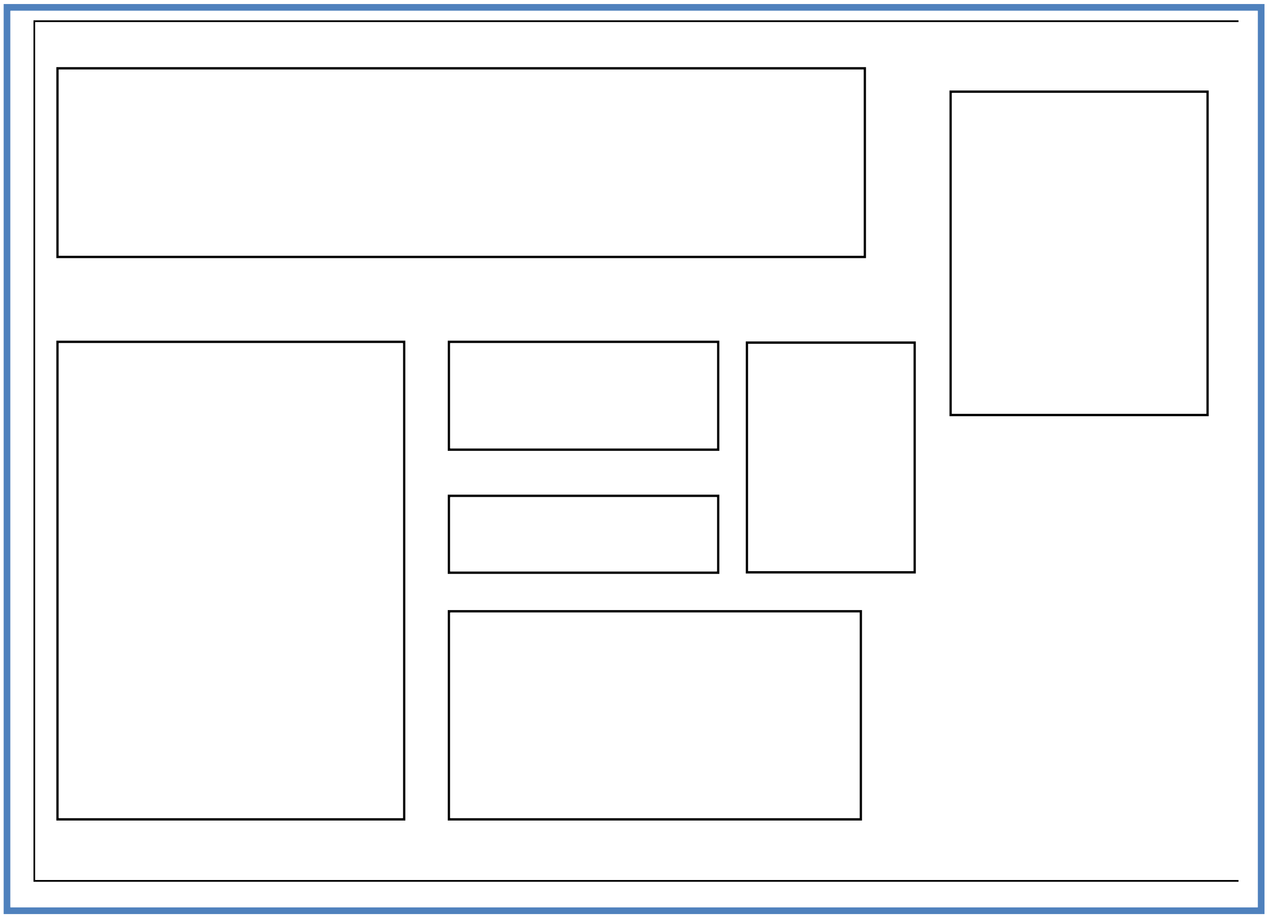
Exhibit 16-8 STEP 8: Sign Placement



Add all regulatory and warning signs necessary to complete the design. The signs used must be designed and located in conformance with Publication 46, Publication 111, Publication 212, and Publication 236.

Complete the design by adding items such as dimensions, labeling of signal heads, poles, detectors, pavement markings, etc. Add the phasing and timing of signal operation as determined by an engineering study and engineering judgment. Diagrams showing all permissible and prohibited movements shall be provided for each phase. Separate intervals illustrating the displayed indication of each signal head shall be provided for each occurrence of a change of any displayed indication.

Exhibit 16-9 STEP 9: Development of a Tabulation Sheet



Complete the various tables on the tabulation sheet in conformance with the guidelines set forth in Publication 14M (Design Manual 3) to provide a complete and accurate listing of all construction items composing the traffic signal design. Complete the tabulation of the electrical distribution items from the wiring diagram. Finally, check both the plan sheet and tabulation sheet to ensure completeness and accuracy.

16.2 Plan Format Checklist

The following checklist is to be used as a guide to prepare a permit plan sheet and/or the construction plans.

In general, the permit plan is used to show operational information and “above ground” traffic signal equipment, signs, and pavement markings related to the operational and safety aspects of the intersection. The roadway geometrics and all traffic control equipment should generally be presented on the permit plan as if they were existing features. The construction plan and tabulation sheet are primarily used as a tool for contractors to know what equipment and items are to be installed new and which items are preexisting that shall remain. The construction plan adds to the information provided on the permit plan by including conduit, junction boxes, controller cabinet, electrical service location, wiring diagram, pavement marking notes, utilities, contractor notes, and any other items specifically needed to relay the full intent of the construction scope of work to a contractor.

Plan Sheet

The information listed below is to be provided on both the permit plan and the construction plan unless indicated otherwise.

Sign Tabulation

- ☐ Locate on lower left of sheet.
- ☐ Title.
- ☐ Column headings.
- ☐ Plan symbol.
- ☐ Description.
- ☐ Size.
- ☐ Data Required
- ☐ Plan symbol beginning with letter "A".
- ☐ Description includes sign nomenclature from Publication 236 and actual legend.
- ☐ Size by width and height.

Movement, Phasing, and Sequence Chart

- ☐ Locate on upper left of sheet.
- ☐ Designate the phases using NEMA phasing. See Chapter 3 of this publication or Appendix A for examples.
- ☐ Diagrammatic representation of movements for respective phase, including pedestrian movements with dashed lines.
- ☐ Beginning with 1, horizontally list the interval numbers for the cycle.
- ☐ Add preemption phases.
- ☐ Vertically list the signal head numbers as shown on the plans.
- ☐ For each interval, show the signal head display by indicating:

G	for Green
R	for Red
Y	for Yellow
W	for “WALKING PERSON” indication or “WALK” indication
H or DW	for “UPRAISED HAND” indication or “DONT WALK”
FH or FD	for Flashing “HAND” indication or Flashing “DONT WALK” indication
←G-	for Green Arrow indication
←Y-	for Yellow Arrow indication
←R-	for Red Arrow indication

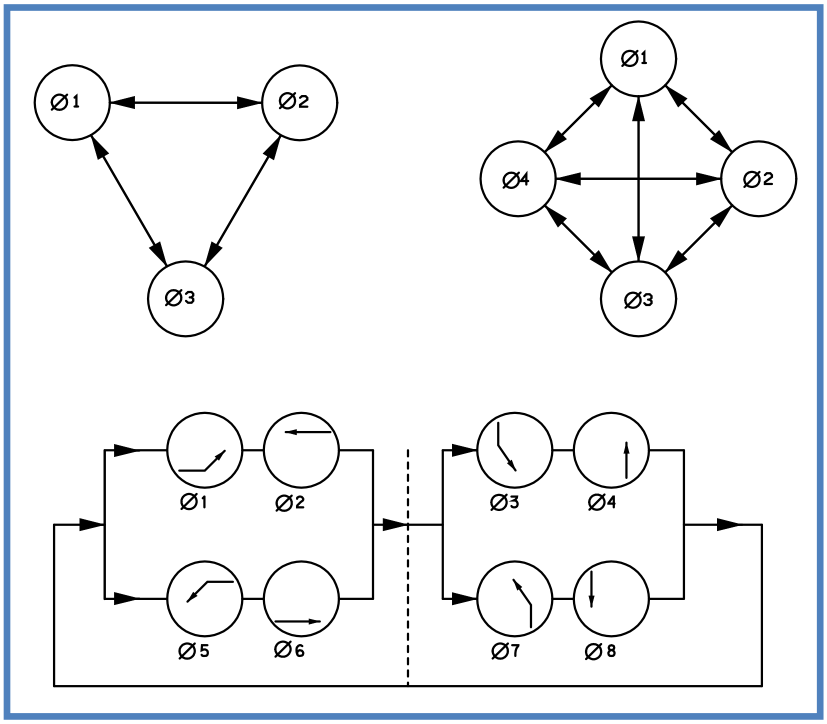
- ☐ At bottom of chart indicate the time settings for each interval, using the method indicated in Figure A-3 of this publication.
- ☐ On right of chart, color the signals shall indicate when flashing. If not flashing, indicate "OFF".
- ☐ Indicate “Flash” (and hours of flashing).
- ☐ Show the required operational notes for controller operation.
- ☐ If railroad or emergency vehicle preemption is needed, add required phases and appropriate notes.

Phasing Diagram (Required only when sequencing is unusual or needs clarification.)

- ☐ Locate next to phasing chart.

- ☐ ∅ symbol for phase.
- ☐ ← Indicate sequence of controller with arrows.
- ☐ ----- Symbol for phase sequence barrier.
- ☐ Number of various phases, using numbers 1, 2, 3 etc. (the NEMA standard). Letters (A, B, C) should not be used.

Exhibit 16-10 Example Phasing Diagram (use standard NEMA phasing)



Signal Head Identification

- ☐ Located at bottom middle of plan.

Vehicle Signals

- ☐ Diagram of signal faces.
- ☐ Show signal numbers as they appear on the plans.
- ☐ Indicate colors and type.
  - R = red ball
  - Y = yellow ball
  - G = green ball
  - ←G- = green arrow indication
  - ←Y- = yellow arrow indication
  - ←R- = red arrow indication
- ☐ Indicate size of signal.
  - 8-inch signal
  - 12-inch signal

- ☐ Indicate type of visors.
- ☐ Indicate if backplates are to be installed.
- ☐ Indicate louvers (if required).

Pedestrian Signals

- ☐ Diagram of signal faces.
- ☐ Show signal numbers as they appear on the plans.
- ☐ Indicate messages and location.
  - Upraised hand indication
  - Walking person indication
  - Countdown digits indication
- ☐ Indicate size of message.

Legend

- ☐ Located at bottom right of page.
- ☐ Indicate all symbols here which appear on the intersection representation that need explanation in addition to those indicated on the sample plan.
- ☐ After each symbol, give a definition of what it represents.
- ☐ Indicate existing equipment and items as hollow and/or with slanted text.
- ☐ Indicate proposed equipment and items as filled in solid and/or with upright text.

Title Block

- ☐ Located at bottom right corner.
- ☐ Locate in the top quarter of the box the following categories:
  - ☐ County: insert respective county
  - ☐ Municipality: insert respective municipality
  - ☐ Intersection of: insert street name/number of roads.
  - ☐ Locate in the second quarter, the following:
  - ☐ Approved By:____________________________ ________
    Municipal Official Date
  - ☐ Locate in the third quarter, the following:
  - ☐ Recommended____________________________ ________
    District Traffic Engineer Date
- ☐ Locate at bottom quarter of box, the following:
  - ☐ Scale: (Bar Type) either 1 inch = 20 feet or 1 inch = 25 feet.

For all of the above, the respective information must be filled in for each project.

Notes

- ☐ Locate general notes on right hand side of sheet.

Signal Wiring Diagram (Construction Plan ONLY)

- ☐ Locate where able on sheet or place on additional sheet.
- ☐ Provide diagram of wire routing through the intersection.
- ☐ Indicate location of wire splices.
- ☐ Indicate wire conductor and size.

Upper Title Block

The following items should be located at the top right corner of the sheet, as required.

- ☐ Project data block (PENNDOT CONSTRUCTION PLAN ONLY)
- ☐ District - indicate number.
- ☐ County - indicate county.
- ☐ Route - indicate the routes involved.
- ☐ Section - indicate section number.
- ☐ Sheet - indicate sheet number of contract plan set.
- ☐ Permit block (PERMIT PLAN ONLY)
- ☐ Permit No. - indicate number.
- ☐ Date Issued - Date original permit was issued.
- ☐ Sheet ____of____- this is for this sheet number and for total number of sheets in permit.
- ☐ Revision block (PERMIT AND CONSTRUCTION PLAN).

Once plans have been approved, and changes are made, they should be indicated as follows:

- ☐ Revision number - indicate number (1, 2, 3, etc.).
- ☐ Revision - indicate revision.
- ☐ Date - indicate date revision was made.
- ☐ By - indicate who made revision.

Intersection

- ☐ Located in center of sheet using scale of 1 inch = 20 feet or 1 inch = 25 feet.
- ☐ Plan view of intersection.
- ☐ North arrow.

(a) Show the following information on both the permit and construction plan:

- ☐ Curbs.
- ☐ Pavement markings.
- ☐ Supports.
- ☐ Signals with #'s.
- ☐ Pedestrian signals and pushbuttons with #'s or letter designation.
- ☐ Detectors with dimensions.
- ☐ Signs with letter designation.
- ☐ Right-of-way with dimensions and easements.
- ☐ SR, segment, and offset.
- ☐ Phasing symbols of each approach.
- ☐ Lane widths
- ☐ Speed limit of each approach
- ☐ Average grades of each approach
- ☐ Nearest signal in each direction (or “no signal within one mile”)
- ☐ Municipal border if appropriate

(b) Plot the following proposed data on construction plan.

- ☐ Existing data as per Publication 13M (Design Manual 2).
- ☐ New curbs.
- ☐ Pavement markings (indicate existing versus proposed).
- ☐ Supports with pole #'s.
- ☐ Controller cabinet.
- ☐ Detectors with #'s.

- ☐ Signs with letter designation (indicate existing versus proposed).
- ☐ Junction boxes with #'s.
- ☐ Conduit and its size.
- ☐ Electrical service location and type.

Tabulation Sheet

Prepare the following tabulations only for construction plans.

Traffic Signal Supports

- ☐ Location.
- ☐ Mast arms.
- ☐ Strain poles.
- ☐ Sign and signal locations.
- ☐ Item numbers.

Electrical and Conduit Items

- ☐ Location.
- ☐ Conduit.
- ☐ Trench.
- ☐ Signal cable.
- ☐ Junction box.
- ☐ Electrical service.
- ☐ Detector items.
- ☐ Item numbers.

Detectors

- ☐ Amplifier.
  - ☐ Description.
  - ☐ Quantity.
  - ☐ Location.
  - ☐ Operation.
  - ☐ Item numbers.
- ☐ Sensors.
  - ☐ Description.
  - ☐ Quantity.
  - ☐ Size.
  - ☐ Location.
  - ☐ Item numbers.

Miscellaneous

- ☐ Item numbers.
- ☐ Controller assembly.
- ☐ Vehicle signal heads .
- ☐ Pedestrian signal heads.
- ☐ Systems.
- ☐ Communications.
- ☐ Preemption.

Pavement Markings

- ☐ Item numbers.
- ☐ Quantity.
- ☐ Description.

Signs

- ☐ Description.
- ☐ Size.
- ☐ Square feet.
- ☐ Item numbers.
- ☐ Sign Type/Mount.
  - ☐ Type B.
  - ☐ Type F.
  - ☐ Structure-Mounted.

16.3 Computer Aided Drafting (CAD)

All signal plans shall be completed using industry standard computer aided drafting software. The electronic drawing file must be in MicroStation (dng) format and shall be provided to the Department prior to final approval of the design for both permit and construction plans. The file shall be organized with appropriate levels or layers to allow convenient isolation of title blocks, text, signal equipment, signs, MST diagram, sign tabulation, legend, proposed versus existing equipment, etc.

CHAPTER 17. TRAFFIC SIGNAL DESIGN REPORT

The traffic signal design report is important to document the traffic signal design process.

17.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 17 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 17 - TRAFFIC SIGNAL DESIGN REPORT

The traffic signal design report should generally follow the outline shown in Exhibit 17-1. Items not applicable to the project may be omitted. A brief description of each section follows the outline.

Exhibit 17-1 Traffic Signal Design Report Outline

(1) Project Description
(2) Roadway and Traffic Data
   a. Approach Geometrics
   b. Vehicular Volume
      i. Existing Volume
      ii. Trip Generation
      iii. Projected Opening Year Volumes
      iv. Discussion of Vehicular Movements
   c. Turn Lane Warrant Analysis
   d. Existing Signal and/or System
   e. Railroad Grade Crossings
(3) Pedestrian and ADA Accommodations
(4) Traffic Signal Design
   a. Timing and Phasing
      i. Change and Clearance intervals
      ii. Left Turn Phasing
      iii. Queuing
      iv. Cycle Lengths
      v. Pedestrian Timing
      vi. Volume-Density and/or indecision Zone Protection
      vii. Capacity Analysis and Level of Service
      viii. Progression Analysis and System Engineering
   b. Equipment Placement
   c. Modifications to Existing Intersections
(5) Conclusion
(6) Appendices
   a. Crash Data Analysis
   b. Speed Data
   c. Warrant Analysis

Outline Definitions

Project Description

Provide a thorough description of the project so the reviewer can have a full understanding of the overall project intent and purpose, owner, location, scope, history and background, expected outcome, land uses in the vicinity, and any other information to help the Department fully understand the project.

Roadway and Traffic Data

a. Approach Geometrics
Provide a description of the horizontal and vertical alignment of each intersection approach and, if needed, describe how it may specifically affect the signal design in an unusual way (sight distance, clearance times, etc.)

b. Vehicular Volume
Provide traffic volume data as necessary to show that the signal is warranted and for developing the timings to be used. Opening year traffic volumes should be used for proposed traffic signals and modifications to existing signals.

   i. Existing Volume
   ii. Trip Generation
   iii. Projected Opening Year Volumes
   iv. Discussion of Vehicular Movement

c. Crash Data Analysis
Provide an analysis of the previous three full years of crash data and how it relates to the traffic signal design. Discuss patterns that may be correctable through signalization and any anticipated adverse effects of signalization.

d. Speed Data
Provide a spot speed study in accordance with guidance in the Institute of Transportation Engineers' *Manual of Transportation Engineering Studies, 2nd Edition.* The speed study results may be used for purposes of calculating change and clearance intervals as well as other settings such as advanced loop detection distances and lane shift tapers.

e. Warrant Analysis
Provide a brief summary of the warrant analysis that should have been completed during Step 1 of the traffic signal permit process (see Chapter 4 of Publication 46)

f. Turn Lane Warrant Analysis
Provide an analysis and discussion of turn lane requirements at the signalized intersection if required by the Department in accordance with Chapter 11.16 of Publication 46.

g. Existing Signal and/or System
If there is an existing traffic signal and/or interconnected system at the project intersection describe them in detail including existing operational features of the signal, condition of existing equipment, controller unit type and features, detection type, presence of emergency preemption, communication infrastructure type, system architecture (e.g. closed loop, central, GPS time-based, on-street master, etc.)

h. Railroad Grade Crossings
Discuss any nearby grade crossings that are included in the operation of the traffic signal. Provide information as discussed in Chapter 19 of this publication.

Pedestrian and ADA Accommodations

Provide a brief discussion of the results of the pedestrian study as completed per Chapter 4 of this publication and if/how pedestrians will be accommodated in the design of the traffic signal.

Traffic Signal Design

i. Timing and Phasing

i. *Change and Clearance Intervals*
Provide a brief discussion on the completion of the CCIs. Provide the calculations in the report appendix.

ii. *Left Turn Phasing*
Provide a brief discussion on the completion of left turn conflict factor analysis and its results as well as the recommendations for left turn phasing.

iii. *Queuing*
Provide a brief discussion on the results of queuing analysis and existing and/or projected queues that may be of concern.

iv. *Cycle Lengths*
Provide a brief discussion on existing (if appropriate) and proposed cycle lengths.

v. *Pedestrian Timing*
Provide a brief discussion on the proposed pedestrian timings and any special features such as leading, lagging, or exclusive pedestrian phases, etc.

vi. *Volume-Density and/or Indecision Zone Protection*
Provide a brief discussion on proposed volume-density and/or indecision zone detection including the design speed and how it is proposed to operate.

vii. *Capacity Analysis and Level of Service*
Provide a discussion on the capacity analysis and its results including existing (if appropriate) and projected levels of service for the periods studied.

viii. *Progression Analysis and System Engineering*
Provide a brief discussion on progression analysis that was completed for the project including existing (if appropriate) versus proposed green band efficiency (calculated as bandwidth divided by cycle length).

j. Equipment Placement
Discuss the placement of signal equipment and any circumstances that would cause a reviewer to question the placement of signal supports and/or other equipment.

k. Modifications to Existing Intersections
Provide a description of proposed changes to existing signal equipment.

Conclusion

Provide a concluding paragraph that summarizes the project and the final conclusions and recommendations for signalization under the project.

Appendices

Provide all calculations, capacity analysis, intersection pictures, etc. in the appendices.

CHAPTER 18. ADDITIONAL DESIGN CONSIDERATIONS

In this chapter, additional design considerations are considered.

18.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 18 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

In addition to the materials indicated throughout this chapter, please consult the MUTCD, Section 4D.27.

CHAPTER 18 - ADDITIONAL DESIGN CONSIDERATIONS

18.1 Design Considerations Based on Project Funding

In general, traffic signal designs should not differ based on the project funding source. It is imperative that the safe and efficient movement of people and goods be the primary objective of every signal design. However, the project budget and installation costs should be of primary concern regardless of the project funding source. All factors such as safety, desired functionality, long term maintenance, installation costs, traffic control, constructability, etc. shall be considered during the design and approval process. Cost should not be a reason for leaving out important operational features of an intersection that may compromise safety or efficiency. Likewise, additional special features that are not needed to provide the desired functionality should not be required if they add substantial cost or if they are likely to not be maintained properly.

18.2 Special Provisions

Special provisions for traffic signal projects should be written in accordance with Publication 51, Chapter 1, Section E, Special Provisions. Only items that are not standard Publication 408 items need a special provision. Consult the local PennDOT engineering district and/or central office to confirm if a standard special provision exists for an item that may be needed under a traffic signal design project.

For Traffic Signal items, please review Publication 46, Chapter 4 and complete TE-152 "Traffic Signal Proprietary Item Analysis Engineering and Traffic Study" prior to submitting for approval. Also District Traffic Engineer or designee approval is required prior to submitting to the Bureau of Maintenance and Operations.

18.3 Proprietary Equipment Approvals

Consult Publication 46, Chapter 4, Section 4.7 regarding the process for requesting proprietary equipment approvals.

18.4 Municipal Traffic Signal Specifications

Consideration shall be given to municipal traffic signal specifications during the design process. If a municipality has an adopted technical specification for traffic signal installations the designer and project owner should do their best to accommodate the municipality's needs since the municipality is the permittee and ultimate owner of the traffic signal. Where proprietary equipment is a requirement, follow the process in Chapter 4 of Publication 46. Installation and long term maintenance costs as well as long term functionality must be considered when adhering to a municipal specification.

CHAPTER 19. SIGNALS NEAR RAILROAD CROSSINGS

Traffic signals near rail crossings are covered in this Chapter.

19.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 19 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

In addition to the materials indicated throughout this chapter, please consult the MUTCD, Section 4D.27.

CHAPTER 19 - TRAFFIC CONTROL SIGNALS AT OR NEAR RAILROAD OR TRANSIT GRADE CROSSINGS

19.1 General

Consult the MUTCD, Sections 8C.09, 8C.10, and 8C.11 , Publication 371, and the Institute of Transportation Engineers' Preemption of Traffic Signals Near Railroad Crossings, A Recommended Practice.

At some street and highway intersections, railroad tracks are within or near the intersection area; therefore, it may be necessary that the control of the vehicular traffic signals be preempted to avoid stopping vehicles on the tracks and to avoid the conflicting aspects of traffic signals and the flashing train approach signal. Such control must assure clearance of the tracks by all vehicular traffic before the arrival of the train at the crossing.

It is important to remember that these at-grade crossings come under the jurisdiction of the Pennsylvania Public Utility Commission (PUC) and any application or request for traffic control that may affect a crossing must be reviewed and approved by the PUC. In view of the PUC's jurisdiction over train approach signals, all designs for traffic signals at intersections within 300 feet of a grade crossing must be reviewed by the PUC before a permit for vehicular traffic signals may be issued by the Secretary of Transportation. Control of the traffic flow near the grade crossing should be designed to provide the vehicle operators using the crossing a measure of safety at least equal to that which existed prior to the installation of such signals. Accordingly, design, installation, and operation should be based upon a total systems approach in order that all relevant features may be considered.

When there are railroad or transit crossings at grade within 300 feet of the intersection, in any direction, the following information shall be submitted for any traffic signal request.

a) The name(s) of the railroad or others using the crossing.

b) The type of crossing (freight, shifting, spur, etc.).

c) The number of crossings per day.

d) The approximate time of crossing(s), or number per hour in case of a trolley crossing.

e) The average length of time it takes the train to clear the area of the intersection.

f) The type and operation of crossing protection presently in use.
[If flashers, gates, bells, or combinations of these are present, determine the time element (maximum – minimum) that they are in operation prior to the time a train or transit vehicle reaches the crossing.]

g) The train speed on each approach to the crossing (track speeds).

h) The number and position of the tracks should be shown on the condition diagram.

19.2 Diagnostic Team

A diagnostic team should be established at the beginning of the project prior to beginning design of the traffic signal. The team shall consist of all stakeholders involved in the design, approval, operation, and maintenance of the grade crossing and signal. At a minimum the team should include:

a) Design engineer

b) PennDOT representatives from all applicable units (Traffic, Utilities, Project Management, etc.)

c) Operating railroad

d) PA Public Utilities Commission

e) Signal controller expert for the make and model to be used

f) Municipality (including the municipal traffic engineer)

g) Developer (if involved)

The purpose of the diagnostic team is to ensure the proper design and operation of the grade crossing and traffic signal by providing an opportunity for all stakeholders to provide input and relay concerns and technical details relevant to the installation and operation of the traffic signal.

The diagnostic team should meet at the project site during preliminary engineering. A sign-in sheet with each team member's contact information should be gathered and distributed to the team.

Information that should be gathered from the diagnostic team includes, but is not necessarily limited to:

a) Signal controller operations

    a. Preempt delay time,

    b. Controller response time

b) Emergency flash operation

c) Type of train(s) using the crossing

d) Train speeds

e) Train frequency

f) Railroad timings

    a. Gate delay

    b. Gate descent

    c. Gate down

g) Clearance/separation time

h) Advanced preemption time

i) Minimum walk time during right-of-way transfer

j) Pedestrian clearance time during right-of-way transfer

k) Crash history

19.3 Design

It is important to note that coordination with the PUC and railroad is required during the design of the preemption system to the traffic signal.

When the grade crossing is equipped with an active traffic control system, the normal sequence of highway intersection signal indications should be preempted upon approach of trains to avoid entrapment of vehicles on the crossing by conflicting aspects of the highway traffic signals and the grade crossings signals. The preemption feature requires an electrical circuit between the control relay of the grade crossing warning system and the traffic controller. The circuit shall be of the closed circuit principle; that is, the traffic signal controller is normally energized and the circuit is wired through a closed contact of the energized control relay of the grade crossing warning system. This is to establish and maintain the preemption condition during the time that the grade crossing signals are in operation. Where multiple or successive preemption may occur from differing modes, train actuation should receive first priority and emergency vehicles second priority.

Where a signalized highway intersection is adjacent to a grade crossing not provided with an active traffic control system, the possibility of vehicles being trapped on the crossing remains and preemption of the signal controller is usually required. However, at some locations, the characteristics of the crossing and intersection area along with favorable speeds of both vehicular and train traffic may permit alternate methods of warning traffic. Where preemption of the traffic signal control is determined to be desirable, consideration should be given to the installation of active traffic control devices at the grade crossing, since the cost of the grade crossing devices would usually represent a minor addition to the cost of the railroad circuits required for the preemption function.

The preemption sequence initiated when the train first enters the approach circuit shall at once bring into effect a highway signal display which will permit traffic to clear the tracks before the train reaches the crossing. The preemption shall not cause any short vehicular clearances, and all necessary vehicular clearances shall be provided. However, because of the relative hazards involved, pedestrian clearances may be abbreviated in order to provide the track clearance display as early as possible.

To avoid misinterpretation during the time the clear-out signals are green, consideration should be given to the use of 12-inch red lenses in the signals which govern highway traffic movement over the crossing with adequately screened or louvered green lenses in the clear-out signals beyond the crossing.

After the track clearance phase, the highway intersection traffic control signals should be operated to permit vehicle movements that do not cross the tracks, but shall not provide a through circular green or arrow indication for movement over the tracks. This does not prohibit green indications for highway traffic movements on a roadway paralleling the tracks.

Where feasible, consider operating traffic control signals near grade crossings so that vehicles are not required to stop on the tracks, even though in some cases this will increase the waiting time. The exact nature of the display and the location of the signals to accomplish this will depend on the physical relationship of the tracks to the intersection area.

Highway traffic control signals shall not be used on mainline railroad crossings in lieu of flashing light signals. However, at industrial track crossings and other places where train movements are very slow (as in switching operations), highway traffic control signals may be used in lieu of conventional flashing light signals to warn vehicle operators of the approach or presence of a train. The provisions relating to traffic signal design, installation, and operation are applicable as appropriate where highway traffic signals are so used.

Calculations for determining the right-of-way transfer time, queue clearance time, maximum preemption time, warning time, track clearance time, and vehicle-gate interaction check should be completed using the worksheet and instructions provided in Appendix D from the "Guide for Determining Time Requirements for Traffic Signal Preemption at Highway Rail Grade Crossings".

19.4 Plan Presentation

The train preemption intervals should be shown in the regular Movement, Sequence, and Timing Diagram, and numbered sequentially. The preemption times should not be included in any coordinated programs that may be present at the intersection.

A section of the traffic signal condition diagram should be reserved for Train Preemption Notes. This section should contain, at a minimum:

a) A note explaining which signals may remain green when going into train preemption.
b) A note explaining that the regular yellow and all-red intervals should time out before going into train preemption.
c) A note explaining the operation of the signal if preemption occurs during flashing operation.
d) A note explaining the operation of the pedestrian intervals.
e) A note explaining emergency preemption operation with train preemption.

19.5 Additional Considerations

The installation of train preemption at a new or existing signalized intersection will require evaluation of the left-turns. Termination of one or more through phases at the beginning of train pre-emption may cause a left-turn trap to occur depending on the phase sequencing. Protected-only left turn phasing should be considered at these locations.

If the left-turn phase would not normally be warranted, Capacity analysis should be completed comparing intersection levels-of-service and delays with and without the left turn phase. If inclusion of the left-turn phase results in unacceptable additional intersection delays, the use of an W25-1 “Oncoming Traffic has Extended Green” sign should be considered in lieu of the left-turn phase.

Two Series R8-8 “Do Not Stop on Tracks” signs should be considered for each direction at each track crossing location. One should be placed before the crossing (or gates if present), and one after.

CHAPTER 20. CRITERIA FOR THE DESIGN OF TRAFFIC SIGNAL SUPPORTS

This chapter is intended to define standard structural loadings for a typical mast arm. If a design is greater than what is provided, then a special design is needed. The information shown is a handout from Publication 149.

20.1 Handout from Publication 149

The information in this section is a handout of select pages of Chapter 20 from Publication 149. It is recommended that you review all original reference material to check for updates. The latest available version of the PennDOT publications can be found at the traffic signal portal, www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html#.

CHAPTER 20 - CRITERIA FOR THE DESIGN OF TRAFFIC SIGNAL SUPPORTS

The criteria stated herein shall be utilized in the design of galvanized steel structures used for the support of traffic signals. This chapter is intended to define standard structural loadings for a typical mast arm; if a design is greater then what is provided then a special design is needed.

20.1 Design Criteria for All Support Structures

(See Section 20.2; "Design Criteria for Strain Poles," for additional requirements for strain poles.)

Vertical poles and mast arms shall be designed and constructed in accordance with the 2001 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals" including interim specifications (2002, 2003, and 2006), hereafter referred to as the "AASHTO Specifications." In this part, the AASHTO Specifications article numbering system is followed. Where new sections, articles, equations, figures, or tables have been added, the suffix P is used to designate "Pennsylvania Article." All references to the AASHTO Specifications sections, articles, equations, figures, or tables carry the prefix A, except where noted. References to the AASHTO Specifications commentary carry the prefix AC, except where noted.

a) Provide base and connection plates as indicated in PennDOT Publication 148; TC-8801 sheet 10 of 10.

b) Provide a complete joint penetration weld for the connection of the column or shaft to the base plate and the connection of the arm to the flange plate for mast arm and strain pole structures only (this is not a requirement for pedestal poles).

c) Attach a back-up ring as specified in the AASHTO Specifications (Table 11-2, Detail 11). The back-up ring shall be attached to the plate with a full-penetration weld or with a continuous fillet weld around the interior face of the back-up ring.

d) For pole diameters 18 inch and larger, seal the top of the backing ring with a continuous 1/8-inch fillet weld to seal off the area between the ring and the pole. For pole diameters less than 18 inch, seal the top of the backing ring with a continuous bead of caulk after galvanizing to seal off the area between the ring and the pole.

e) Provide 6 inch complete penetration longitudinal shaft welds at the base plate connection.

f) The use of mast arm plate socket connections with fillet welds are prohibited.

g) Provide welded connections as shown in PennDOT Publication 148; TC-8801 sheet 10 of 10.

h) The minimum thickness for the main column and mast arms shall be 3/16 inch (7 gauge). When the main column and mast arms are less than 5/16 inch, submit a non-destructive testing plan where UT testing is required to be performed to the Structural Materials Section, Bridge Design and Technology Division, Bureau of Project Delivery.

i) Provide a built-up box on columns with mating splice plate for mast arm connection as shown in Example 8 of Figure 11-1(c) in AASHTO Specifications. With prior Department approval, alternate mast arm connections as shown in the AASHTO Specifications (Example 16 of Figure 11-1(c)) are permitted.

Introduction

Applicable Specifications

The following shall replace the first sentence of A1.3.

The following specification documents shall be referenced for additional information on design, materials, fabrication, and construction:

The following shall supplement A1.3.

PennDOT Publication 408.

General Features of Design

Roadside Requirements for Structural Supports

Breakaway Supports

The following shall supplement A2.5.2.

Breakaway supports or yielding-type supports shall not be used for traffic signal support structures, except when permitted by this Handbook and specified in the plans and/or specifications for the project.

Loads

Dead Load

The following shall supplement A3.5.

Dead loads for signs, traffic signals, backplates, brackets, and all appurtenances shall be as given in this Handbook.

Live Load

Delete A3.6.

Wind Load

The following shall replace A3.8.

Wind load shall be the pressure of the wind acting horizontally on the supports, signs, luminaires, traffic signals, and other attachments computed in accordance with this Handbook and AASHTO Appendix C.

Steel Design

Details of Design

Slip Type Field Splice

The following shall replace A5.14.3.

Telescoping (slip-fit) splices for mast arms, which rely solely on friction between the members for their connection, will not be permitted. A thru-bolt must be provided for a positive connection when such slip fit connections are used.

Welded Connections

The following shall supplement A5.15.

Transverse welds shall not be used to splice pole sections.

Anchor Bolts

Design Basis

The following shall supplement A5.17.3.

A minimum of six (6) anchor bolts shall be required.

Bending Stress in Anchor Bolts

The following shall replace A5.17.6.4.

The clearance between the bottom of the leveling nuts and the top of the concrete foundation shall not be greater than one bolt diameter.

Minimum Protection for Structural Steel

General

The following shall replace the first sentence of A5.18.1.

Steel structures shall be protected from the effects of corrosion including those manufactured of high strength steel, by means of galvanizing in accordance with ASTM A 123 (AASHTO M 111). Accessories and hardware shall also be protected from the effects of corrosion by means of galvanizing in accordance with ASTM A 153 (AASHTO M 232).

Fatigue Design

Fatigue Importance Factors

The following shall supplement A11.6.

Traffic signal structures with mast arms less than or equal to 60 feet shall be designed for Fatigue Category II. Traffic signal structures with mast arms greater than 60 feet shall be designed for Fatigue Category I. Strain poles should be considered as an alternative to traffic signal structures with mast arms greater than 60 feet.

Fatigue Design Loads

Galloping

The following shall replace A11.7.1.

The dead load and wind surface area of a standard mitigation device shall be considered in the design of cantilevered traffic signal support structures in accordance with the standard drawings. The mitigation device should be installed only within the 180-day monitoring period in accordance with the standard drawings.

Truck-Induced Gust

Delete A11.7.4.

Design Aids

This section shall supplement AASHTO Appendix B.

Stresses for Tubular Sections

The following shall supplement **Exhibit 20-1**:

Maximum shear stress due to torsion (fvt) for round stepped tubes (hot-swaged shrink fit) shall be computed using the following formula:

$$f_{vt} = \frac{M_z k_t}{6.28 R^2 t}$$

Where:

fvt	=	Maximum shear stress due to torsion, lb/in2
Mz	=	Total torsional moment, in-lb
R	=	Radius at mid-thickness of smaller diameter tube wall, in
t	=	Thickness of smaller diameter tube wall, in
kt	=	Stress concentration factor due to change in tube diameter (use kt = 1.20)

Alternate Method for Wind Pressures

This section shall supplement AASHTO Appendix C.

Wind Load

The following shall replace the second sentence of the first paragraph of C.2:

The design wind pressures shall be computed using the wind pressure formula, Eq. C-1, for a fastest-mile wind speed (Vfm) of 80 MPH as shown in Figure C-3.

20.2 Design Criteria for Strain Poles

(*See Section 20.1*; "Design Criteria for All Support Structures," for additional requirements.)

Allowable Unit Stresses

The design and construction of strain pole structures shall conform to the allowable unit stresses provided in Section 5 – Steel Design in the 2001 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals", hereafter referred to as the "AASHTO specifications."

Span and Tether Wires

Span wire shall conform to ASTM A 475, Class A, Siemens-Martin Grade, or ASTM B 416. Tether wire shall conform to ASTM A 475, Class A, Common Grade.

Strain poles shall be designed for a sag of 5% of the span distance between poles under dead load. In computing dead load, the mass of the span and tether wire shall be based on a value of 1 lb/ft [load=1 lb/ft].

Strain Pole Deflection

The maximum horizontal deflection of strain poles, at the span wire connection, due to dead loads only, shall be 2.5% of the distance measured from the base of the strain pole to the span wire connection point.

When strain poles support more than one span, the resultant horizontal deflection, due to the combined action of all span wire loadings, shall not exceed the above.

Stringing Tension

To determine the stringing tension in the span wire system between the two strain poles, due to the dead loads of traffic signals, traffic signs, signal wire, and other attachments, the following procedure[1] shall be used:

a) Determine the effective load of each item on the span wire (traffic signal, traffic sign, signal wire, and/or other attachment) by adding to the load of each item, the load of the span wire for a length equal to half the distance in each direction to the next adjacent item or strain pole.

b) Determine the vertical reaction at each strain pole structure by summing the moments (due to the effective load of each item and the vertical reaction at the strain pole) about the other strain pole structure. As a check, the sum of the vertical reactions of the two strain pole structures should be equivalent to the sum of the effective loads of each item.

c) Determine the lowest point due to sag in the span wire by finding the point at which the slope of the span wire changes sign (which will be at the location of one of the load items, most probably a traffic signal). Beginning with the vertical reaction at one of the strain pole structures, determine the vertical shear acting on the span wire by successively and algebraically adding the effective load of each item in moving across to, and ending with the vertical reaction of, the other strain pole structure. The low point in the span wire is the point at which the sign of the vertical shear changes (which indicates that the slope of the span wire has changed). If the vertical shear happens to be zero at any point between the strain pole structures, this indicates that two load items are at the same elevation and share the low point of the span wire. As a check, the vertical shear must begin and end at zero at the constituent strain pole structures.

d) Determine the stringing tension by evaluating the summation of moments about the low point in the span wire. Since the span wire cannot resist bending moment, set the sum of the moments about the low point of all forces acting on the span wire between the low point and either of the strain pole structures equal to zero, where the horizontal pull acting on that strain pole structure is an unknown force acting at a distance equal to the maximum allowable sag (5% of the span distance) above the low point of the span wire. The stringing tension in the span wire can then be determined by solving the aforementioned summation for the unknown horizontal force acting on each of the strain pole structures.

e) In the case where a strain pole structure supports wires and loading from more than one span, determine the stringing tension of each span wire that it supports, and combine these separate stringing tensions to produce the maximum resultant stringing tension acting on the given strain pole structure to evaluate the required design and construction considerations.

Sag

To determine the sag at any load item on the span wire, assume that the span wire follows a straight line between adjacent load items which slopes at a rate equal to the vertical shear at the given load item divided by the horizontal stringing tension. The change in elevation between successive load items is then equivalent to the slope of the span wire between these two load items multiplied by the distance between them. As a check, the elevation of the span wire connection at the second strain pole structure must be obtained by beginning with the connection at the first strain pole structure and successively adding the respective elevation increments in moving across the span wire.

Application of Wind Load (see Figure B-1)

W_h for strain pole structures may be applied as a series of concentrated loads along the span wire normal to the span, and W_p (normal to sign faces) shall be applied normal to the span. Strain poles (assuming a single span wire is attached to the support) shall be designed for wind loads W_h and W_p, (normal to the sign faces) applied normal to the span. Only the wind load, W_v, shall account for wind from any direction. The basic load, BL (see Section 3.9.3 of the AASHTO specifications) normal to the span shall be the effect from the wind load W_v, applied at the center of pressure of the support. The full transverse component shall be applied to the support.

Design Tension

For a strain pole structure with the ends of the span wire at the same elevation, the following approximate method may be used to determine the force component in the span wire parallel to the span for a wind loading normal to the span.

The span wire loadings (dead load, wind, and ice) are applied as a series of concentrated loads along the wire to represent the actual uniform loadings with a minimum of five equal concentrated loads recommended. The tension forces throughout the wire now become a series of vectors with the vector component in the direction of the span of equal magnitude for each vector. Knowing that the ratio of the vector length over the vector force is proportional to the ratio of the vector component length over a component force, the length of each vector may be expressed by the following equation:

$$\text{Vector Length} = \sqrt{\left(F_x^2 + F_y^2 + F_z^2\right)}\frac{d_x}{F_x}$$

Where:

$$\sqrt{\left(F_x^2 + F_y^2 + F_z^2\right)} = \text{Resultant vector force}$$

F_x = Vector force component in direction of span

F_y = Vector force component in vertical direction

F_z = Vector force component in direction of wind

d_x = Vector length component in direction of span*

(* If sag is small in relation to span length, neglect any displacements in direction of span.)

Fy and Fz for each vector (between concentrated loads of wire, signals, signs, etc.) may be found by the equations of equilibrium for a body in space. The total length of the span wire may be found for a given sag for a loading of dead load alone. The sum of all the vector lengths is equated to the total length of the span wire. F_x may be solved for since it is the only unknown in the equation. A number of trials may be necessary to closely approximate the actual value.

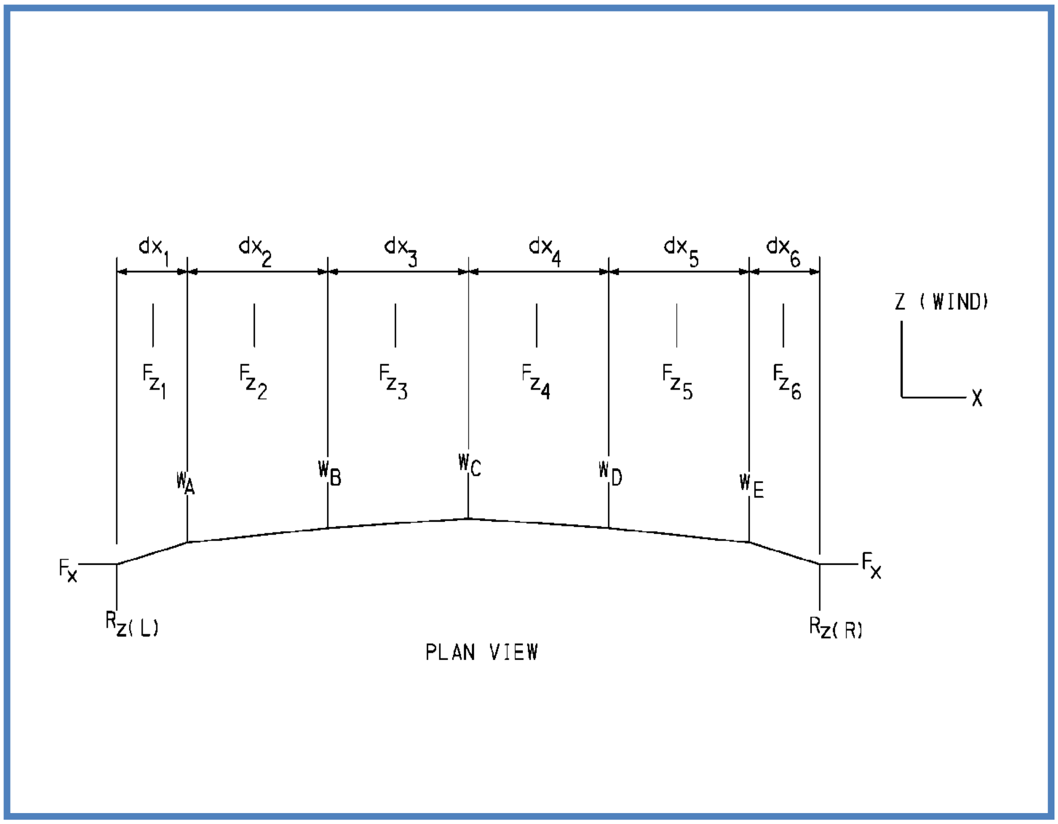
The following illustrates a procedure for determining the vector components F_x and F_z:

In **Exhibit 20-1**:

$$F_{Z1} = R_{Z(L)}$$
$$F_{Z2} = R_{Z(L)} - W_A$$
$$F_{Z3} = R_{Z(L)} - W_A - W_B$$
$$F_{Z4} = R_{Z(R)} - W_E - W_D$$
$$F_{Z5} = R_{Z(R)} - W_E$$
$$F_{Z6} = R_{Z(R)}$$

$$\text{The total length of span wire} = \sqrt{\left(F_x^2 + F_{y1}^2 + F_{z1}^2\right)}\frac{d_{x1}}{F_x} + \sqrt{\left(F_x^2 + F_{y2}^2 + F_{z2}^2\right)}\frac{d_{x2}}{F_x} + \cdots$$

Exhibit 20-1 Force Diagram



The reactions $R_{z(L)}$ and $R_{z(R)}$ may be determined by summing moments about a vertical line at the right end and left end of the span wire respectively. A similar procedure is used in determining F_y components. The reactions in the vertical direction ($R_{y(L)}$ and $R_{y(R)}$) may be determined by summing moments about a horizontal line to the ends of the span wire.

The above procedure neglects the effect of the strain pole deflection. This results in excessively conservative values for the wire's force component in the direction of the span (F_x). The effects of the strain pole deflections on the span wire's force component should be considered by calculating the deflections of the strain pole at the span wire connection, in the direction of the span, and recomputing the wire's force component, as above, after making adjustments to the span to account for the strain pole deflections. The reduction in tension does not apply to dead load tension. Given the wire is installed with the specified sag after the pole dead load deflection already has occurred, the wire tension is not reduced.

Design Stresses

Strain pole structures shall be designed and constructed to withstand maximum stresses based on Group I, Group II, and Group III loadings (whichever controls), as defined in the AASHTO specifications. In the case of strain poles which support more than one span, the resultant of the respective tensions for each span shall be used in combination with the wind applied in the direction which produces maximum stress.

20.3 Acceptance of Structural Designs

The manufacturer shall submit design calculations and detailed structural drawings for those signal supports that are proposed to be supplied in Pennsylvania. In addition, the manufacturer must provide PennDOT with certification, from a professional engineer registered in Pennsylvania, indicating that the designs comply with PennDOT's criteria and are adequate to support the loads specified therein.

After acceptance by the PennDOT, the manufacturer will not be required to submit design calculations or structural drawings on a project-by-project basis, except for signal supports which exceed the standard structure loadings indicated herein. For these special designs, a submission of design calculations, structural drawings and the professional engineer's certification must be made for each different support.

Shop drawings will be required for all traffic signal supports on each project (PennDOT Approved Shop Drawings).

For structural design computations use PennDOT's District Design spreadsheets which include:

Mast Arm Analysis provides a tool to evaluate whether a traffic signal complies to loading requirements specified within Publication 149, Chapter 20 and TC-8801. If the loading is exceeded within this spreadsheet then a special traffic signal structural support and foundation design would be needed.

Span Wire Analysis provides a tool to determine the appropriate span wire tension by providing geometric specific information. This will ensure that appropriate design tensions are used for span wires.

Strain Pole Analysis provides a tool to evaluate whether a traffic signal complies to loading requirements specified within Publication 149, Chapter 20 and TC-8801. If the loading is exceeded within this spreadsheet then a special traffic signal structural support and foundation design would be needed.

Exhibit 20-2 Strain Pole Structure

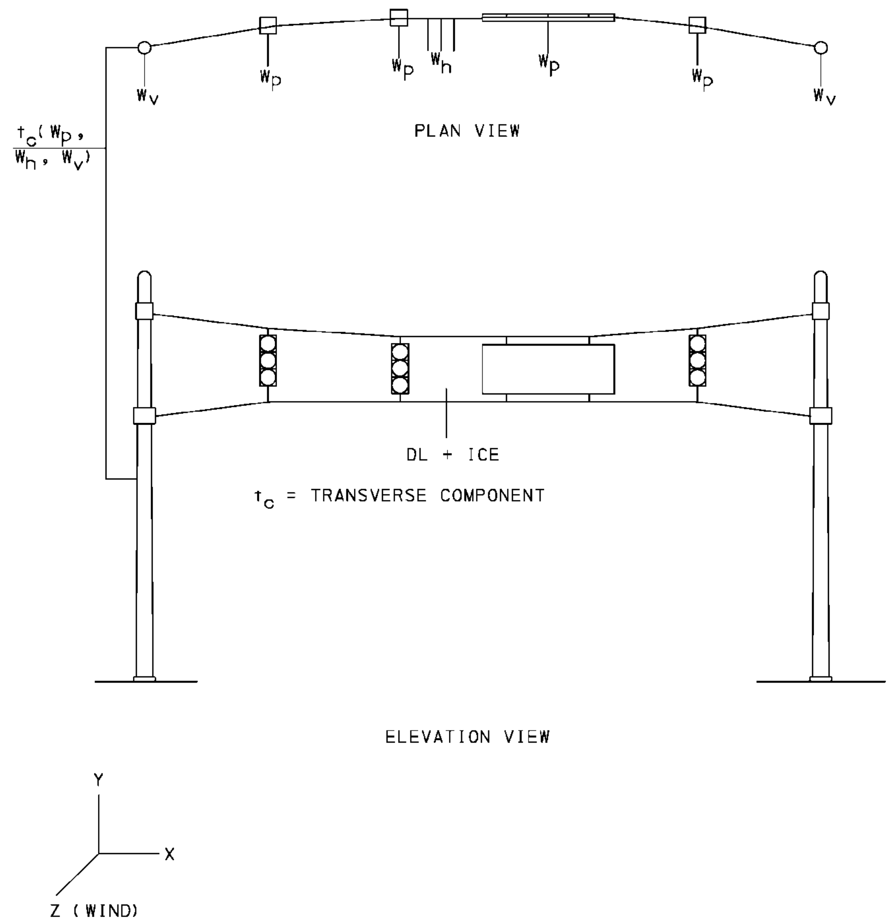
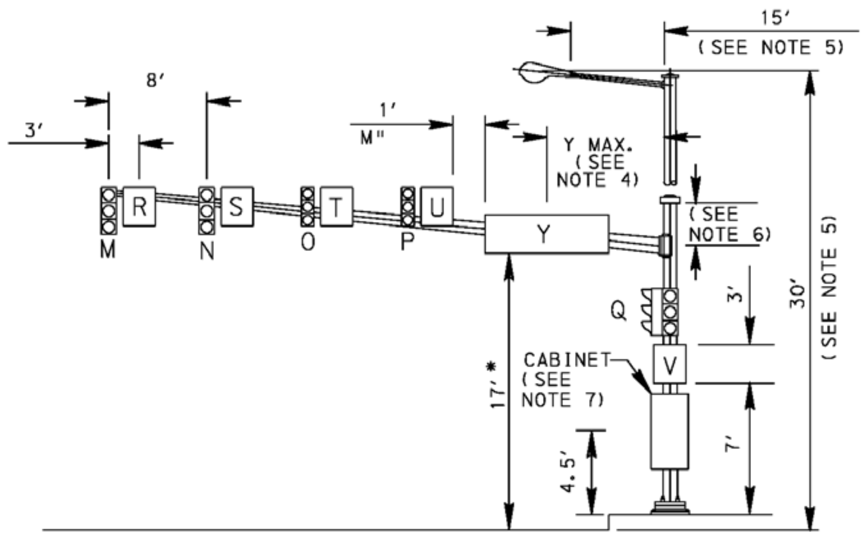


Exhibit 20-3 Mast Arm – Standard Structure Loading



* CLEARANCE BETWEEN ROADWAY AND LOWEST SIGN OR SIGNAL HEAD

NOTES :

1. THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY IN ORDER TO SHOW HORIZONTAL AND VERTICAL DIMENSIONS. SEE MAST ARM IN STANDARD STRUCTURE LOADING TABLE FOR AREAS AND LOADS TO BE USED FOR EACH ITEM UNDER STANDARD STRUCTURE LOADING. SIGNAL HEADS DEPICTED ON THIS DRAWING MAY DIFFER FROM THE SIGNAL HEADS SHOWN IN THE STANDARD STRUCTURE LOADING TABLE. (FOR EXAMPLE, THIS DRAWING MAY DEPICT A 3-SECTION HEAD WHERE A 5-SECTION HEAD IS USED IN THE TABLE.)
2. ASSUME ALL OVERHEAD SIGNALS HAVE 12" LENSES WITH BACKPLATES 5" BORDER.
3. ASSUME SIGNS R, S, T, U AND V ARE 30" BY 36". FOR MAST ARM LENGTHS OF 10' OR LESS, SIGN Y IS ASSUMED TO BE 72" BY 21". FOR ALL OTHER MAST ARM LENGTHS, SIGN Y IS ASSUMED TO BE 96" BY 32".
4. Y MAX. IS THE MAXIMUM ALLOWABLE DISTANCE FROM THE SHAFT TO THE CENTROID OF SIGN Y.
5. FOUNDATION DESIGN IN PUBLICATION 148 ASSUMES LUMINAIRES, WHEN USED, HAVE A 30' MOUNTING HEIGHT AND A 15' ARM LENGTH.
6. WHEN THE SHAFT OF THE SUPPORT IS EXTENDED IN LENGTH BY 36" MINIMUM TO ALLOW A FUTURE LUMINAIRE VIA AN OVERLAP SLIP JOINT, PROVIDE APPROPRIATE FOUNDATION AND SUPPORT DESIGN.
7. FOUNDATION DESIGN IN PUBLICATION 148 ASSUMES A CABINET, WHEN USED, HAS A 4'-3" HEIGHT, 2'-6" WIDTH, 1'-10" DEPTH AND DEAD LOAD OF 281 lbs..

Exhibit 20-4 Mast Arm – Standard Structure Loading Tables

Note: For standard structure loading, place indicated signals and signs beginning at the furthermost point on the arm and then proceeding toward the shaft in accordance with the dimensions shown on **Exhibit 20-3** and Publication 148, TC-8801.

W= Load in (lb) A=Area in (ft^2)

Mast Arm Length (0-10 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	70				123					39	87	5.2
A	8.76				8.82					7.48	10.5	

Mast Arm Length (>10-15 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	70				123	39				39	106	6.6
A	8.76				8.82	7.48				7.48	21.33	
OR												
W	70				123					39	106	9.5
A	8.76				8.82					7.48	21.33	

Mast Arm Length (>15-20 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70			123	39				39	106	6.6
A	13.89	8.76			8.82	7.48				7.48	21.33	

Mast Arm Length (>20-25 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70			123	39	39			39	106	8.5
A	13.89	8.76			8.82	7.48	7.48			7.48	21.33	

Mast Arm Length (>25-30 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70	97		123	39	39			39	106	8.5
A	13.89	8.76	13.89		8.82	7.48	7.48			7.48	21.33	
OR												
W	97	70			123	39	39			39	106	13.5
A	13.89	8.76			8.82	7.48	7.48			7.48	21.33	

Mast Arm Length (>30-35 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70	97		123	39	39	39		39	106	10.8
A	13.89	8.76	13.89		8.82	7.48	7.48	7.48		7.48	21.33	

Mast Arm Length (>35-40 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70	70	97	123	39	39		39	39	106	7.9
A	13.89	8.76	8.76	13.89	8.82	7.48	7.48		7.48	7.48	21.33	
OR												
W	97	70	70	70	123	39	39			39	106	10.8
A	13.89	8.76	8.76	8.76	8.82	7.48	7.48			7.48	21.33	
OR												
W	97	70	97		123	39	39	39		39	106	15.7
A	13.89	8.76	13.89		8.82	7.48	7.48	7.48		7.48	21.33	

Mast Arm Length (>40-45 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70	70	97	123	39	39		39	39	106	12.8
A	13.89	8.76	8.76	13.89	8.82	7.48	7.48		7.48	7.48	21.33	
OR												
W	97	70	70	70	123	39	39			39	106	15.7
A	13.89	8.76	8.76	8.76	8.82	7.48	7.48			7.48	21.33	
OR												
W	97	70	97		123	39	39	39		39	106	20.7
A	13.89	8.76	13.89		8.82	7.48	7.48	7.48		7.48	21.33	

Mast Arm Length (>45-50 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70	70	97	123	39	39		39	39	106	17.7
A	13.89	8.76	8.76	13.89	8.82	7.48	7.48		7.48	7.48	21.33	
OR												
W	97	70	70	70	123	39	39			39	106	20.7
A	13.89	8.76	8.76	8.76	8.82	7.48	7.48			7.48	21.33	
OR												
W	97	70	97		123	39	39			39	106	28.5
A	13.89	8.76	13.89		8.82	7.48	7.48			7.48	21.33	

Mast Arm Length (>50-60 ft.)

	Signals					Signs						Max Y (ft)
	M	N	O	P	Q	R	S	T	U	V	Y	
W	97	70	70	97	123	39	39		39	39	106	27.9
A	13.89	8.76	8.76	13.89	8.82	7.48	7.48		7.48	7.48	21.33	
OR												
W	97	70	70	70	123	39	39			39	106	30.8
A	13.89	8.76	8.76	8.76	8.82	7.48	7.48			7.48	21.33	
OR												
W	97	70	97		123	39	39			39	106	38.7
A	13.89	8.76	13.89		8.82	7.48	7.48			7.48	21.33	

Exhibit 20-5 Loads and Projected Wind Areas for Traffic Signal Heads

Lens Size– in All Sections	Signal Configuration (1) (See Exhibit 20-6)	Signal Sections Each Direction	Directions	Load- Pound (lb) Without backplate (2)	Wind Area - Square feet (ft^2) Without Backplate (3),(4)	Load - Pound (lb) With Backplate (2)	Wind Area - Square feet (ft^2) With Backplate 5 in Border (3),(5)	Wind Area - Square feet (ft^2) With Backplate 8 in Border (3),(5)
8	A	5	1	58	3.99	69	9.17	12.46
8	B	3	2	82	2.4	88	5.97	8.79
8	C	3	2	84	5.12	90	8.69	11.51
8	B	4	2	101	3.19	109	7.42	10.69
8	C	4	2	103	6.82	111	11.09	14.32
8	B	5	2	110	3.99	131	9.17	12.46
8	D	3	3	120	5.12	129	8.69	11.51
8	E	3	3	120	7.84	129	11.41	14.23
8	D	4	3	147	6.82	159	11.09	14.32
8	E	4	3	147	10.45	159	14.72	17.95
8	F	3	4	156	7.84	168	11.41	14.23
8	F	4	4	193	10.45	209	14.72	17.95
12	A	3	1	66	4.17	70	8.76	12.23
12	A	4	1	84	5.55	89	11.04	15.09
12	A	5	1	90	6.94	97	13.89	17.9
12	B	3	2	121	4.17	129	8.76	12.23
12	C	3	2	123	8.82	131	13.41	16.88
12	B	4	2	155	5.55	165	11.04	15.09
12	C	4	2	157	11.75	167	17.24	21.29
12	B	5	2	179	6.94	189	13.89	17.9
12	D	3	3	178	8.82	190	13.41	16.88
12	E	3	3	178	13.47	190	18.06	21.53
12	D	4	3	227	11.75	242	17.24	21.29
12	E	4	3	227	17.95	242	23.44	27.49
12	F	3	4	233	13.47	249	18.06	21.53
12	F	4	4	299	17.95	318	23.44	27.49
12PED	A	2	1	43	2.77	-	-	-
12PED	C	2	2	86	6.93	-	-	-
18PED	A	1	1	40	2.47	-	-	-
18PED	C	1	2	80	5.14	-	-	-

Notes:

(1) Refer to **Exhibit 20-6**, Traffic Signal Configurations and Designations.

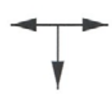
(2) A one-way 8-inch lens section is 9 pounds without attachment hardware and backplate. A one-way 12-inch lens section is 15 pounds without attachment hardware and backplate.

(3) The area for an 8-inch lens section without backplate is based on a 10 inch height by a 11.5 inch width, and the area for a 12-inch lens section without backplate is based on a 13.5 inch height by a 14.8 inch width.

(4) The area for a 2-section pedestrian signal assumes a 14.1 inch height and a 14.1 inch width for each section. The area of a 1-section pedestrian signal assumes a 18.9 inch height and a 18.9 inch width.

(5) Values in *shaded area* are generally not used.

Exhibit 20-6 Traffic Signal Configurations and Designations

Designation	Traffic Signal Configuration	Directions
A		1
B		2
C		2
D		3
E		3
F		4