OS-299 (7-08)

pennsylvania
DEPARTMENT OF TRANSPORTATION

TRANSMITTAL LETTER

PUBLICATION:

Publication 149 - Traffic Signal Design Handbook

DATE:

10/14/10

SUBJECT:

Revision to Publication 149, Chapter 20 (Criteria for the Design of Traffic Signal Supports) - March 2009 Edition

INFORMATION AND SPECIAL INSTRUCTIONS:

The revised Pub 149, Chapter 20 (Oct 2010) replaces Pub. 149 Chapter 20 (March 2009). The revised Chapter 20 goes into effect immediately. Pub. 149 - (Chapter 20 Rev Oct 2010) is attached. This revision coincides with SOL 407-10-06: Update to Publication 148 (Traffic Standards – Signals [TC-8800 Series]) and Publication 149 (Traffic Signal Design Handbook), Chapter 20 (Criteria for the Design of Traffic Signal Supports).

This publication is available for download by PennDOT staff at: ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/Pub%20149.pdf.

Hard copies are also available for purchase through the PennDOT Sales Store.

CANCEL AND DESTROY THE FOLLOWING:

Publication PUB 149, Chapter 20 dated March 2009.

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

TRAFFIC SIGNAL DESIGN HANDBOOK

PUBLICATION 149

October 14, 2010 – Metric and English Dimensions Edition

PUB-149 (10-10)

BUREAU OF HIGHWAY SAFETY AND TRAFFIC ENGINEERING
PUBLICATION 149
TRAFFIC SIGNAL DESIGN HANDBOOK

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1.0 GENERAL

This Handbook is to be used as a guide for the design and operation of a traffic signal installation. The guidelines established in this Handbook may be used to design new traffic control signals and existing traffic control signal features that are to be modified.

As indicated in Pennsylvania Department of Transportation (PennDOT) Publication 212, the Commonwealth of Pennsylvania has adopted the Manual of Uniform Traffic Control Devices (MUTCD), as published by the Federal Highway Administration (FHWA). The following types and uses of highway traffic signals are discussed in Part 4 of the MUTCD 2003 Edition and herein: traffic control signals; flashing beacons; pedestrian signal heads; traffic control signals at or near highway-rail grade crossings; traffic control signals for emergency vehicle access; lane-use control signals; traffic control signals for freeway entrance ramps; traffic control signals for one-lane, two-way facilities; and in-roadway lights. Information is also contained in the Pennsylvania Vehicle Code (75 Pa.C.S.).

PennDOT publications that also contain supplemental information pertaining to traffic control signals and related traffic control devices include: Publication 35 (Bulletin 15), Publication 46, Publication 111M, Publication 148, Publication 191, Publication 212, Publication 213, Publication 236M, and Publication 408.

This publication contains some direct quotations from the MUTCD 2003 Edition, and they are shown in italic print. Definitions of common terms are found in Chapter 24.0 of this publication.

1.1 TRAFFIC CONTROL SIGNALS

A traffic control signal installation shall be operated in either a steady (stop-and-go) mode or a flashing mode at all times.

All traffic signal installations shall be provided with an electrical flashing mechanism supplementary to the controller unit. A manual switch, or where appropriate, automatic means, shall be provided to actuate the flashing mechanism. The controller unit shall be removable without affecting the flashing mechanism.

When used as a flashing signal (during emergencies or periods of low traffic flow), normally yellow indications should be used for the major street and red indications for the other approaches.

Each vehicular signal face shall have at least three lenses, but not more than five. The lenses shall be red, yellow, or green in color, and shall give a circular or arrow type of indication. Allowable exceptions to the above are where a single section right green arrow is used alone to indicate a continuous movement or where a red and a green indication are used on a single face for a ramp metering signal.

1.2 FLASHING BEACONS

Consult the MUTCD 2003 Edition Chapter 4K Flashing Beacons. Additional information is also contained in Appendix A and Appendix B of this publication.

1.3 PEDESTRIAN SIGNAL HEADS

Pedestrian signal heads provide special types of traffic signal indications intended for the exclusive purpose of controlling pedestrian traffic. These indications consist of the solid illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DONT WALK).

All new pedestrian signal head indications shall be rectangular in shape and shall consist of filled symbolized messages, except that existing pedestrian signal head indications with lettered messages may be retained for the remainder of their useful service life.

All new pedestrian signal heads shall be countdown pedestrian signals, except at locations where the crossing is so short that the duration of the pedestrian change interval is 3 seconds or less. Countdown pedestrian signals shall meet the design and operational requirements of the MUTCD 2003 Edition Section 4E.07.

When illuminated, the WALK indication shall be white, with all except the symbols or letters obscured by an opaque material. When illuminated, the DONT WALK indication shall be Portland orange, with all except the symbols or letters obscured by an opaque material.

Pedestrian signal heads shall be illuminated during "stop-and-go" operation. They shall not be illuminated during flashing operation. However, vehicular signal heads specifically for pedestrians may be illuminated during flashing operation. During periods of special preemption, pedestrian signal heads shall generally display a steady DONT WALK indication.

Accessible Pedestrian Signals (APS) should conform to Sections 4E.06 and 4E.09 of the MUTCD 2003 Edition.

1.4 TRAFFIC CONTROL SIGNALS AT OR NEAR HIGHWAY-RAIL GRADE CROSSINGS

Consult the MUTCD 2003 Edition Section 4D.13, Part 8 Traffic Controls for Highway-Rail Grade Crossings, Part 10 Traffic Controls for Highway-Light Rail Transit Grade Crossings, and Chapter 14.0 of this publication.

When there are railroad or transit crossings at grade within 60 m (200 ft) of the intersection, in

any direction, the following information shall be submitted for any traffic signal request.

1. The name(s) of the railroad or others using the crossing.
2. The type of crossing (freight, shifting, spur, etc.).
3. The number of crossings per day.
4. The approximate time of crossing(s), or number per hour in case of a trolley crossing.
5. The average length of time it takes the train to clear the area of the intersection.
6. 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.]
7. The train speed on each approach to the crossing (track speeds).
8. The number and position of the tracks should be shown on the condition diagram.

1.5 TRAFFIC CONTROL SIGNALS FOR EMERGENCY VEHICLE ACCESS

Consult the MUTCD 2003 Edition Chapter 4F Traffic Control Signals for Emergency Vehicle Access.

1.6 LANE-USE CONTROL SIGNALS

Consult the MUTCD 2003 Edition Chapter 4J Lane-Use Control Signals.

1.7 TRAFFIC CONTROL SIGNALS FOR FREEWAY ENTRANCE RAMPS

Consult the MUTCD 2003 Edition Chapter 4H Traffic Control Signals for Freeway Entrance Ramps.

All ramp control signals shall utilize vertically aligned lenses with a minimum nominal diameter of 200 mm (8 in).

1.8 TRAFFIC CONTROL SIGNALS FOR ONE-LANE, TWO-WAY FACILITIES

Consult the MUTCD 2003 Edition Chapter 4G Traffic Control Signals for One-Lane, Two-Way Facilities and PennDOT Publication 213.

1.9 IN-ROADWAY LIGHTS

Consult the MUTCD 2003 Edition Chapter 4L In-Roadway Lights. The Department considers these devices to be experimental devices. As such, a limited number of installations statewide may be considered for evaluation purposes. PennDOT Engineering District Office and Central Office approval must be requested and obtained on a case-by-case basis in advance of installation.

2.0 MEANING AND APPLICATION OF COLORS AND INDICATIONS

2.1 CIRCULAR RED

2.1.1 MEANING

(a) Vehicular Traffic: Vehicular traffic facing a steady circular red shall stop at a clearly marked stop line, or if none, before entering the crosswalk on the near side of the intersection, or if none, then before entering the intersection and shall remain standing until an indication to proceed is displayed, except as provided in the next paragraph.

Unless a sign is in place prohibiting a turn, vehicular traffic facing a steady circular red may enter the intersection to turn right, or to turn left from a one-way roadway onto a one-way roadway, after stopping as required above. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

(b) Pedestrian Traffic: Unless otherwise directed by a pedestrian signal, pedestrians facing a steady circular red shall not enter the roadway.

2.1.2 APPLICATION

(a) Vehicular Traffic: A steady circular red shall be given when it is intended to prohibit traffic from entering the intersection or other controlled area.

A steady circular red may be displayed with the appropriate green arrow indications when it is intended to permit vehicular traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the controlled area.

(b) Pedestrian Traffic: A steady circular red shall be given when it is intended to prohibit all traffic, except pedestrians directed by a pedestrian signal, from entering the roadway.

2.2 CIRCULAR YELLOW

2.2.1 MEANING

(a) Vehicular Traffic: Vehicular traffic facing a steady circular yellow is thereby warned that the related green movement is being terminated or that a red indication will be displayed immediately thereafter.

(b) Pedestrian Traffic: Pedestrians facing a steady circular yellow, unless otherwise directed by a pedestrian signal, are thereby advised that there is insufficient time to cross

the roadway before a red indication is shown and no pedestrian shall then start to cross the roadway.

2.2.2 APPLICATION

A steady circular yellow shall be given following a circular green indication in the same signal face.

2.3 CIRCULAR GREEN

2.3.1 MEANING

(a) Vehicular Traffic: Vehicular traffic facing a circular green may proceed straight through or turn right or left unless a sign indicates otherwise. But vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfully within the intersection or an adjacent crosswalk, at the time such signal is exhibited.

(b) Pedestrian Traffic: Unless otherwise directed by an official sign or by a pedestrian signal, pedestrians facing a circular green may proceed with caution across the roadway within any marked or unmarked crosswalk.

2.3.2 APPLICATION

A steady circular green shall be given only when it is intended to permit traffic to proceed in any direction which is lawful and practical.

2.4 GREEN ARROW

2.4.1 GENERAL

(a) Vehicular Traffic: The green arrow shall be reserved to indicate those vehicular movements which are protected from conflicting vehicular and pedestrian movement(s) across or into the path of the vehicular movement indicated by the green arrow.

(b) Pedestrian Traffic: Use of green arrows will necessitate separate signal indications for the pedestrian or the prohibition of the pedestrian conflict. Turn arrows shall not be used in conflict with the WALK indication, or circular green indication permitting walk.

2.4.2 STRAIGHT-THROUGH GREEN ARROW

Vehicular traffic facing the straight-through green arrow may proceed through, but shall not turn right or left.

2.4.3 LEFT GREEN ARROW

Vehicular traffic facing a left green arrow may proceed to the left, but shall not turn right or go straight through unless a steady circular green is displayed in the same face.

A left green arrow may be displayed with a circular red when through movements are stopped on the same approach.

A left green arrow may be displayed over an exclusive left turn lane, either so designed or signed, when accompanied by through movements on that approach.

A left green arrow may be displayed with a circular green.

Left green arrows shall not be used in a right approach signal.

2.4.4 RIGHT GREEN ARROW

Vehicular traffic facing a right green arrow may proceed to the right, but shall not turn left or go straight through unless a circular green is displayed in the same face.

A right green arrow may be displayed with a circular red when through movements are stopped on that approach.

A right green arrow may be displayed over an exclusive right turn lane, either so designed or signed, when accompanied by through movements on that approach.

Right green arrows shall not be used in a left approach signal.

2.5 YELLOW ARROW

2.5.1 MEANING

(a) Vehicular Traffic: Vehicular traffic facing a steady yellow arrow is thereby warned that the related green movement is being terminated or that a red indication will be displayed immediately thereafter.

(b) Pedestrian Traffic: Pedestrians facing a steady yellow arrow, unless otherwise directed by a pedestrian signal, are thereby advised that there is insufficient time to cross the roadway before a red indication is shown and no pedestrian shall then start to cross the roadway.

2.5.2 APPLICATION

A steady yellow arrow shall be used to terminate a green arrow which is displayed simultaneously with a circular red in the same signal face.

A steady yellow arrow shall be used to terminate a green arrow in a separate signal face or faces controlling only a separately controlled turn lane(s).

A steady yellow arrow shall be used to indicate the change interval following the termination of a green arrow which has been displayed simultaneously with a continuing circular green in the same signal face.

2.6 MUTCD PROVISIONS

The MUTCD 2003 Edition Section 4D.04 Meaning of Vehicular Signal Indications and Section 4D.05 Application of Steady Signal Indications indicate:

Section 4D.04 Meaning of Vehicular Signal Indications

Support:

The "Uniform Vehicle Code" (see Section 1A.11) is the primary source for the standards for the meaning of vehicular signal indications to both vehicle operators and pedestrians as set forth below, and the standards for the meaning of separate pedestrian signal indications as set forth in Section 4E.02.

Standard:

The following meanings shall be given to highway traffic signal indications for vehicles and pedestrians:

A. Steady green signal indications shall have the following meanings:

1. Traffic, except pedestrians, facing a CIRCULAR GREEN signal indication is permitted to proceed straight through or turn right or left except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, or roadway design. But vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfully within the intersection or an adjacent crosswalk, at the time such signal indication is exhibited.

2. Traffic, except pedestrians, facing a GREEN ARROW signal indication, shown alone or in combination with another signal indication, is permitted to cautiously enter the intersection only to make the movement indicated by such arrow, or such other movement as is permitted by other signal indications shown at the same time. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

3. Unless otherwise directed by a pedestrian signal head, pedestrians facing any green signal indication, except when the sole green signal indication is a turn arrow, are permitted to proceed across the roadway within any marked or unmarked crosswalk. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the green signal indication is first shown.

B. Steady yellow signal indications shall have the following meanings:

1. Traffic, except pedestrians, facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication is thereby

warned that the related green movement is being terminated or that a red signal indication will be exhibited immediately thereafter when vehicular traffic shall not enter the intersection.

2. *Pedestrians facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication, unless otherwise directed by a pedestrian signal head, are thereby advised that there is insufficient time to cross the roadway before a red signal indication is shown, and no pedestrian shall then start to cross the roadway.*

C. *Steady red signal indications shall have the following meanings:*

1. *Vehicular traffic facing a steady CIRCULAR RED signal indication alone shall stop at a clearly marked stop line, but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, then before entering the intersection, and shall remain stopped until a signal indication to proceed is shown, or as provided below.*

   Except when a sign is in place prohibiting a turn on red or a RED ARROW signal indication is displayed, vehicular traffic facing a CIRCULAR RED signal indication is permitted to enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

2. *Vehicular traffic facing a steady RED ARROW signal indication shall not enter the intersection to make the movement indicated by the arrow and, unless entering the intersection to make another movement permitted by another signal indication, shall stop at a clearly marked stop line; but if there is no stop line, before entering the crosswalk on the near side of the intersection, or if there is no crosswalk, then before entering the intersection, and shall remain stopped until a signal indication permitting the movement indicated by such RED ARROW is shown.*

   When an R10-17a sign (see Section 2B.45) is in place permitting a turn on a RED ARROW signal indication, vehicular traffic facing a RED ARROW signal indication is permitted to enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

3. *Unless otherwise directed by a pedestrian signal head, pedestrians facing a steady CIRCULAR RED or RED ARROW signal indication alone shall not enter the roadway.*

D. *Flashing signal indications shall have the following meanings:*

1. *Flashing yellow—when a yellow lens is illuminated with rapid intermittent flashes, vehicular traffic is permitted to proceed through the intersection or past such signal indication only with caution.*
2. *Flashing red—When a red lens is illuminated with rapid intermittent flashes, vehicular traffic shall stop at a clearly marked stop line; but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. The right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.*
3. *Flashing RED ARROW and flashing YELLOW ARROW signal indications have the same meaning as the corresponding flashing circular signal indication, except that they apply only to vehicular traffic intending to make the movement indicated by the arrow.*

Section 4D.05 Application of Steady Signal Indications

Standard:

When a traffic control signal is being operated in a steady (stop-and-go) mode, at least one lens in each signal face shall be illuminated at any given time.

A signal face(s) that controls a particular vehicular movement during any interval of a cycle shall control that same movement during all intervals of the cycle.

Steady signal indications shall be applied as follows:

A. *A steady CIRCULAR RED signal indication:*
   1. *Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area. Turning after stopping is permitted as stated in Item C.1 of Section 4D.04.*
   2. *Shall be displayed with the appropriate GREEN ARROW signal indications when it is intended to permit traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the intersection or other controlled area, except in protected only mode turn signal faces, or in protected/permissive mode left-turn operation with separate left-turn signal faces (see Section 4D.06).*

B. *A steady CIRCULAR YELLOW signal indication:*
   1. *Shall be displayed following a CIRCULAR GREEN or straight-through GREEN ARROW signal indication in the same signal face.*
   2. *Shall not be displayed in conjunction with the change from the CIRCULAR RED signal indication to the CIRCULAR GREEN signal indication.*
   3. *Shall be followed by a CIRCULAR RED signal indication*

except that, when entering preemption operation, the return to the previous CIRCULAR GREEN signal indication shall be permitted following a CIRCULAR YELLOW signal indication (see Section 4D.13).

4. *Shall not be displayed to an approach from which drivers are turning left permissively unless one of the following conditions exists:*
   - *(a) A steady CIRCULAR YELLOW signal indication is also being shown simultaneously to the opposing approach;*
   - *(b) A separate left-turn signal face is provided and operated as described in Section 4D.06;*
   - *(c) An engineering study has determined that, because of unique intersection conditions, the conditions described in items (a) and (b) above cannot reasonably be implemented without causing significant operational or safety problems and that the volume of impacted left turning traffic is relatively low, and those left-turning drivers are advised that the opposing traffic is not simultaneously being shown a CIRCULAR YELLOW signal indication if this operation occurs continuously by the installation near the left-most signal head of a W25-1 sign (see Section 2C.39) with the legend ONCOMING TRAFFIC HAS EXTENDED GREEN; or*
   - *(d) Drivers are advised of the operation if it occurs only occasionally, such as during a preemption sequence or because of the skipping of actuated phases, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.39) with the legend ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN.*

C. *A steady CIRCULAR GREEN signal indication shall be displayed only when it is intended to permit traffic to proceed in any direction that is lawful and practical.*

D. *A steady RED ARROW signal indication shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area to make the indicated turn. Except as described in Item C.2 of Section 4D.04, turning on a steady RED ARROW signal indication shall not be permitted.*

E. *A steady YELLOW ARROW signal indication:*

1. *Shall be displayed in the same direction as a GREEN ARROW signal indication following a GREEN ARROW signal indication in the same signal face, unless:*
   - *(a) The GREEN ARROW signal indication and a CIRCULAR GREEN (or straight-through GREEN ARROW) signal indication terminate simultaneously*

in the same signal face, or

(b) The green arrow is a straight-through GREEN ARROW.

2. Shall not be displayed in conjunction with the change from a RED ARROW signal indication to a GREEN ARROW signal indication.

3. Shall not be displayed when any conflicting vehicular movement has a green or yellow signal indication or any conflicting pedestrian movement has a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication (see Section 4D.09).

4. Shall be terminated by a RED ARROW signal indication for the same direction or a CIRCULAR RED signal indication except:

(a)When entering preemption operation, the return to the previous GREEN ARROW signal indication shall be permitted following a YELLOW ARROW signal indication.

(b)When the movement controlled by the arrow is to continue on a permissive mode basis during an immediately following CIRCULAR GREEN signal indication.

F. A steady GREEN ARROW signal indication:

1. Shall be displayed only to allow vehicular movements, in the direction indicated, that are not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication (see Section 4D.09).

2. Shall be displayed on a signal face that controls a left-turn movement when said movement is not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication (see Section 4D.09).

3. Shall not be required on the stem of T-intersections or for turns from one-way streets.

Option:

Steady RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications, if not otherwise prohibited, may be used instead of the corresponding circular signal indications at the following locations:

A. On an approach intersecting a one-way street;

B. Where certain movements are prohibited; and

C. Where certain movements are physically impossible.

If U-turns are permitted from the approach and if drivers making a right turn from the conflicting approach to the left are simultaneously being shown a right-

turn GREEN ARROW signal indication, drivers making a U-turn may be advised of the operation by the installation near the left-turn signal face of a U-TURN YIELD TO RIGHT TURN (R10-16) sign (see Section 2B.45).

2.7 SIMULTANEOUS DISPLAY OF CONFLICTING INDICATIONS

The MUTCD 2003 Edition Section 4D.08 Prohibited Steady Signal Indications indicates:

Section 4D.08 Prohibited Steady Signal Indications

Standard:

The following combinations of signal indications shall not be simultaneously displayed on any one signal face:

A. CIRCULAR GREEN with CIRCULAR YELLOW.

B. CIRCULAR RED with CIRCULAR YELLOW.

C. CIRCULAR GREEN with CIRCULAR RED.

D. Straight-through GREEN ARROW with CIRCULAR RED.

The above combinations shall not be simultaneously displayed in different signal faces on any one approach unless one of the following conditions exists:

A. One of the signal faces is a turn signal controlling a protected only mode turn, and a LEFT (RIGHT) TURN SIGNAL sign (R10-10) (see Sections 4D.06 and 4D.07) is mounted adjacent to each such signal face, or

B. The signal faces are shielded, hooded, louvered, positioned, or designed so that the combination is not confusing to approaching road users.

A straight-through RED ARROW signal indication or a straight-through YELLOW ARROW signal indication shall not be displayed on any signal face, either alone or in combination with any other signal indication.

2.8 PEDESTRIAN SIGNALS

2.8.1 WALK INDICATION (WALKING PERSON SYMBOL)

Pedestrians facing a WALK indication (walking person symbol) may proceed across the roadway in the direction of the indication and shall be given the right-of-way by the drivers of all vehicles. (Vehicles may enter or turn across these pedestrian crosswalks.)

2.8.2 DONT WALK INDICATION (UPRAISED HAND SYMBOL)

Pedestrians facing a DONT WALK indication (upraised hand symbol) shall not start to cross the roadway in the direction of the indication.

2.8.3 FLASHING DONT WALK INDICATION (FLASHING UPRAISED HAND SYMBOL)

Pedestrians facing a flashing DONT WALK indication (flashing upraised hand symbol) shall not start to cross the roadway in the direction of the indication, but any pedestrian

who has partly completed a crossing during the WALK indication (walking person symbol) shall proceed to a sidewalk or safety zone, and all drivers of vehicles shall yield to the pedestrian.

2.8.4 APPLICATION

Pedestrian signals shall be installed in conjunction with vehicular traffic signals (which meet one or more of the traffic signal warrants set forth in PennDOT Publication 212 or the MUTCD) under any of the following conditions:

(a) When a traffic signal is installed under the pedestrian volume or school crossing warrant.

(b) When an exclusive interval or phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped. This does not mandate the installation of pedestrian signals for pedestrians crossing the approach leg of a one-way street.

(c) When vehicular indications are not visible to pedestrians such as on one-way streets, at "T" intersections, or when the vehicular indications are in a position which would not serve pedestrians. This does not mandate the use of pedestrian signals if three-section vehicle signals have been installed and are visible to pedestrians.

(d) At established school crossings (as promulgated by the school and municipal traffic officials responsible for school pedestrian safety) at intersections signalized under any warrant.

Pedestrian signals may also be installed under any of the following conditions:

(a) When the volume of pedestrian activity requires use of a pedestrian change interval to minimize vehicle-pedestrian conflicts or when it is necessary to assist pedestrians in making a safe crossing.

(b) When multi-phase indications (as with split-phase timing) would tend to confuse pedestrians guided only by vehicle signal indications and any volume of pedestrian activity is present.

(c) When pedestrians cross part of the street, to or from an island, during a particular interval where they should not be permitted to cross another part of that street during any part of the same interval.

2.9 MUTCD PROVISIONS

The MUTCD 2003 Edition Section 4E.02 Meaning of Pedestrian Signal Head Indications and Section 4E.03 Application of Pedestrian Signal Heads indicate:

Section 4E.02 Meaning of Pedestrian Signal Head Indications

Standard:

Pedestrian signal head indications shall have the following meanings:

A. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the WALKING PERSON (symbolizing WALK) signal indication is first shown.

B. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed out of the traveled way.

C. A steady UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.

D. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

Section 4E.03 Application of Pedestrian Signal Heads

Standard:

Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:

A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);

B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped; or

C. At an established school crossing at any signalized location.

D. Where engineering judgment determines that multiphase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.

Guidance:

Pedestrian signal heads should be used under any of the following conditions:

A. If it is necessary to assist pedestrians in making a reasonably safe crossing or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;

B. If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval; and/or

C. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting or continuing a crossing provide insufficient guidance for them to decide when it is reasonably safe to cross, such as on one-way streets, at T-intersections, or at multiphase signal operations.

2.10 LANE-USE CONTROL SIGNAL INDICATIONS

The MUTCD 2003 Edition Section 4J.02 Meaning of Lane-Use Control Signal Indications indicates:

Section 4J.02 Meaning of Lane-Use Control Signal Indications

Standard:

The meanings of lane-use control signal indications are as follows:

A. A steady DOWNWARD GREEN ARROW signal indication shall mean that a road user is permitted to drive in the lane over which the arrow signal indication is located.

B. A steady YELLOW X signal indication shall mean that a road user is to prepare to vacate, in a reasonably safe manner, the lane over which the signal indication is located because a lane control change is being made to a steady RED X signal indication.

C. A steady WHITE TWO-WAY LEFT-TURN ARROW signal indication (see Figure 4J-1) shall mean that a road user is permitted to use a lane over which the signal indication is located for a left turn, but not for through travel, with the understanding that common use of the lane by oncoming road users for left turns is also permitted.

D. A steady WHITE ONE WAY LEFT-TURN ARROW signal indication (see Figure 4J-1) shall mean that a road user is permitted to use a lane over which the signal indication is located for a left turn (without opposing turns in the same lane), but not for through travel.

E. A steady RED X signal indication shall mean that a road user is not permitted to use the lane over which the signal indication is located and that this signal indication shall modify accordingly the meaning of all other traffic controls present. The road user shall obey all other traffic controls and follow normal safe driving practices.

Pavement markings (see Section 3B.03) shall be used in conjunction with reversible-lane control signals.

3.0 FLASHING OPERATION OF TRAFFIC CONTROL SIGNALS

3.1 GENERAL

Unless an engineering and traffic study indicates otherwise, traffic control signals may be flashed during periods of low traffic volumes. Flashing operation may be considered if the total volume of vehicles entering the intersection drops below 325 vehicles per hour in urban areas or 225 vehicles per hour in rural areas for a period of four or more consecutive hours. Some factors which may preclude instituting programmed flashing operation during periods of low volume include inadequate sight distance, an increase in the number or severity of crashes, an observed increase in vehicular conflicts, undesirable increases in traffic speeds, or actuated operation.

3.2 MEANING

Flashing Red: When a red lens is illuminated with rapid intermittent flashes, drivers of vehicles shall stop in the same manner as at a stop sign, and the right to proceed shall be subject to the rules applicable after making a stop at a stop sign.

Flashing Yellow: When a yellow lens is illuminated with rapid intermittent flashes, drivers of vehicles may proceed through the intersection or past such signal only with caution.

3.3 APPLICATION

When a traffic control signal is put on flashing operation, normally yellow indications should be used for the major street and red indications for the other approaches. Yellow indications shall not be used for all approaches. The following shall apply whenever signals are placed in flashing operation:

(a) A circular yellow shall be flashed instead of any yellow arrow which may be included in that signal face.

(b) No steady circular green or green arrow or flashing yellow shall be terminated and immediately followed by a steady red or flashing red without the display of the steady yellow indication; however, transition may be made directly from a steady circular green or green arrow to a flashing yellow.

(c) Stop signs should not be used with traffic control signals during normal flashing operations.

3.4 OPERATION

Flashing shall be continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.

Changes from flashing to stop-and-go operation shall be made at the beginning of the major street green interval, preferably at the beginning of the common major street green interval (i.e., when a green indication is shown in both directions on the major street). Programmed changes from stop-and-go to flashing operation shall be made at the end of the common major street red interval (i.e., when a red indication is shown in both directions on the major street).

Where there is no common major street green interval, the change from flashing to stop-and-go operation shall be made at the beginning of the green interval for the major traffic movement on the major street. It may be necessary to provide a short, steady all-red interval for the other approaches before changing from flashing yellow or flashing red to green on the major approach.

3.5 MUTCD PROVISIONS

The MUTCD 2003 Edition Section 4D.11 Application of Flashing Signal Indications and Section 4D.12 Flashing Operation of Traffic Control Signals indicate:

> ***Section 4D.11 Application of Flashing Signal Indications***
> *Standard:*
> *The light source of a flashing signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.*
> *Flashing signal indications shall comply with the requirements of other Sections of this Manual regarding shielding or positioning of conflicting signal indications, except that flashing yellow signal indications for through traffic shall not be required to be shielded or positioned to prevent visual conflict for road users in separately controlled turn lanes.*
> *The following applications shall apply whenever a traffic control signal is operated in the flashing mode:*
> *A. Each approach or protected only mode turn movement that is controlled during steady mode (stop-and-go) operation shall display a signal indication during flashing operation.*
> *B. All signal faces that are flashed on an approach shall flash the same color, either yellow or red, except that separate signal faces for protected only mode turn movements and separate signal faces for protected/permissive left-turn movements shall be permitted to flash a CIRCULAR RED or RED ARROW signal indication when the through signal indications are flashed yellow. Shared signal faces for protected/permissive left-turn movements*

shall not be permitted to flash a CIRCULAR RED signal indication when the through signal indications are flashed yellow.

C. The appropriate RED ARROW or YELLOW ARROW signal indication shall be flashed when a signal face consists entirely of arrow lenses.

D. If a signal face includes both circular and arrow signal lenses of the color that is to be flashed, only the circular signal indication shall be flashed.

Guidance:

When a traffic control signal is operated in the flashing mode, a flashing yellow signal indication should be used for the major street and a flashing red signal indication should be used for the other approaches unless flashing red signal indications are used on all approaches.

Section 4D.12 Flashing Operation of Traffic Control Signals

Standard:

Each traffic control signal shall be provided with an independent flasher mechanism that operates in compliance with Section 4D.11. The flashing operation shall not be terminated by removal or turn off of the controller unit or of the conflict monitor (malfunction management unit) or both.

When a traffic control signal is operated in the flashing mode:

A. Flashing yellow signal indications shall not be displayed for approaches with conflicting traffic movements, except for permissive left-turn movements.

B. At least one signal indication in each signal face on an approach shall be flashed except in the following circumstance:

A single-section signal face consisting of a continuously-illuminated GREEN ARROW signal lens that is used alone to indicate a continuous movement in the steady (stop-and-go) mode shall remain continuously illuminated when the traffic control signal is operated in the flashing mode.

A manual switch, a conflict monitor (malfunction management unit) circuit, and, if appropriate, automatic means shall be provided to initiate the flashing mode.

The transition from steady (stop-and-go) mode to flashing mode, if initiated by a conflict monitor (malfunction management unit) or by a manual switch, shall be permitted to be made at any time.

Programmed changes from steady (stop-and-go) mode to flashing mode shall be made under either of the following circumstances:

A. At the end of the common major-street red interval (such as just prior to the start of the green in both directions on the major street), or

B. Directly from a steady CIRCULAR GREEN or GREEN ARROW signal indication to a flashing CIRCULAR YELLOW or YELLOW ARROW signal indication, respectively.

During programmed changes, no steady green signal indication or flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication. Changes from flashing mode to steady (stop-and-go) mode shall be made under one of the following procedures:

A. Yellow-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made at the beginning of the major-street green

interval (when a green signal indication is shown to through traffic in both directions on the major street), or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

B. Red-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made by changing the flashing red indications to steady red indications followed by appropriate green indications to begin the steady mode cycle. These green indications shall be the beginning of the major-street green interval (when a green signal indication is shown to through traffic in both directions on the major street) or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

Guidance:

When changing from the yellow-red flashing mode to steady (stop-and-go) mode, if there is no common major-street green interval, the provision of a steady red clearance interval for the other approaches before changing from a flashing yellow or a flashing red signal indication to a green signal indication on the major approach should be considered.

The steady red clearance interval provided during the change from red-red flashing mode to steady (stop and go) mode should have a duration of 6 seconds.

Support:

Section 4E.09 contains information regarding the operation of accessible pedestrian signal detector pushbutton locator tones during flashing operation.

4.0 NUMBER OF SIGNAL FACES

4.1 TRAFFIC CONTROL SIGNALS

There shall be a minimum of two vehicular signal faces on each approach.

4.1.1 SUPPLEMENTAL VEHICULAR SIGNALS

A supplemental signal face shall be provided when one of the following conditions exist:

(a) The nearest vehicular signal face on an approach is more than 45 m (150 ft) beyond the stop line.

(b) More than one lane is used for an exclusive turning movement.

(c) When vehicular signals are in a position which would not adequately serve pedestrians.

A supplemental signal face may be provided when one of the following conditions exist:

(a) The desired signal visibility is not available due to the skew or grade of an approach.

(b) Conditions of sunlight, background lighting, or glare impairs signal visibility.

(c) Truck or bus traffic restricts the visibility of the primary signals.

(d) Other unusual conditions dictate the need.

4.1.2 VEHICULAR SIGNALS FOR TURN LANES

A signal face shall be provided for a turn lane controlled by an exclusive phase; however, when there is more than one turning lane on an approach, each lane shall have a separate signal face. Such signals shall be in addition to the two signal faces required for the approach.

When the left or right turning movement is terminated at a time other than the through movement for that approach, a separate signal face shall be provided for the turning movement in addition to the two signal faces for the approach. A sign "Left Turn Signal" or "Right Turn Signal" shall be located near the signal.

When the left or right turn movement is followed by a circular green, the left or right green arrow should be included in the signal face for the through movement (the left arrow in the signal face to the left, the right arrow in the signal face to the right of the face approach).

4.1.3 MUTCD PROVISIONS

The MUTCD 2003 Edition Section 4D.15 Size, Number, and Location of Signal Faces by Approach indicates:

Section 4D.15 Size, Number, and Location of Signal Faces by Approach

Support:

Sections 4D.05, and 4D.16 through 4D.18 contain additional information regarding the design of signal faces.

Standard:

There shall be two nominal diameter sizes for vehicular signal lenses: 200 mm (8 in) and 300 mm (12 in). Three-hundred millimeter (12 in) signal lenses shall be used:

A. For signal indications for approaches (see definition in Section 4A.02) where road users view both traffic control and lane-use control signal heads simultaneously;

B. If the nearest signal face is between 35 m (120 ft) and 45 m (150 ft) beyond the stop line, unless a supplemental near-side signal face is provided;

C. For signal faces located more than 45 m (150 ft) from the stop line;

D. For approaches to all signalized locations for which the minimum sight distance in Table 4D-1 cannot be met; and

E. For arrow signal indications.

A 200 mm (8 in) signal lens for a CIRCULAR RED signal indication shall not be used in combination with a 300 mm (12 in) signal lens for a CIRCULAR GREEN signal indication or a 300 mm (12 in) signal lens for a CIRCULAR YELLOW signal indication.

Option:

Different sizes of signal lenses may be used in the same signal face or signal head, except for the prohibitions listed in the Standards in this Section.

Guidance:

Three-hundred millimeter (12 in) signal lenses should be used for all signal indications for the following:

A. Approaches with 85th-percentile approach speeds exceeding 60 km/h (40 mph);

B. Approaches where a traffic control signal might be unexpected;

C. All approaches without curbs and gutters where only post-mounted signal heads are used; and

D. Locations where there is a significant percentage of elderly drivers.

Standard:

The signal faces for each approach to an intersection or a midblock location shall be provided as follows:

A. A minimum of two signal faces shall be provided for the major movement on the approach, even if the major movement is a turning movement.

B. See Section 4D.06 for left-turn signal faces.

C. See Section 4D.07 for right-turn signal faces.

D. Except where the width of an intersecting roadway or other conditions make it physically impractical:

1. A signal face installed to satisfy the requirements for left-turn signal faces (see Section 4D.06) and right-turn signal faces (see Section 4D.07), and at least one and preferably both of the two signal faces required for the major movement on the approach shall be located:

(a) Not less than 12 m (40 ft) beyond the stop line.

(b) Not more than 55 m (180 ft) beyond the stop line unless a supplemental near side signal face is provided.

(c) As near as practical to the line of the driver's normal view, if mounted over the roadway.

2. Where the nearest signal face is located between 45 and 55 m (150 and 180 ft) beyond the stop line, engineering judgment of the conditions, including the worst-case visibility conditions, shall be used to determine if the provision of a supplemental near side signal face would be beneficial.

3. A signal face installed to satisfy the requirements for left-turn signal faces (see Section 4D.06) and right-turn signal faces (see Section 4D.07), and at least one and preferably both of the two signal faces required for the major movement on the approach shall be located no higher than at a maximum height to the top of the signal housing mounted over a roadway of 7.8 m (25.6 ft) above the pavement (see Section 4D.17). For viewing distances between 12 m (40 ft) and 16 m (53 ft) from the stop line, the maximum mounting height to the top of the signal housing shall be as shown on Figure 4D-1. (See Section 4D.17 for additional information regarding mounting heights.)

4. At least one and preferably both of the signal faces required by Item A in this Standard shall be located between two lines intersecting with the center of the approach at a point 3 m (10 ft) behind the stop line, one making an angle of approximately 20 degrees to the right of the center of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended (see Figure 4D-2)

5. If both of the signal faces required by Item A in this Standard are post-mounted, they shall both be on the far side of the intersection, one on the right and one on the left of the approach lane(s).

E. If the minimum sight distance in Table 4D-1 cannot be met, a sign shall be installed to warn approaching traffic of the traffic control signal.

F. Required signal faces for through traffic on any one approach shall be located not less than 2.4 m (8 ft) apart measured horizontally perpendicular to the approach between the centers of the signal faces.

G. If more than one turn signal face is provided for a protected-mode turn and if one or both of the signal faces are located over the roadway, the signal faces shall be located not less than 2.4 m (8 ft) apart measured horizontally perpendicular to the approach between the centers of the signal faces.

H. If supplemental signal faces are used, the following limitations shall apply:

1. Left-turn arrows shall not be used in near-right signal faces.

2. Right-turn arrows shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

Guidance:

The two signal faces required for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance indicated in Table 4D-1 in advance of and measured to the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or unless another signalized location is within this range.

If two or more left-turn lanes are provided for a separately controlled protected only mode left-turn movement, or if a left-turn movement represents the major movement from an approach, two left-turn signal faces should be provided.

If two or more right-turn lanes are provided for a separately controlled right-turn movement, or if a right-turn movement represents the major movement from an approach, two right-turn signal faces should be provided.

Near-side signal faces should be located as near as practical to the stop line.

If a signal face controls a specific lane or lanes of an approach, its position should make it readily visible to road users making that movement.

Supplemental signal faces should be used if engineering judgment has shown that they are needed to achieve intersection visibility both in advance and immediately before the signalized location. If supplemental signal faces are used, they should be located to provide optimum visibility for the movement to be controlled.

At signalized midblock crosswalks, at least one of the signal faces should be over the traveled way for each approach.

Option:

If a sign is installed to warn approaching road users of the traffic control signal, the sign may be supplemented by a Warning Beacon (see Section 4K.03).

A Warning Beacon used in this manner may be interconnected with the traffic signal controller assembly in such a manner as to flash yellow during the period when road users passing this beacon at the legal speed for the roadway might encounter a red signal indication (or a queue resulting from the display of the red signal indication) upon arrival at the signalized location.

4.2 INTERSECTION CONTROL BEACONS

A minimum of two separate signal sections shall be provided for each approach. Supplemental signal sections may be needed on one or more approaches in order to provide adequate visibility to approaching motorists. Refer to the MUTCD 2003 Edition Chapter 4K Flashing Beacons. Additional information is contained in Appendix B of this publication.

4.3 PEDESTRIAN SIGNALS

The MUTCD 2003 Edition Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications indicates:

Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications

Standard:

All new pedestrian signal head indications shall be displayed within a rectangular background and shall consist of symbolized messages (see Figure 4E-1), except that existing pedestrian signal head indications with lettered or outline style symbol messages may be retained for the remainder of their useful service life. The symbol designs that are set forth in the "Standard Highway Signs" book shall be used. Each pedestrian signal head indication shall be independently illuminated and emit a single color.

The UPRAISED HAND (symbolizing DONT WALK) signal section shall be mounted directly above or integral with the WALKING PERSON (symbolizing WALK) signal section.

The WALKING PERSON (symbolizing WALK) signal indication shall be white, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section1A.11), with all except the symbol obscured by an opaque material.

The UPRAISED HAND (symbolizing DONT WALK) signal indication shall be Portland orange, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

When not illuminated, the WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK) symbols shall not be readily visible to pedestrians at the far end of the crosswalk that the pedestrian signal head indications control.

For pedestrian signal head indications, the symbols shall be at least 150 mm (6 in) high.

The light source of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.

Guidance:

Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 3 m (10 ft) from the end of the controlled crosswalk during both day and night.

For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the pedestrian signal head indications, the symbols should be at least 225 mm (9 in) high.

4.4 MID-BLOCK SIGNALS

At mid-block crosswalks, there shall be at least two vehicular signal faces for each approach. Refer to Section 4.1 Traffic Control Signals of this publication.

5.0 LOCATION OF SIGNAL FACES

5.1 TRAFFIC CONTROL SIGNALS

Vehicular signal faces for an approach will preferably be located over the roadway. For traffic control signals on fixed supports, a minimum of one signal face shall be located over the roadway unless the approach speed limit is 40 km/h (25 mph) or less.

5.1.1 DISTANCE FROM STOP LINE

5.1.1.1 Overhead Signal Faces

Minimum: 12 m (40 ft) [18 m (60 ft) desirable] and at least one face, preferably all faces, beyond the center of the intersection.

Maximum: 36 m (120 ft). When more than 36 m (120 ft), use 300 mm (12 in) lenses. When more than 45 m (150 ft), also provide a supplemental signal face located as close as practical to the stop line for that approach.

5.1.1.2 Post-Mounted Signal Faces

Where both of the signal faces are to be post-mounted, they shall be on the far side of the intersection, with one signal to the right and one to the left of the roadway centerline extended. When more than 36 m (120 ft), use 300 mm (12 in) lenses. When more than 45 m (150 ft), also provide a supplemental signal face located as close as practical to the stop line for that approach.

5.1.1.3 Mid-Block Signals

There shall be at least one signal face over the roadway for each approach. In other respects, a traffic control signal at a mid-block location shall meet the requirements set forth herein for a traffic control signal.

5.1.2 LATERAL PLACEMENT

5.1.2.1 General

A minimum of two signal faces for through traffic should be continuously visible from a point at least the following distances in advance of the stop line, unless physical obstruction of their visibility cannot be avoided.

Table 5-1

Minimum Visibility Distance in Advance of Stop Line

85th Percentile Speed km/h (mph)	Minimum Visibility Distance, m (ft)
30 (20)	54 (175)
40 (25)	66 (215)
50 (30)	83 (270)
55 (35)	100 (325)
65 (40)	119 (390)
70 (45)	141 (460)
80 (50)	165 (540)
90 (55)	191 (625)
95 (60)	218 (715)

At least one and preferably two signal faces shall be located between two lines intersecting the center of the approach at the stop line, one making an angle of approximately 20 degrees to the right of the center of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended as shown in Figure 4D-2 of the MUTCD 2003 Edition. If only one signal is within the cone, it must also be at least 12 m (40 ft) from the stop line.

5.1.2.2 Overhead Signals

It is desirable to keep a minimum distance of 0.6 m (2 ft) horizontally between any overhead signal and the edge of pavement, curb line, or if parking is permitted from the edge of the parking lane.

The left approach signal, except when an exclusive left turn signal is installed, should be located at or to the right of the marked centerline of the roadway. A minimum distance of 0.9 m (3 ft) should be maintained between signal heads for opposing traffic movements to avoid blocking the motorists' view of the indications.

The preferred distance between signal faces is 3.6 m (12 ft); the minimum distance shall be 2.4 m (8 ft) measured between centers of signal faces along a line perpendicular to the centerline of the approach.

When turning movements are signalized separately, signals for through movements should be placed at approximately 1/3 points of the approach unless it is only one lane. If the through approach is one lane, one of the primary signals may be post-mounted if the location criteria cannot be satisfied.

An exclusive left turn signal shall be located within the center third of the lane being signalized. For opposing left turn lanes, the signals should not overlap.

An exclusive right turn signal shall be located at or to the right of the center of the turn lane being signalized.

When a supplemental near side signal is used overhead, it shall be located as near as practical to the stop line but should not interfere with the visibility of other signals.

5.1.2.3 Post-Mounted Signals

A far right post-mounted signal shall have a minimum horizontal clearance of 0.6 m (2 ft) to the right of the curb line or edge of shoulder line of the approach extended, but not more than 1.5 m (5 ft).

A far left post-mounted signal shall have a minimum horizontal clearance of 0.6 m (2 ft) to the left of the curb line or edge of shoulder line of the approach extended, but not more than 1.5 m (5 ft).

A median-mounted signal may serve as a far left signal, or as an exclusive left turn signal.

When a supplemental near right signal is used, it shall be located as near as practical to the stop line but normally not in advance of the stop line. Its location relative to the curb or pavement edge shall be as set forth above for a far right post-mounted signal.

5.1.3 VERTICAL PLACEMENT

5.1.3.1 Overhead

The bottom of the housing of a vehicle signal face mounted or suspended over a roadway shall be at least 4.6 m (15 ft) but not more than 5.8 m (19 ft) above the pavement grade at the center of the roadway, but normally should be 4.9 m (16 ft).

Within the above limits, optimum visibility and adequate clearance should be the guiding considerations in deciding signal height. Grades on approaching streets may be important factors, and should be considered in determining the most appropriate height.

5.1.3.2 Post-Mounted

The bottom of the housing of a vehicle signal face, not mounted or suspended over a roadway, shall be at least 2.5 m (8 ft) but not more than 4.6 m (15 ft) above the sidewalk or, if none, above the pavement grade at the center of the highway. [If the side-mounted signal face is less than 12 m (40 ft) from the stop line, the bottom shall not be more than 3.6 m (12 ft) above the sidewalk or pavement grade.]

5.1.4 MUTCD PROVISIONS

See the MUTCD 2003 Edition Section 4D.15 Size, Number, and Location of Signal Faces by Approach and Section 4.1.3 of this publication.

5.2 INTERSECTION CONTROL BEACONS

Locate intersection control beacons overhead near the center of the intersection where they will be continuously visible for the distances provided in Section 5.1.2.1 of this publication and will meet the vertical placement provisions of Section 5.1.3.1 of this publication.

The distance between signal faces on an approach shall be as provided in Section 5.1.2.2 of this publication.

See the MUTCD 2003 Edition Chapter 4K Flashing Beacons.

5.3 PEDESTRIAN SIGNALS

5.3.1 LATERAL PLACEMENT

Pedestrian signal faces shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crossing. Pedestrian signals shall otherwise meet the requirements herein for post-mounted vehicular signals.

Pedestrian signals shall not be used across “yield” movements, such as at signalized intersections where a right turn “yield” movement is allowed.

5.3.2 VERTICAL PLACEMENT

Pedestrian signal faces shall be mounted with the bottom not less than 2.2 m (7 ft) nor more than 3.0 m (10 ft) above the sidewalk level.

The upraised hand indication shall be mounted directly above or integral with the walking person indication.

Pedestrian signal faces may be mounted separately or on the same support with vehicular signal faces. When mounted with vehicular signal faces, there shall be a physical separation between the two types.

5.3.3 MUTCD PROVISIONS

The MUTCD 2003 Edition Chapter 4E.05 Location and Height of Pedestrian Signal Heads indicates:

Section 4E.05 Location and Height of Pedestrian Signal Heads

Standard:

Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 2.1 m (7 ft) nor more than 3 m (10 ft) above sidewalk level, and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk.

If pedestrian signal heads are mounted on the same support as vehicular signal heads, there shall be a physical separation between them.

5.4 EMERGENCY–VEHICLE TRAFFIC CONTROL SIGNALS

See the MUTCD 2003 Edition Section 4F.02 Design of Emergency-Vehicle Traffic Control Signals and Section 5.1 of this publication.

5.5 LANE-USE CONTROL SIGNALS

See the MUTCD 2003 Edition Section 4J.03 Design of Lane-Use Control Signals.

5.6 TRAFFIC CONTROL SIGNALS FOR FREEWAY ENTRANCE RAMPS

On entrance ramps having more than one lane, there shall be a signal face mounted on the left side and on the right side.

See the MUTCD 2003 Edition Section 4H.02 Design of Freeway Entrance Ramp Control Signals.

5.7 TRAFFIC CONTROL SIGNALS FOR ONE-LANE, TWO-WAY FACILITIES

See the MUTCD 2003 Edition Section 4G.02 Design of Traffic Control Signals for One-Lane, Two-Way Facilities.

5.8 SIGNAL DISPLAYS FOR CURVE APPROACHES

When the location to be signalized involves horizontal or vertical curve approaches, there are two design issues that require special consideration. The first issue relates to the minimum visibility distances specified earlier in this chapter, and the second issue involves driver

expectancy with regard to the lateral placement of the signal displays.

To resolve the minimum visibility issue on vertical curves, several techniques may be applied. Signal faces may be raised to their maximum heights, 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 Figure 5-1. On very high-speed approaches, overhead advance warning signs may also be considered.

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.

Figure 5-2 illustrates a layout with three possible supplemental signal locations. In this illustration, *a* represents a low, post-mounted near-left location; *b* is a mast arm-mount near-left on the back of a primary 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.

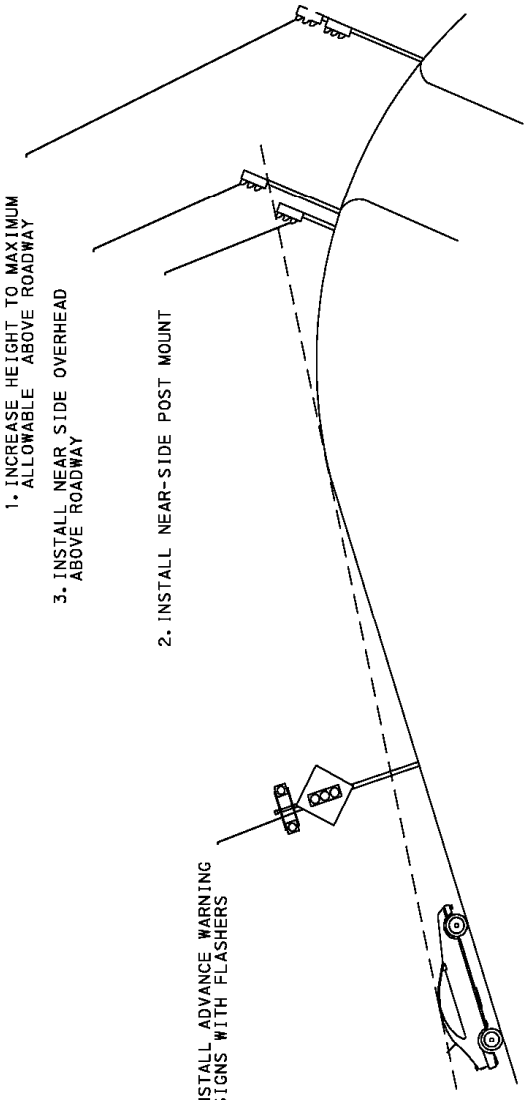


FIGURE 5-1

ADDRESSING SIGNAL VISIBILITY AT VERTICAL CURVES

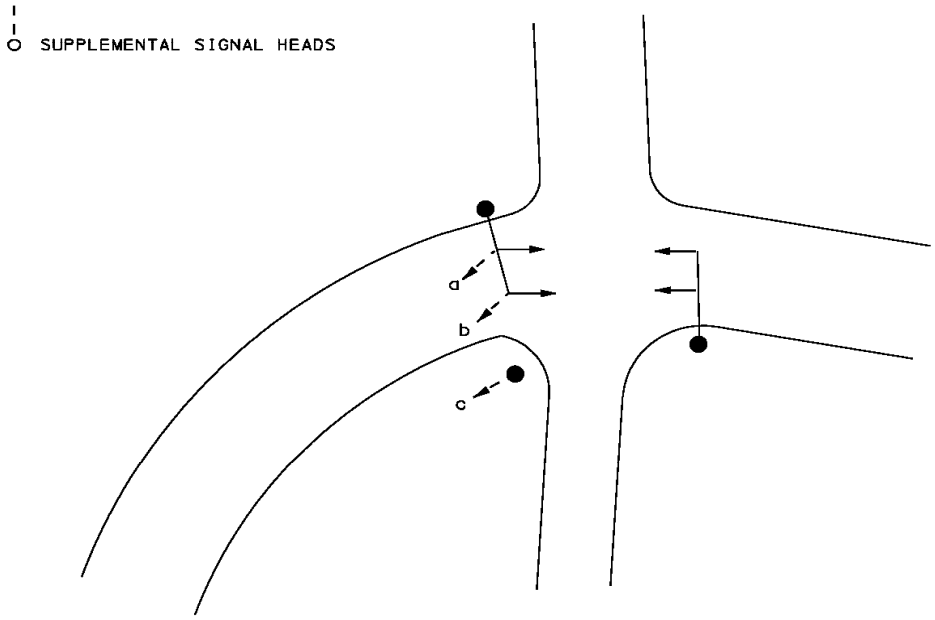


FIGURE 5-2

SUPPLEMENTAL SIGNAL PLACEMENTS FOR HORIZONTAL CURVES

6.0 ARRANGEMENT OF LENSES IN VEHICULAR SIGNAL FACES

6.1 MUTCD PROVISIONS

The MUTCD 2003 Edition Section 4D.16 Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces indicates:

Section 4D.16 Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces

Standard:

Each signal face at a signalized location shall have three, four, or five signal sections.

A single-section signal face shall be permitted at a traffic control signal if it consists of a continuously illuminated GREEN ARROW signal lens that is being used to indicate a continuous movement. Arrows shall be pointed:

A. Vertically upward to indicate a straight-through movement;

B. Horizontally in the direction of the turn to indicate a turn at approximately or greater than a right angle; and

C. Upward with a slope at an angle approximately equal to that of the turn if the angle of the turn is substantially less than a right angle.

The signal lenses in a signal face shall be arranged in a vertical or horizontal straight line, except that in a vertical array, signal lenses of the same color may be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement. Such clusters shall be limited to two identical signal lenses or to two or three different signal lenses of the same color.

In each signal face, all red signal lenses in vertically arranged signal faces shall be located above, and in horizontally arranged signal faces shall be located to the left, of all yellow and green signal lenses.

If a CIRCULAR YELLOW signal lens is used, it shall be located between the red signal lens or lenses and all other signal lenses.

In vertically arranged signal faces, each YELLOW ARROW signal lens shall be located immediately above the GREEN ARROW signal lens to which it applies. If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used, the lenses shall be in the same position relative to other lenses as are the GREEN ARROW signal lenses in a vertically arranged signal face.

In horizontally arranged signal faces, the YELLOW ARROW signal lens shall be located immediately to the left of the GREEN ARROW signal lens. If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used, the dual left-turn arrow signal lens shall be located immediately to the right of the CIRCULAR YELLOW signal lens, the straight-through GREEN ARROW signal lens shall be located immediately to the right of the CIRCULAR

GREEN signal lens, and the dual right-turn arrow signal lens shall be located to the right of all other signal lenses.

The relative positions of signal lenses within the signal face shall be as follows:

A. In a vertically arranged signal face from top to bottom:

CIRCULAR RED
Left-turn RED ARROW
Right-turn RED ARROW
CIRCULAR YELLOW
CIRCULAR GREEN
Straight-through GREEN ARROW
Left-turn YELLOW ARROW
Left-turn GREEN ARROW
Right-turn YELLOW ARROW
Right-turn GREEN ARROW

B. In a horizontally arranged signal face from left to right:

CIRCULAR RED
Left-turn RED ARROW
Right-turn RED ARROW
CIRCULAR YELLOW
Left-turn YELLOW ARROW
Left-turn GREEN ARROW
CIRCULAR GREEN
Straight-through GREEN ARROW
Right-turn YELLOW ARROW
Right-turn GREEN ARROW

C. If adjacent signal indications in a signal face are not identical, their arrangement shall follow Items A or B above, as applicable.

Option:

In a vertically arranged signal face, identical signal indications may be repeated in adjacent horizontal locations within the same signal face. Horizontally arranged and vertically arranged signal faces may be used on the same approach provided they are separated to meet the lateral separation spacing required in Section 4D.15.

Support:

Figure 4D-3 illustrates some of the possible arrangements of signal lenses in signal faces.

6.2 TYPICAL ARRANGEMENTS

See the MUTCD 2003 Edition Figure 4D-3 Typical Arrangements of Signal Lenses in Signal Faces. Typical design arrangements used in Pennsylvania are shown in Figure A-1, Appendix A of this Handbook.

7.0 SIZE OF SIGNAL LENSES

7.1 VEHICULAR SIGNALS

There shall be two nominal diameter sizes for vehicular signal lenses: 200 mm (8 in) and 300 mm (12 in).

Three-hundred millimeter (12 in) signal lenses shall be used:

(a) For signal indications for approaches where road users view both traffic control and lane-use control signal heads simultaneously.

(b) If the nearest signal face is between 35 m (120 ft) and 45 m (150 ft) beyond the stop line, unless a supplemental near-side signal face is provided.

(c) For signal faces located more than 45 m (150 ft) from the stop line.

(d) For approaches to all signalized locations for which the minimum visibility distance in Table 5-1 of this publication cannot be met.

(e) For arrow signal indications.

Three-hundred millimeter (12 in) signal lenses should be used for all signal indications for the following:

(a) Approaches with 85th percentile approach speeds exceeding 60 km/h (40 mph).

(b) Approaches where a traffic control signal might be unexpected.

(c) All approaches without curbs and gutters where only post-mounted signal heads are used.

(d) Locations where there is a significant percentage of elderly drivers.

Different size lenses may be used in the same signal face, except that a 200 mm (8 in) circular red shall not be used with a 300 mm (12 in) circular green or a 300 mm (12 in) circular yellow.

See the MUTCD 2003 Edition Section 4D.15 Size, Number, and Location of Signal Faces by Approach and Section 4.1.3 of this publication.

7.2 PEDESTRIAN SIGNALS

For pedestrian signal head indications, the symbols shall be at least 150 mm (6 in) high. Countdown pedestrian signal numbers shall be at least 150 mm (6 in) in height.

For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the pedestrian signal head indications, the symbols should be at least 225 mm (9 in) high. Also, for crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from a countdown pedestrian signal display, the numbers should be at least 225 mm (9 in) in height.

Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 3 m (10 ft) from the end of the controlled crosswalk during both day and night.

See Section 4.3 of this publication and the MUTCD 2003 Edition Section 4D.15 Size, Number, and Location of Signal Faces by Approach and Section 4E.07 Countdown Pedestrian Signals.

8.0 VISIBILITY AND SHIELDING OF SIGNAL FACES

8.1 GENERAL

Each signal face shall be located to provide maximum effectiveness to the approaching traffic for which it is intended.

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 1.1 m/s (3.5 ft/s). Use Figure 8-1 of this publication to determine if the signal location is within acceptable limits. If not, install a vehicular signal head that will be visible to pedestrians. See Figure 8-2 of this publication for the procedure to be followed when using Figure 8-1.

See the MUTCD 2003 Edition Section 4D.17 Visibility, Shielding, and Positioning of Signal Faces.

8.2 VISORS

There are 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.

A visor shall be used on all signal faces to:

(a) Aid in directing the signal indication specifically to approaching traffic.

(b) Shade the signal lenses from sun, sky, and other conditions which may sometimes tend to make a lens look illuminated when it is not.

(c) Shield the lens from motorists on other approaches who might be confused if they were they to see the lens.

8.3 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.

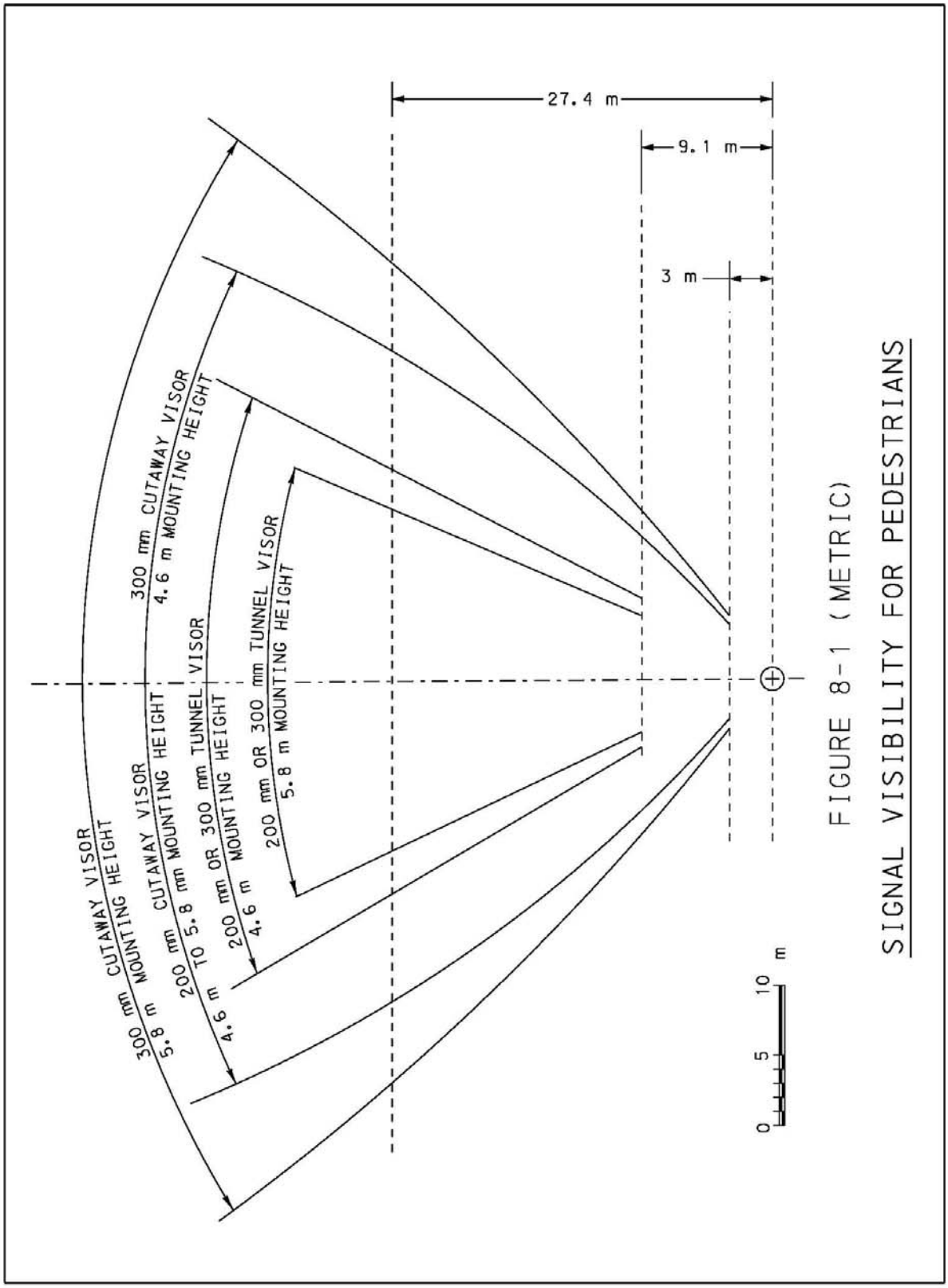


FIGURE 8-1 (METRIC)

SIGNAL VISIBILITY FOR PEDESTRIANS

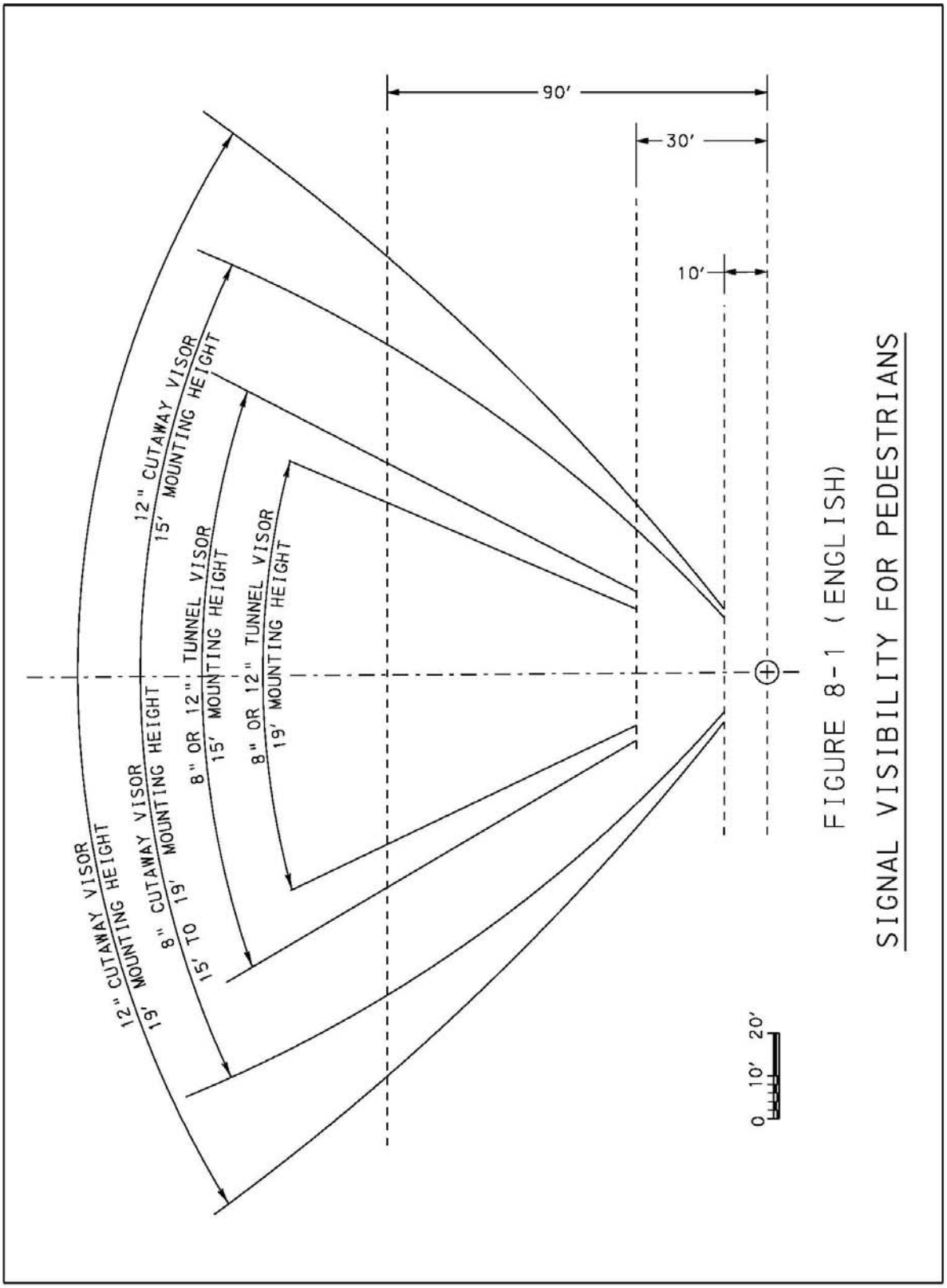


FIGURE 8-1 (ENGLISH)

SIGNAL VISIBILITY FOR PEDESTRIANS

Procedure for use of Figure 8-1 (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 1.1 m/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 pedestrian.

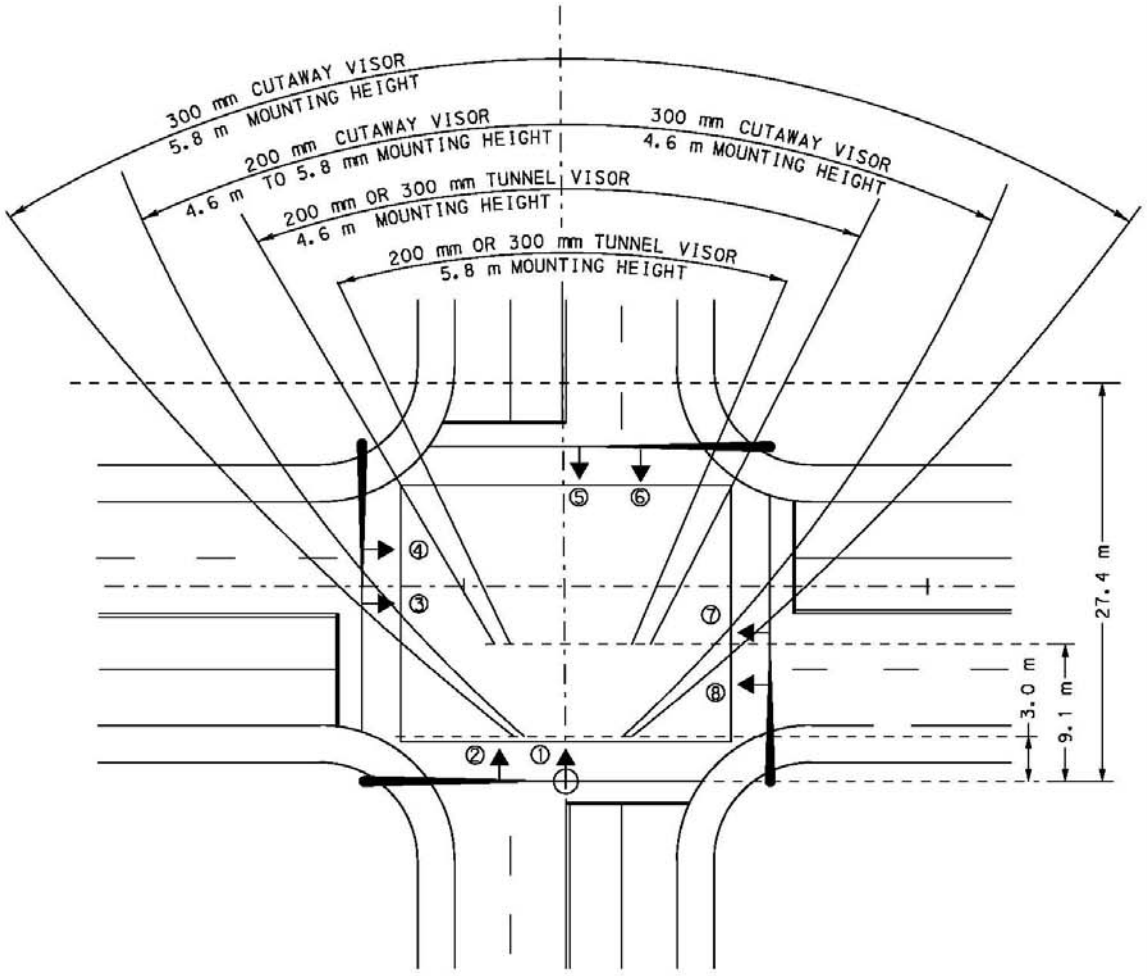


FIGURE 8-2 (METRIC)
PROCEDURE FOR USE OF FIGURE 8-1,
SIGNAL VISIBILITY FOR PEDESTRIANS

Procedure for use of Figure 8-1 (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 pedestrian.

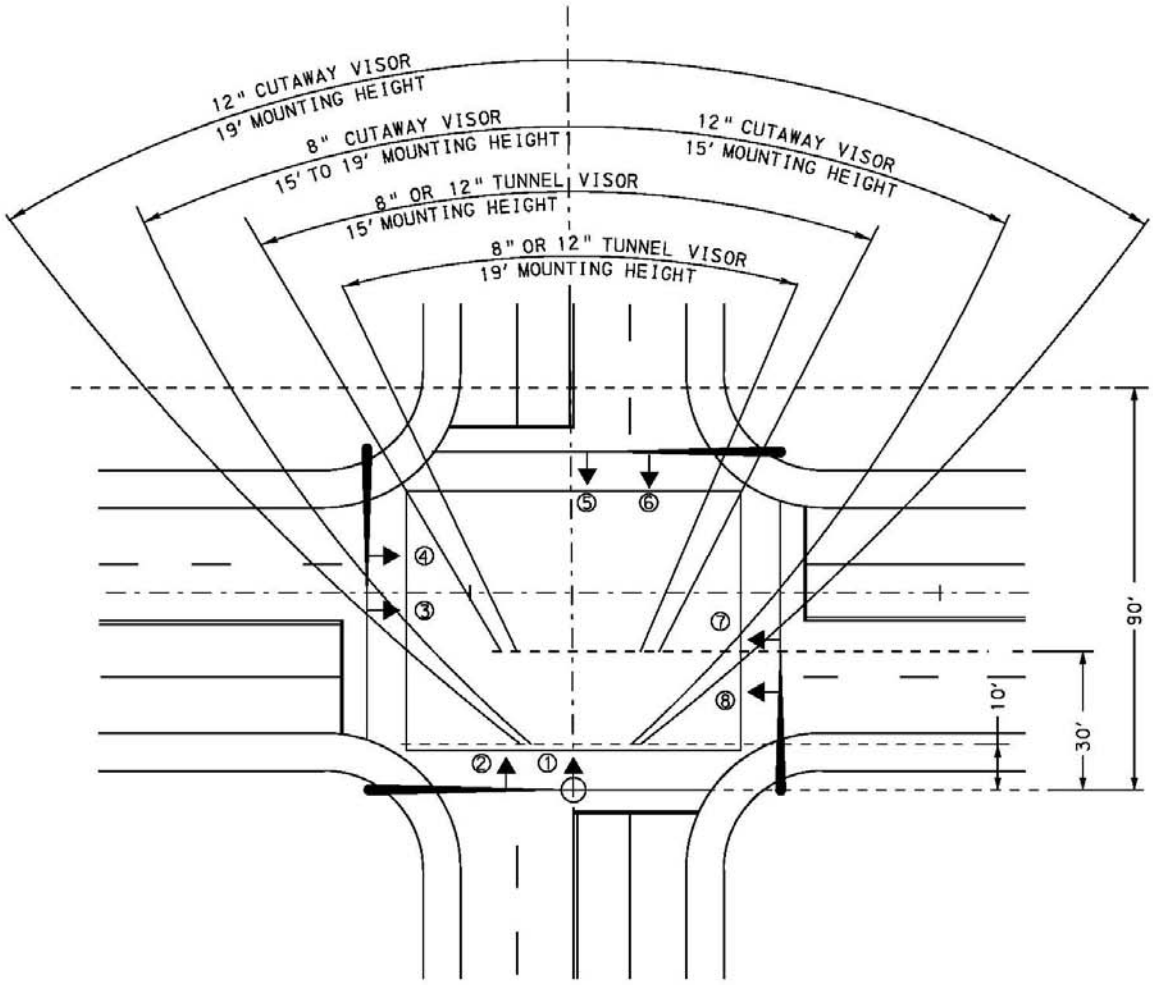


FIGURE 8-2 (ENGLISH)
PROCEDURE FOR USE OF FIGURE 8-1,
SIGNAL VISIBILITY FOR PEDESTRIANS

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.

8.4 BACKPLATES

Backplates may be used to improve the visibility of signals that would otherwise be impaired by background lighting, sunlight, or glare behind the signal face.

9.0 OPTICALLY PROGRAMMED SIGNAL HEADS

9.1 GENERAL

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

See the MUTCD 2003 Edition Section 4.17 Visibility, Shielding, and Positioning of Signal Faces.

9.2 MOUNTING

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

9.3 INSTALLATION DESIGN

9.3.1 CLOSELY SPACED INTERSECTIONS

When intersections are less than 60 m (200 ft) apart or very closely spaced, a motorist may see upstream signal indications and become confused as to which signals control the intersection he/she is approaching. This confusion is greatest during the clearance interval of the intersection. Oftentimes, this results in the motorist becoming trapped within the intersection area, thus creating delays and potential hazards to other motorists.

The potential for such occurrences can be drastically reduced by the use of optically programmed signals and "distance limiting" their area of visibility. Distance limiting is the programming of the signal so that a motorist cannot see the signal display until he/she enters the immediate approach to that signal. The layout of the optically programmed signals at closely spaced intersections is identical to that for other vehicular traffic signals.

9.3.2 INTERNAL CLEARANCE

The situation described above also occurs at intersections where the cross streets are offset or where a railroad runs parallel to 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 Section 5.0 of this publication. The second consists of optically programmed signals placed at the far side of the intersection. These signals shall be distance limited to be visible to the motorist beyond the stop line.

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 for a duration sufficient to allow a vehicle which enters the intersection during the yellow interval of the standard signals to clear the intersection. The internal clearance allows the motorist entering the intersection during the normal yellow interval to see the green indication of the programmed signal once he/she crosses the stop line. Thus, the motorist is informed he/she has the right-of-way to complete the movement.

9.3.3 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.

9.3.4 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.

10.0 TRAFFIC SIGNAL PHASING

10.1 GENERAL

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

10.2 STANDARD NEMA PHASING

NEMA (the National Electrical Manufacturers Association) uses a specific procedure for the numbering of the eight standard vehicle movements of a signalized intersection. Typically, even numbers are used to designate the through movements while odd numbers are used to designate left turning movements. NEMA phasing diagrams are used to graphically represent traffic signal phase rotations. Refer to the following standard diagram to accurately represent correct NEMA phasing for anticipated movements (where applicable).

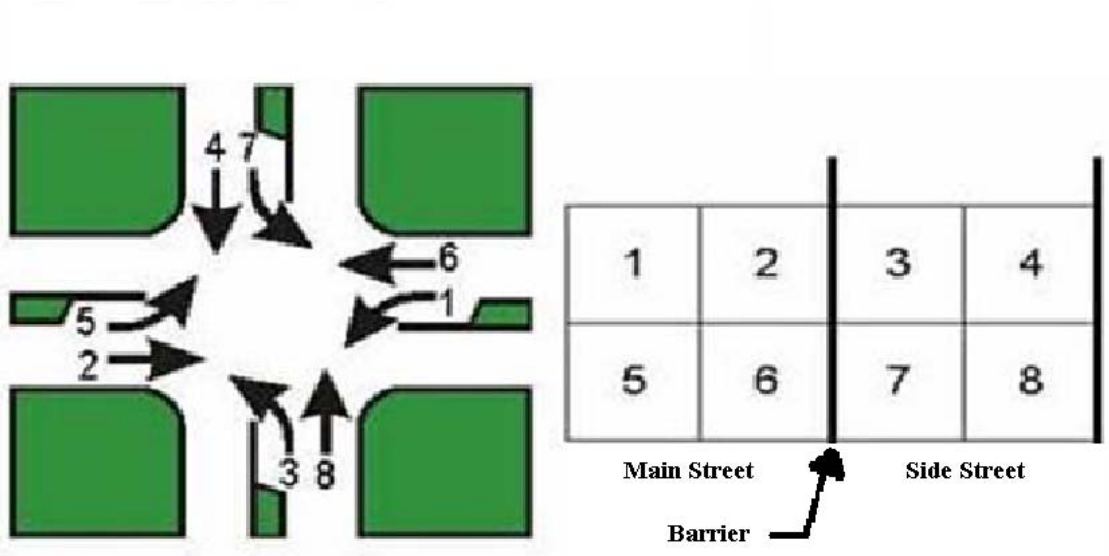


Figure 10-1: Intersection with NEMA Phase Labels

10.3 PHASE RECALL DETERMINATION

Determination of the phase recall is very important because it allows the intersection to operate more efficiently during non-peak traffic periods. The operation of the traffic signal during non-peak periods should be determined using an engineering study and engineering judgment to allow safe and efficient traffic movements to occur. This operation shall be located on the signal permit plan so that proper operation may be maintained.

10.3.1 MINIMUM RECALL

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 minimum phase's green interval, but green intervals may be increased if actual vehicle actuation occurs prior to termination of the passage time (see Section 11.7 of this publication).

10.3.2 MAXIMUM RECALL

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.

10.3.3 SOFT RECALL

Soft recall is very similar to minimum recall, but a phase will discontinue its call for the green interval if there are conflicting phase calls at the intersection by the actual vehicle demand.

10.3.4 LOCKING MODE

Locking mode is when a particular phase receives a call, and that call will remain until the phase has been serviced.

10.3.5 NON-LOCKING MODE

Non-locking mode allows particular phase calls to be processed, but if that call is dropped during a conflicting phase, the original phase call will be removed from memory.

10.4 TYPES OF LEFT TURN PHASES

Determination of the need for advance or exclusive phases for left turning vehicles should be made as indicated in Section 10.7 of this publication. The left turn phase calculations should always be completed and, upon review of the engineering study, engineering judgment shall be used to determine the most appropriate intersection operation. Also reference Section 4.5.5 of PennDOT Publication 46 for additional left turn phasing criteria.

10.4.1 PROTECTED/PROHIBITED LEFT TURN PHASING

With protected/prohibited 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 Figure A-1 of Appendix A).

10.4.2 PROTECTED/PERMITTED LEFT TURN PHASING

Protected/permitted 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 Figure A-1 of Appendix A).

10.4.3 PERMITTED LEFT TURN PHASING

Permitted 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.

10.4.4 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).

10.4.5 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.

10.4.6 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 “left turn trap.” The left turn trap occurs when a motorist making a permitted left turn from the approach that is opposite the lag phase observes the signal heads on his or her 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.

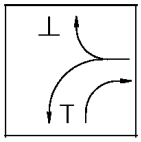
10.5 SPLIT PHASING

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).

10.6 OVERLAPS

An overlap is a vehicle movement, generally a right turn, which is allowed to run concurrently with two standard phases. An example is depicted below:



Overlapping of non-conflicting phases may be a desirable option at some signalized intersections.

10.7 OTHER PHASING OPTIONS

Other phasing 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.

10.8 CRITERIA FOR SIGNALIZATION OF LEFT TURN MOVEMENTS

The following criteria shall be used to determine the type of signal phasing that should be considered for 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. Reference Section 10.4 of this publication and Section 4.5.5 of PennDOT Publication 46 for additional guidance and information on left turn signal phasing.

10.8.1 VOLUME

Based upon the Department's experience and the data in the Highway Capacity Manual, 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. 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.

10.8.1.1 Consider Protected/Permitted Left Turn Phasing:

A. When a separate turn lane is <u>not</u> <u>present</u> and:

(1) One opposing lane exists; then two or more one-hour period conflict factors (CF) need to be greater than 35,000.

(2) Two opposing lanes exist; then two or more one-hour period conflict factors (CF) need to be greater than 45,000.

B. When a separate turn lane is <u>present</u> and:

(1) One opposing lane exists; then two or more one-hour period conflict factors (CF) need to be greater than 50,000.

(2) Two opposing lanes exist; then two or more one-hour period conflict factors (CF) need to be greater than 65,000.

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

(1) One opposing lane exists; then two or more one-hour period conflict factors (CF) need to be greater than 67,500.

(2) Two opposing lanes exist; then two or more one-hour period conflict factors (CF) need to be greater than 90,000.

(3) For dual left turn lanes.

10.8.2 GEOMETRIC AND OPERATIONAL CHARACTERISTICS

Other factors to be considered in the evaluation of an intersection should include the following:

10.8.2.1 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 accidents within this period may justify consideration of a left turn

phase.

10.8.2.2 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.

10.8.3.3 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.)

10.8.3.4 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.

10.9 NUMBER OF PHASES

10.9.1 GENERAL

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 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.

10.9.2 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.

10.9.3 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.

10.9.4 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.

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

10.9.5 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.

10.10 TYPE OF CONTROLLER

The type of control used can have a profound effect on the operational efficiency of any signal and, if incorrectly chosen, can defeat the purpose for which the signals were installed. The selection of the best form of control for any location can be made only with a full knowledge of local conditions but, in general, can be based on:

(a) The variation between peak and average hourly volumes on the main street.

(b) The variation between morning and afternoon average hourly volumes on the

main street.

(c) The variation between morning and afternoon average hourly volumes on the cross street.

(d) The percentage of the total average hourly volume using the intersection that enters from the cross street.

Factors (b) and (c) can be determined by studying the manual traffic count data, while Factors (a) and (d) can be obtained directly from the flow diagram.

The following table may be used as a guide for the selection of the type of controller at an isolated intersection, subject to variations in local conditions:

	Factor	Fixed-Time	Fully-Actuated	Volume-Density
(a)	Main street average to peak value	Any	More than 20%	More than 30%
(b)	Main street average hour variation	Less than 20%	More than 20%	More than 30%
(c)	Cross street average hour variation	Less than 20%	More than 20%	More than 30%
(d)	Cross street volume	More than 25%	Any value	More than 30%

In the preceding table, a 20% volume variation is taken as the critical value. With average volumes, this variation would require a change in cycle length that, under the conditions indicated, could not be provided for, except by changing the type of control.

The pretimed controller, if selected, shall be capable of providing multiple timing patterns to better accommodate directional shifts or volume variations in traffic during different portions of the day.

Often, it is found that certain movements (such as left turns or movements from a minor approach) cannot be accommodated adequately without the provision of special phases such as advance or exclusive phases. The demand for such special phases varies from cycle to cycle. In such cases, an actuated controller shall be selected. This would enable the special phases to be extended, skipped, or maintained as demand warrants without causing unnecessary delays to the major movements.

On the basis of research, only three types of controllers should receive consideration for installation at the majority of individual intersections: pretimed, fully-actuated, and volume-density. Semi-actuated control should be considered only for cases with very light cross street traffic in interconnected systems.

In order to allow for future expansion, the controller should be capable of providing additional phases of operation and timing patterns regardless of the number of phases and timing patterns required in the initial design.

10.11 SAMPLE DRAWINGS FOR PHASING AND SEQUENCING

Appendix A of this publication shows sample drawings for phasing and sequencing. The intent of this Appendix is to help guide the designer when determining "Phasing and Sequencing". The sample figures are not to scale and not all required and desirable signs, pavement markings, pedestrian features, traffic signal timing, and other traffic signal features are depicted. These examples should not be used in place of sound engineering judgment.

11.0 TRAFFIC SIGNAL TIMING

11.1 GENERAL

The full value of any signal installation is realized only when it is operating in a manner that is consistent with traffic demands. The use of an excessively long cycle or an improper cycle split can cause disrespect of the traffic signal and poor observance of traffic signal indications that may affect intersection safety.

11.2 TRAFFIC SIGNAL ANALYSIS SOFTWARE

Various software packages are available to analyze, optimize, and simulate traffic flow at signalized intersections or along signalized corridors or networks. Consult Chapter 12 of PennDOT Publication 46 for information on PennDOT-supported software.

11.3 TRAFFIC SIGNAL CONTROL TYPES

The type of traffic signal control is very important when determining signal timing. It is also essential to understand the pros and cons of each type of operation so that the most safe and efficient type is selected for the given conditions. In addition to the information in Sections 10.9 and 10.10 of this publication, the following are some typical traffic signal control operations that are presently used throughout the Commonwealth.

Pretimed traffic signal control is a set of phases with fixed green, yellow, and red intervals that make up the cycle length that does not vary. Typically, pretimed traffic control is most effective when used in an area where traffic patterns are predictable by time of day.

Semi-actuated traffic signal control generally has detection on the minor approaches to provide green time for the minor street phases based upon minor street traffic demand. Typically, semi-actuated traffic control operation is most efficient when the minor street has low volumes during the off-peak traffic periods.

Fully-actuated traffic signal control has detection on all approaches to allow the green times to vary and non-actuated phases to be skipped based on the traffic demand. Typically, fully-actuated traffic signal control is the most responsive operation to traffic demands.

Coordinated traffic signal control allows multiple signalized intersections to work together to optimize traffic flow along a corridor.

11.4 CYCLE LENGTH

The cycle length of a traffic signal is the time required for one complete sequence of signal indications at an intersection.

For pretimed signals, the cycle length is predetermined and consistent. Pretimed signal cycle lengths may vary from 45 seconds to 120 seconds, although cycle lengths less than 60 seconds are uncommon. Traffic-actuated signals (fully-actuated and semi-actuated) do not have a constant time cycle because it varies with the changing demands of traffic. The true cycle length will only be achieved when the intersection is using maximum timings for all of the critical phases. Cycle lengths for actuated signals may vary from 45 seconds to 180 seconds, although 180 seconds should only be considered for unusual situations.

Long cycle lengths reduce the relative amount of lost time taken by the change and clearance intervals, and may minimize the number of times that the major street traffic is stopped each hour. However, under all but most congested traffic conditions, moderate cycle lengths may prove to be more efficient in moving traffic with the least delay on the approaches.

One of the chief difficulties in the determination of cycle lengths comes from the need to accommodate two or more radically different volume patterns at various times during the period of operation. This may be addressed by multi-cycle, multi-split pretimed control, or by providing traffic actuation at the intersection.

The optimum division of the cycle length, or split as it is sometimes called, ordinarily is as important in securing signal efficiency as the selection of the appropriate cycle length and relationship (offset) between adjacent signalized locations. The reason is the direct relationship between the green time-to-cycle time ratio (G/C ratio) and intersection capacity.

The cycle length should normally be as short as practical to handle the traffic demand of individual intersections. With coordinated systems, selection of the cycle length is subject to the spacing of the coordinated signalized intersections and the prevailing speed along the corridor. Therefore, it will be assumed that the value of the cycle length has been specified based on these factors, and that the task is to divide it equitably. This task includes three parts:

(a) Computation of vehicle change and clearance times at each coordinated intersection.

(b) Selection of a minimum green interval time.

(c) Proportioning of the green intervals to correspond with traffic flow and efficiency of movement.

11.5 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.

11.5.1 YELLOW CHANGE INTERVAL

A yellow change interval should have a duration of approximately 3 to 6 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:

Metric:

$$Y = t + \frac{V}{2 \times 3.6(a \pm 9.81g)}$$

English:

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

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; km/h (mph)
a	=	Deceleration rate; [typically 3 m/s^2 (10 ft/s^2)]
g	=	Grade of approach; %/100

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

Table 11-1

Yellow Change Interval

Metric:

$t + \frac{V}{2 \times 3.6(a \pm 9.81 g)}$	V (Approach Speed, km/h)	*g* (Grade of Approach)												
		Uphill						Level	Downhill					
		6%	5%	4%	3%	2%	1%	0%	-1%	-2%	-3%	-4%	-5%	-6%
	30	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.5	2.5	2.6	2.7	2.7
	40	2.5	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.3
	50	2.9	3.0	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
	60	3.3	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.5
	70	3.7	3.8	3.9	4.0	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5.0
	80	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	5.0	5.1	5.3	5.4	5.6
	90	4.5	4.6	4.7	4.8	4.9	5.0	5.2	5.3	5.5	5.6	5.8	6.0	6.2
	100	4.9	5.0	5.1	5.2	5.3	5.5	5.6	5.8	6.0	6.1	6.3	6.5	6.8
	110	5.3	5.4	5.5	5.6	5.8	5.9	6.1	6.3	6.4	6.6	6.9	7.1	7.3

The perception-reaction time (*t*) was assumed to be 1 second, and a deceleration rate (*a*) of 3 m/s^2 was assumed.

English:

$t + \frac{1.47 V}{2a \pm 64.4 g}$	V (Approach Speed, mph)	*g* (Grade of Approach)												
		Uphill						Level	Downhill					
		6%	5%	4%	3%	2%	1%	0%	-1%	-2%	-3%	-4%	-5%	-6%
	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.

11.5.2 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:

Metric:

$$AR = \frac{3.6(W + L)}{V}$$

English:

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

Where:

AR = All-red clearance interval; s
V = Approach speed of the roadway; km/h (mph)
W = Width of intersection (from the near curb line to the center of the far lane); m (ft)
L = Length of vehicle, [typically 6.1 m (20 ft)]

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

Table 11-2

All-Red Clearance Interval

Metric:

	V (Approach Speed, km/h)	*W* (Width of Intersection), m										
		6	9	12	15	18	21	24	27	30)	33	36
$\frac{3.6(W+L)}{V}$	30	1.5	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.3	4.7	5.1
	40	1.1	1.4	1.6	1.9	2.2	2.4	2.7	3.0	3.2	3.5	3.8
	50	0.9	1.1	1.3	1.5	1.7	2.0	2.2	2.4	2.6	2.8	3.0
	60	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.3	2.5
	70	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.9	2.0	2.2
	80	0.5	0.7	0.8	0.9	1.1	1.2	1.4	1.5	1.6	1.8	1.9
	90	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.6	1.7
	100	0.4	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
	110	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4

The length of vehicle was assumed to be 6.1 meters.

English:

	V (Approach Speed, mph)	*W* (Width of Intersection), ft										
		20	30	40	50	60	70	80	90	100	110	120
$\frac{W+L}{1.47V}$	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
	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.

11.5.3 CHANGE AND CLEARANCE INTERVAL

The change and clearance interval is the sum of the yellow change and all-red clearance intervals. The change and clearance interval should be calculated using the following formula:

Metric/English:

$$CCI = Y + AR$$

AR = All-red clearance interval; s
Y = Yellow change interval; s
CCI = Change and clearance interval, s

11.6 Pedestrian Intervals

Refer to the MUTCD 2003 Edition Section 4E.10 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 1.1 m (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. Where pedestrians who walk slower than 1.1 m (3.5 ft) per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.1 m (3.5 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.

11.6.1 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 DONT Walk interval) commences. The walk interval should be at least 7 seconds in length so that pedestrians will 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, walk 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.

11.6.2 PEDESTRIAN CHANGE INTERVAL (FLASHING DONT WALK)

The pedestrian change interval (flashing DONT WALK) interval 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:

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

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; m (ft)
S_w = Walking speed; s [typically 1.1 m/s (3.5 ft/s)]

11.6.3 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 1.8 m (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 0.9 m (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.

11.6.4 MINIMUM GREEN INTERVAL WITHOUT PEDESTRIAN SIGNAL USE

When pedestrian signal indications are not provided but pedestrian requirements are to be considered in the signal timing plan, the length of the green interval should, as a minimum, include sufficient time (T_p) to allow pedestrians to cross the roadway at a walking speed of 1.1 m (3.5 ft) per second, plus additional time (3 seconds) for starting at the beginning of the green.

$$T_p = \frac{L}{S_w} + 3$$

T_p = Minimum green interval without pedestrian signals; s
L = Pedestrian walking distance from the curb or edge of shoulder to the far edge of the traveled way; m (ft)
S_w = Walking speed; s [typically 1.1 m/s (3.5 ft/s)]

11.7 GREEN INTERVALS

Many sophisticated methods have been developed for proportioning the green time at pretimed traffic signals in relation to traffic demand. The capacity calculation provides an approximate means of determining the proportioning of green time. Following the implementation of timing based on this or any other method of calculation, field observation and in-service timing adjustments should be made as needed to optimize the performance of the intersection.

Use the traffic signal analysis software as indicated in Section 11.2 of this publication to determine the most efficient proportioning of green intervals. After determining the desired proportioning of the green intervals, each green interval must be checked against the allowable initial (minimum) green time. Adjustment should be made, when necessary, to guarantee the initial (minimum) green time for each phase. The resultant timing applies directly where pretimed controllers are used.

For traffic-actuated controllers, the calculated timing is used for the maximum green or force-off timing for each phase. With actuated controllers equipped with separate pedestrian timers, the maximum or force-off must be set higher than the pedestrian minimum time. However, certain makes of controllers are equipped to allow the vehicle maximum time to be set to operate below the pedestrian minimum in the absence of a pedestrian actuation. This is an advantage for phases with low vehicular traffic, long crosswalks, and infrequent pedestrians.

Traffic flow data used for calculating the optimum division of the cycle length should represent the peak traffic conditions that will be encountered at the signal location. Fifteen-minute peak data, or peak hour data adjusted for the peak hour factor, is strongly recommended if available. If the different movements at an intersection peak at different time periods, the peak traffic counts from these different times should be evaluated to allow appropriate proportioning of the cycle length.

Greatest efficiency is obtained from traffic-actuated equipment only with proper adjustments to the equipment. This often requires some experimentation and field evaluation upon completion of the installation, and equipment adjustments should only be performed by a qualified and responsible individual.

11.7.1 INITIAL (MINIMUM) INTERVAL (NON-ACTUATED)

Using semi-actuated equipment, the timing for this period determines the initial (minimum) length of the major street green interval. It should be selected in relation to the minor street maximum in the same manner as pretimed signal phases are proportioned. This guaranteed interval is usually set in the range from 30 to 45 seconds.

11.7.2 INITIAL (MINIMUM) INTERVAL (ACTUATED)

During this portion of each actuated phase, green time is provided for vehicles stopped on the red indication between the detector and the stop line to start up and reach the intersection. The length of this period is determined from vehicle headway data. It should provide sufficient time for the last vehicle standing between the detector and the stop line to enter the intersection. Certain controllers also add one unit of passage time (see Section 11.7.3 of this publication) to this period, which must be considered when setting times on the controller unit. Under heavy traffic conditions, it should allow the first vehicle back from the detector to move across the detector and place an actuation. This minimum period (T_I) normally ranges between 5 seconds to 15 seconds when using impulse-type detection. Please see the following equation:

$$T_I = 3.7 + 2.1N$$

Where:

N = Number of vehicles that could be stored between detector and stop line

T_I = Initial (minimum) period; typically between 5 to 15 seconds

11.7.3 PASSAGE

Passage time (T_u) provides an added time increment during the green interval for each vehicle as it passes the detector. This feature also determines the length of gap which, if exceeded, permits the right-of-way to be transferred to another phase. Passage time should be determined by the travel time a vehicle needs to proceed from the detector to the near curb or edge of road of the intersection for the vehicle traveling at the average traveling speed during free flow. A value of 3 seconds to 5 seconds is frequently used with impulse-type detection. If presence-type detection is used and extends beyond the stop line, values of 0 seconds to 3 seconds are normally used. Please see the following equation:

$$T_u = \frac{D + d}{S}$$

Where:

D = Distance from detector to stop line; m (ft)
d = Distance from stop line to center of intersection; m (ft)
S = Speed of approaching vehicles; m/s (ft/s)
T_u = Passage time; s

11.7.4 MAXIMUM

For a semi-actuated controllers, the maximum is the maximum time for which the green indication will be displayed on the actuated phase even though actuations more frequent than the passage time may continue to occur. Semi-actuated equipment is designed to terminate the actuated phase green when the passage time lapses without an actuation. The maximum is usually set in the range of 15 seconds to 30 seconds for semi-actuated signals.

For fully-actuated controllers, the timing of the maximum begins with the first actuation on a phase having a red indication. The green phase will terminate upon a gap in the actuation on that street greater than the unit extension, or when the extension limit has timed out. When traffic volumes on all phases are so heavy that the extension limit terminates each green phase, the signal operates as a pretimed signal. This period is normally set between 30 seconds and 60 seconds for major movements and proportionately less for minor movements.

11.7.5 VOLUME-DENSITY OPERATION

For volume-density operation, the initial green timing varies between minimum green and maximum initial (M_I) by adding the added initial range to the minimum green. The three adjustments (minimum green, added initial, maximum initial) should be set so that sufficient green will be available.

Minimum green: The minimum green feature is set at a low value (8 s to 12 s), and this establishes the initial shortest green interval possible under extremely light traffic.

Maximum initial (M_I): The maximum initial establishes the upper limit of variable initial period. The three adjustments (minimum green, added initial, maximum initial) should be set so that sufficient green will be available to clear the number of vehicles which can be stored between the detector and the stop line.

$$M_I = 3.7 + 2.1N$$ Same as Section 11.7.2 of this publication

Where:

Metric:	English:	
$N = \frac{L}{6}$	$N = \frac{L}{20}$	L= Distance from detector to stop line; m (ft) 6 (20) = Length of vehicle; m (ft)

Variable initial (V_I): The variable initial is determined by a setting labeled as seconds per actuation, which determines the time from zero with each actuation received during the yellow and red intervals.

$$V_I = A_I \bullet N$$

Added initial (A_I): The initial green interval is increased from the minimum green value by the "added initial range" value which is based on the added initial (A_I) feature that adds the time set on the controller for each car which arrives on the red indication. The A_I feature ranges between 0 seconds and 3 seconds per actuation.

$$A_I = \frac{3.7 + 2.1N}{N}$$

Added initial range: As shown in Figure 11-1, the added initial range is determined by subtracting minimum green from variable initial, where V_I is greater than minimum green.

$$\text{Added initial range} = V_I - \text{minimum green}$$

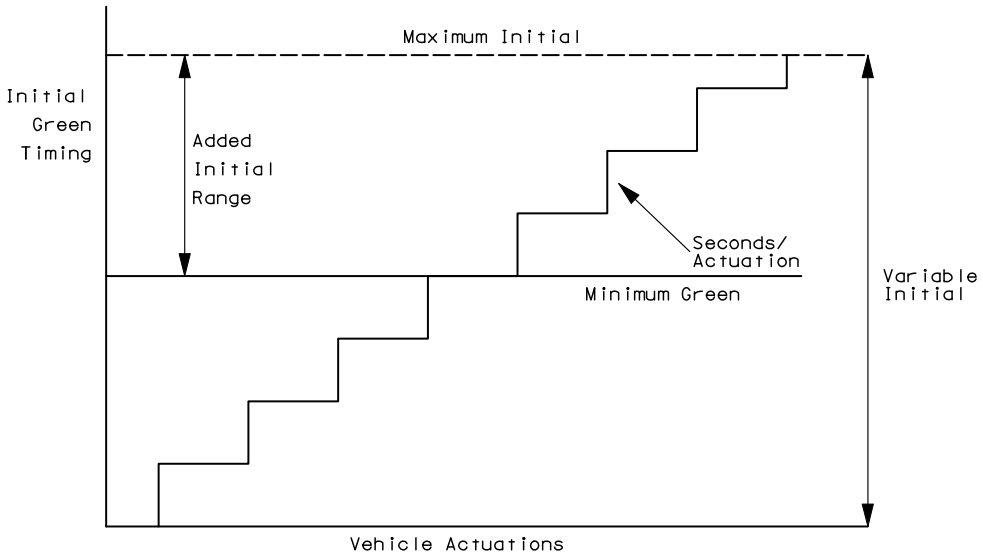


Figure 11–1. Added Initial Range

11.7.6 PASSAGE

This feature is the same as the passage discussed for non-volume-density controllers. Refer to Section 11.7.3 of this publication.

11.7.7 MINIMUM GAP

Provides the minimum value of the allowed gap between actuations for a phase with a

green indication. This value is reached upon expiration of the time to reduce.

11.7.8 TIME BEFORE REDUCTION

This period begins when the phase is green and there is a serviceable conflicting call. If the serviceable conflicting call is withdrawn during this period, this period will be reset to zero until the next serviceable call is received. During this period the passage time cannot be decreased (see Figure 11-2 of this publication). This value can be set to M_I by assuming that a serviceable conflicting call was placed at the start of the initial green timing.

$$TBR = M_I$$

11.7.9 TIME TO REDUCE

Establishes the time period when the allowed gap is reduced from passage time to the minimum gap. This reduction is a linear function (see Figure 11-2 of this publication).

$$TTR = \frac{TBR}{2}$$

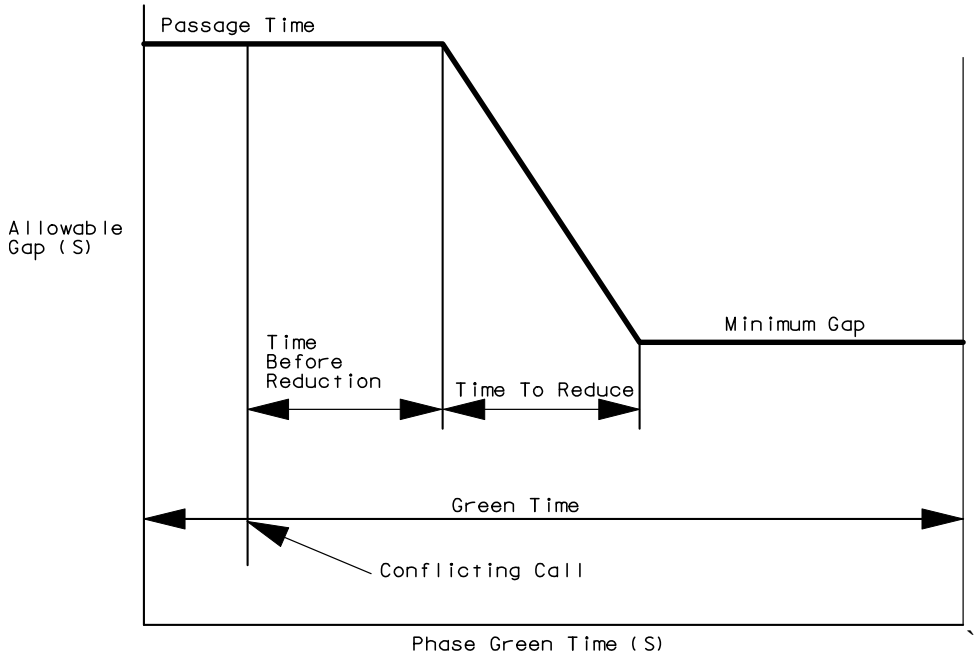


Figure 11–2. Time To Reduce

12.0 CONDUIT AND JUNCTION BOXES

12.1 CONDUIT

12.1.1 GENERAL

A network of conduits shall be designed for project locations requiring underground wiring for traffic signals, detectors, interconnect systems, and utility service connections. All conduit should meet the provisions of PennDOT Publication 148M and Publication 408.

12.1.2 CONDUIT LAYOUT

The conduit layout should be designed to minimize difficulty in construction. 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.

12.1.3 CONDUIT SIZE

In general, conduit sizes of 53 mm (2 in) diameter or greater are to be used for purposes of signalization or interconnection. Use of 27 mm (1 in) diameter conduits will be allowed for the routing of detector leads through the curb into a junction box and for detector lead-in runs to the controller cabinet. Twenty-seven millimeter (1 in) 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 Tables 12-1 and 12-2 of this publication for an example of this analysis.

TABLE 12-1
Conduit Fill Areas – Metric

	Conduit – 40% fill areas, mm^2			
Type	27 mm	53 mm	78 mm	103 mm
Non-metallic *	187	761	1703	3000
Metallic	219	864	1903	3284

* Use these values for design purposes

Conduit Fill Areas – English

	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

* Use these values for design purposes

TABLE 12-2
Signal Cable Areas – Metric

No. of Cables	Signal Cable Areas, mm^2							
	3.30 mm^2				2.08 mm^2			
	3/c	5/c	7/c	Lead-in	3/c	5/c	7/c	Lead-in
1	94	137	177	75	70	98	117	60
2	188	274	354	150	140	196	234	120
3	282	411	531	225	210	294	351	180
4	376	548	708	300	280	392	468	240
5	470	685	885	375	350	490	585	300
Bare Copper Ground Wire 1/c = 8.37 mm^2								

Signal Cable Areas – English

No. 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 1/c = 0.013 in^2								

12.1.4 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 610 mm (24 in). Trenching shall meet the provisions of PennDOT Publication 148M 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 may be considered for the installation of conduit.

(c) Boring. Directional boring may be considered as an alternative to jacking.

12.2 JUNCTION BOXES

12.2.1 GENERAL

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 PennDOT Publication 148M and Publication 408.

12.2.2 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 25 mm (1 in) above the surrounding grade.

12.2.3 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 100 m (330 ft).

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.

12.2.4 TYPES

Several types of junction boxes are detailed in PennDOT Publication 148M and PennDOT Publication 72M (RC Standards). Publication 148M 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 PennDOT 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.

13.0 SIGNAL WIRING

13.1 GENERAL

To aid in the construction and maintenance of signal wiring, the standards contained herein shall be adhered to during design.

13.2 CONDUCTORS

The size of all signal wire shall be determined utilizing the method shown in Figures 13-1 and 13-2 of this publication; 2.08 mm^2 (#14 AWG) shall be the minimum size.

13.3 CABLE SELECTION

The number of conductors to be used for signal head wiring is determined by the number of indication 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 four 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	Cable Size
Pedestrian Pushbutton	3/c
Preemption Beacon	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; and

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

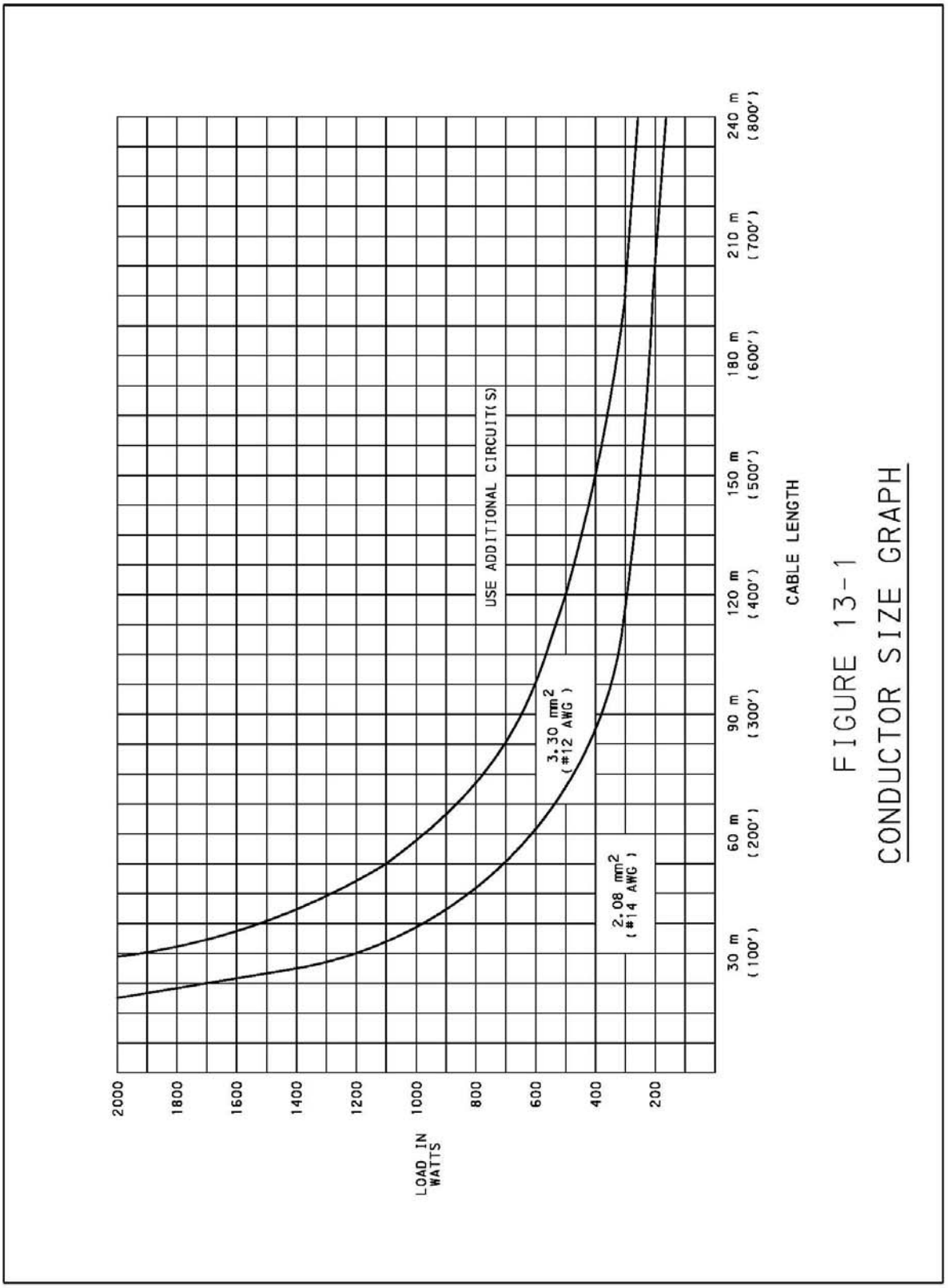


FIGURE 13-1
CONDUCTOR SIZE GRAPH

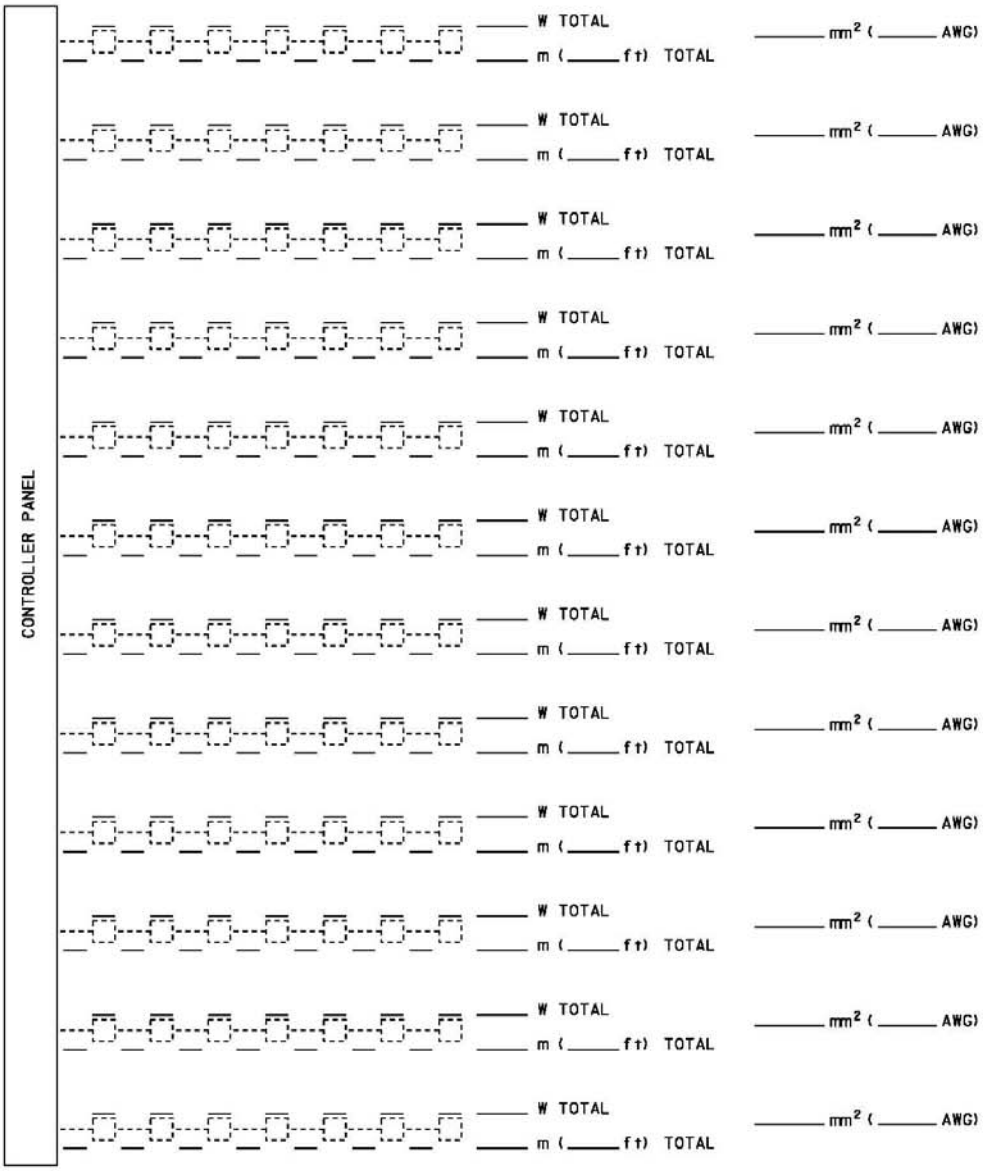


FIGURE 13-2

CONDUCTOR SIZE WORKSHEET

13.4 WIRING METHOD

Prior to the determination of the wiring a traffic signal design requires, 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.

13.5 WIRING DIAGRAM

A schematic wiring diagram shall be prepared or each traffic signalization design location. This diagram shall show the controller, signal heads, detectors, and pushbuttons as well as the required number, size, and types of wiring, and splices. An example of the diagram is illustrated in Figure 13-3 of this publication.

13.6 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	
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

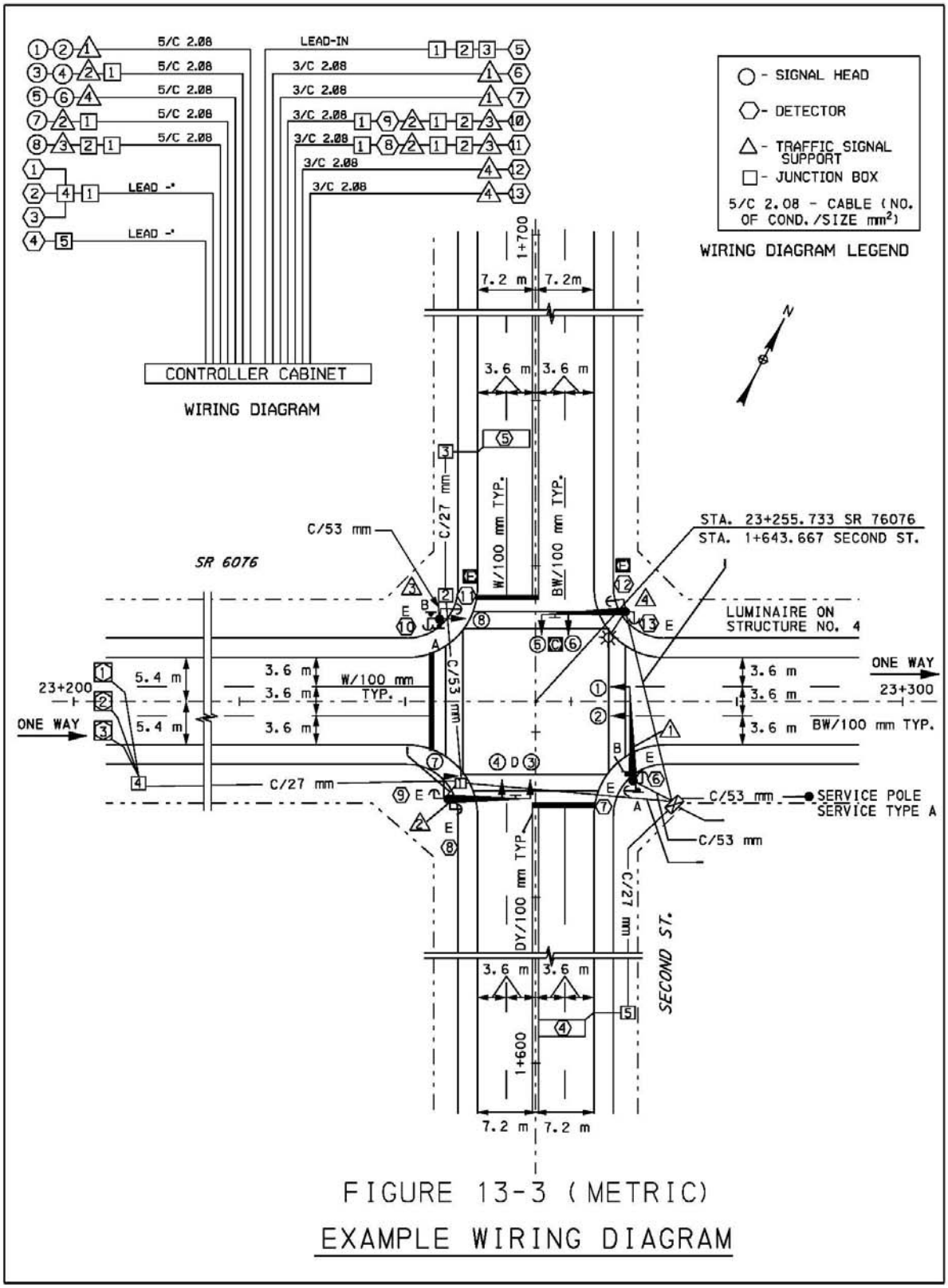


FIGURE 13-3 (METRIC)

EXAMPLE WIRING DIAGRAM

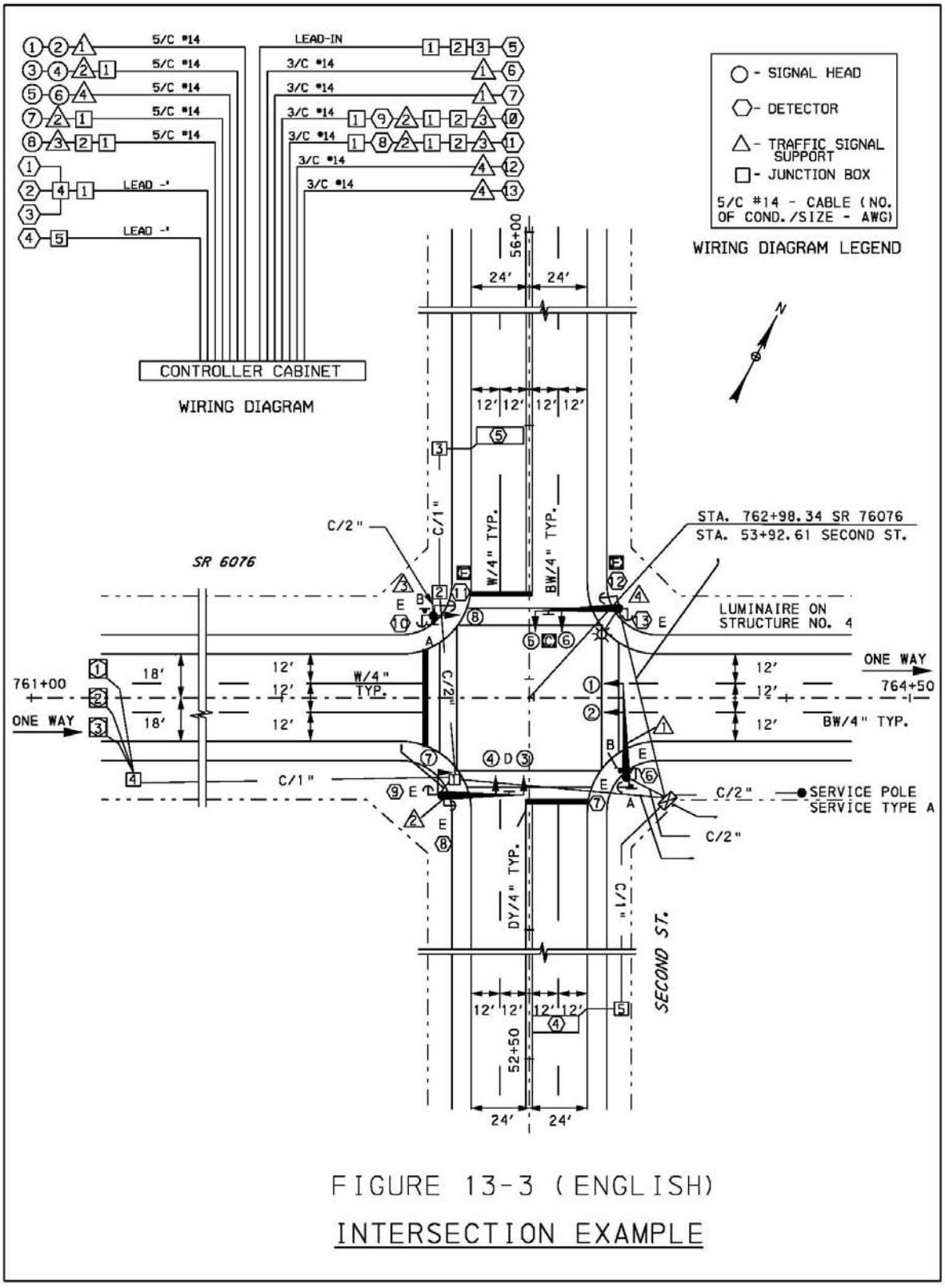


FIGURE 13-3 (ENGLISH)

INTERSECTION EXAMPLE

14.0 TRAFFIC CONTROL SIGNALS NEAR RAILROAD OR TRANSIT GRADE CROSSINGS

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 60 m (200 ft) 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. See Section 1.4 of this publication for additional information.

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 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 300 mm (12 in) 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.

15.0 EMERGENCY VEHICLE PREEMPTION

Consult the MUTCD 2003 Edition Section 4D.13.

Systems in which traffic control signals are preempted by approaching emergency vehicles shall be designed and installed to provide an indication (fail-safe) 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.

15.1 EMERGENCY VEHICLE PREEMPTION 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.

15.1.1 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.

15.1.2 ACOUSTIC PREEMPTION SYSTEMS

Acoustic preemption systems detect the sound from the siren of an emergency vehicle. Acoustic preemption systems do not require an 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.

15.1.3 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.

15.2 EMERGENCY VEHICLE PREEMPTION 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 Chart; Phasing Diagram; and associated notes on the traffic signal permit.

Upon termination of the preemption phase, the controller goes to the pre-designated post preemption phase, then to normal “Phase Next” operation. 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
3+8	----------	4+8
4+7	----------	4+8

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

16.0 VEHICLE DETECTION

16.1 VEHICLE DETECTION COMPONENTS

Vehicle detection systems are generally comprised of three components:

(a) The detector amplifier.

(b) Lead-in cable.

(c) A unit in the roadway surface or overhead.

16.2 MODES OF OPERATION

There are two modes of operation for detectors: pulse and presence.

16.2.1 PULSE MODE

When the mode selection switch is in the PULSE position, the detector provides one output pulse having a pulse width of 75 milliseconds to 150 milliseconds for each vehicle passing or stopping in 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.

16.2.2 PRESENCE MODE

When the mode selection switch is in 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.

16.3 LOOP DETECTOR LAYOUT

A loop is constructed of a continuous length of wire placed in the pavement.

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 three basic configurations of loops which may be utilized:

(a) Short loop.

(b) Long loop.

(c) Modified long loop.

16.3.1 SHORT LOOPS

The short loop may be installed either alone, or in conjunction with other short loops to create a large detection area (see Figure 16-1 of this publication). Sizing and layout criteria are as follows:

(a) The length shall be 1.8 m (6 ft).

(b) The minimum width shall be 1.5 m (5 ft).

(c) The sides of the loop should be 0.9 m (3 ft) from either edge of the travel lane.

(d) For single loops, the location from the stop line is determined by the speed of approaching vehicles.

(e) For sequential short loops, the detection area shall be comprised of four loops and shall be approximately 21 m (70 ft) long. The first loop shall be placed so that it extends 0.9 m (3 ft) beyond the stop line. The second, third, and fourth loops shall be sequentially spaced at 3 m (10 ft), 4.5 m (15 ft) and 6 m (20 ft), respectively.

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

16.3.2 LONG LOOPS

The long loop is used to provide a large detection area with one loop. Each lane of a detectorized approach shall have a separate loop (see Figures 16-1, 16-2, and 16-3 of this publication). Sizing and layout criteria are as follows:

(a) The maximum length shall be 15 m (50 ft).

(b) The maximum width shall be 2.4 m (8 ft) and the minimum 1.5 m (5 ft).

(c) The sides of the loop should be 0.9 m (3 ft) from either edge of the travel lane.

(d) The front edge of the loop may extend 0.9 m (3 ft) beyond the stop line.

Long loops shall operate in the presence mode only.

16.3.3 MODIFIED LONG LOOPS

The modified long 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 8 pattern in the saw cut, thus creating two narrow loops laid side-by-side (see Figure 16-1 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. See Publication 148M for additional loop patterns for small vehicles.

16.3.4 SENSOR DESIGN

The following represents various sensor design options available to the designer:

(a) 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.

(b) Option 2: Consists of a long loop 1.8 m (6 ft) by 15 m (50 ft) 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.

(c) 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.

(d) 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.

(e) 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.

(f) 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 1.8 m (6 ft) x 1.8 m (6 ft) calling detector shall be used in these cases.

16.3.5 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.

16.3.6 JUNCTION BOXES

A sensor should have a junction box located in its immediate vicinity out of the roadway area. Sensors shall be provided with a length of 27 mm (1 in) 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.

16.4 OVERHEAD DETECTION DEVICES

All overhead detection devices should be evaluated prior to a determination of use so that potential problems can be avoided.

16.4.1 VIDEO DETECTION SYSTEMS

Video detection systems use video cameras for vehicle detection. 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) 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.

16.4.2 OTHER DETECTION SYSTEMS

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

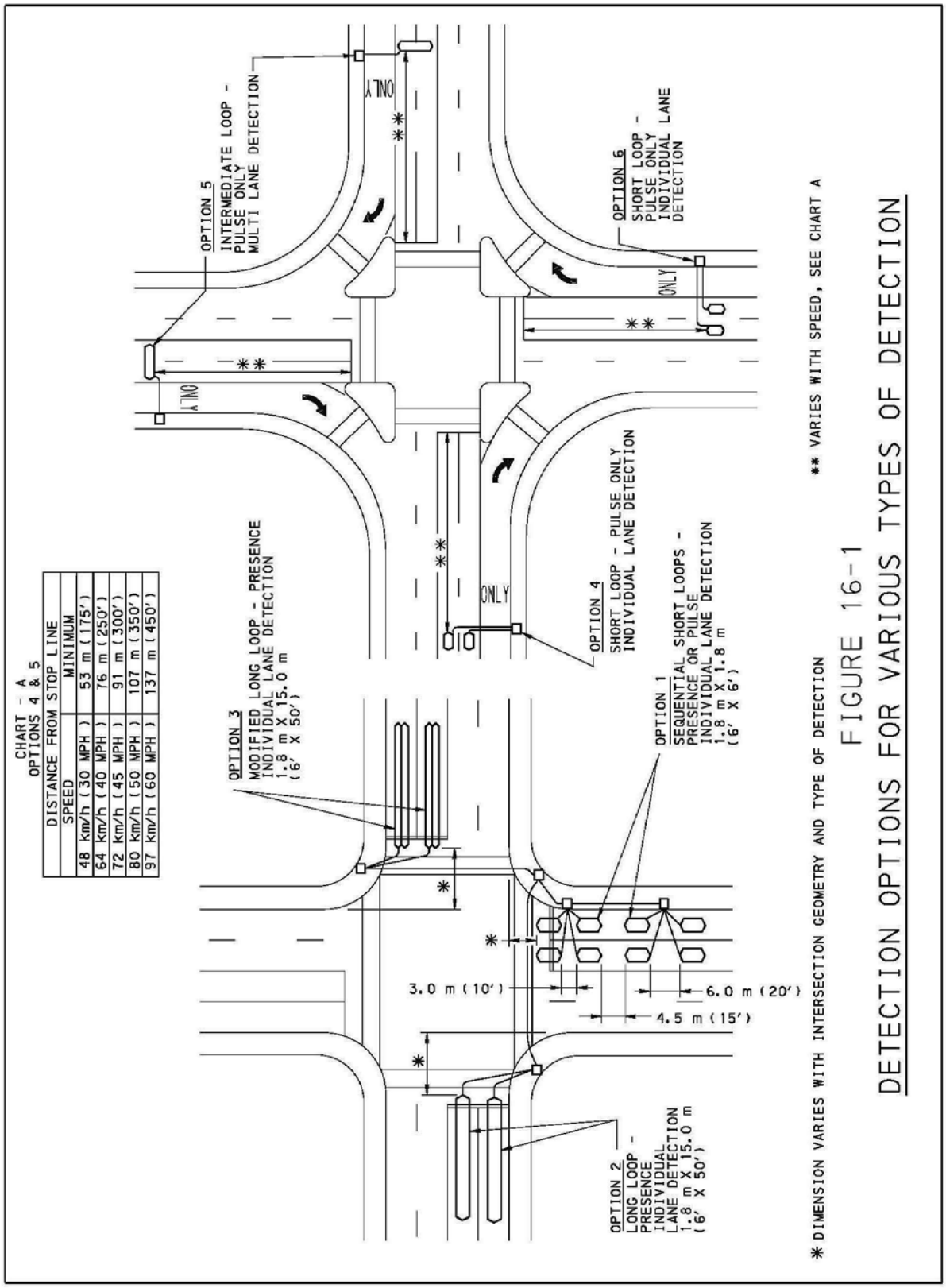
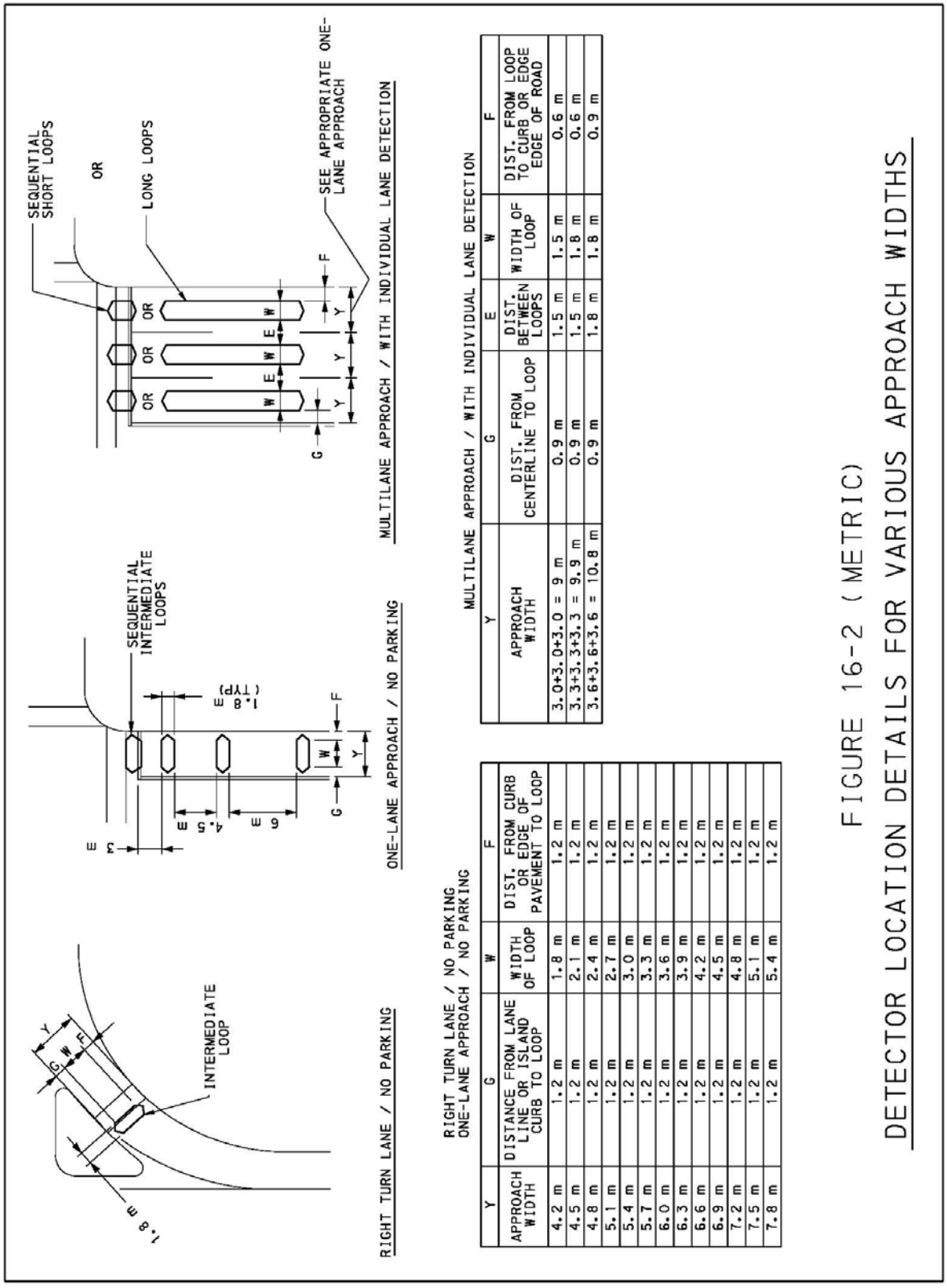


CHART - A
OPTIONS 4 & 5
DISTANCE FROM STOP LINE
SPEED
MINIMUM
48 Km/h (30 MPH) 53 m (175')
64 Km/h (40 MPH) 76 m (250')
72 Km/h (45 MPH) 91 m (300')
80 Km/h (50 MPH) 107 m (350')
97 Km/h (60 MPH) 137 m (450')
OPTION 5
INTERMEDIATE LOOP - PULSE ONLY MULTI LANE DETECTION
OPTION 6
SHORT LOOP - PULSE ONLY INDIVIDUAL LANE DETECTION
OPTION 4
SHORT LOOP - PULSE ONLY INDIVIDUAL LANE DETECTION
OPTION 3
MODIFIED LONG LOOP - PRESENCE INDIVIDUAL LANE DETECTION 1.8 m X 15.0 m (6' X 50')
OPTION 1
SEQUENTIAL SHORT LOOPS - PRESENCE OR PULSE INDIVIDUAL LANE DETECTION 1.8 m X 1.8 m (6' X 6')
OPTION 2
LONG LOOP - PRESENCE INDIVIDUAL LANE DETECTION 1.8 m X 15.0 m (6' X 50')
ONLY
3.0 m (10')
6.0 m (20')
4.5 m (15')
* DIMENSION VARIES WITH INTERSECTION GEOMETRY AND TYPE OF DETECTION
** VARIES WITH SPEED, SEE CHART A
FIGURE 16-1
DETECTION OPTIONS FOR VARIOUS TYPES OF DETECTION



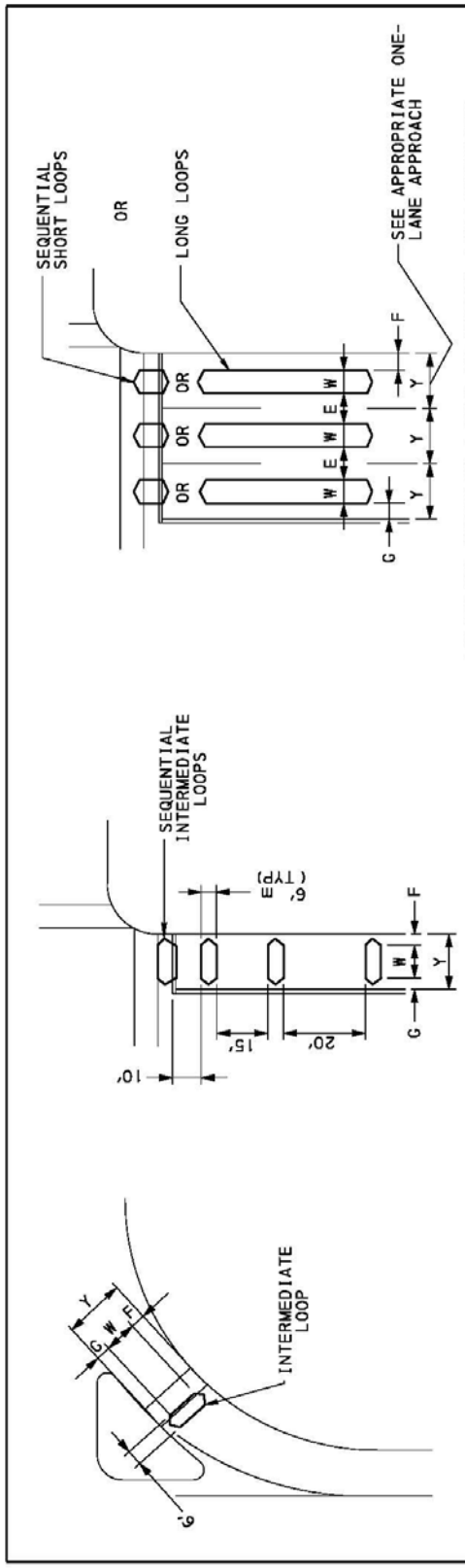
RIGHT TURN LANE / NO PARKING
ONE-LANE APPROACH / NO PARKING

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
4.2 m	1.2 m	1.8 m	1.2 m
4.5 m	1.2 m	2.1 m	1.2 m
4.8 m	1.2 m	2.4 m	1.2 m
5.1 m	1.2 m	2.7 m	1.2 m
5.4 m	1.2 m	3.0 m	1.2 m
5.7 m	1.2 m	3.3 m	1.2 m
6.0 m	1.2 m	3.6 m	1.2 m
6.3 m	1.2 m	3.9 m	1.2 m
6.6 m	1.2 m	4.2 m	1.2 m
6.9 m	1.2 m	4.5 m	1.2 m
7.2 m	1.2 m	4.8 m	1.2 m
7.5 m	1.2 m	5.1 m	1.2 m
7.8 m	1.2 m	5.4 m	1.2 m

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
3.0+3.0+3.0 = 9 m	0.9 m	1.5 m	1.5 m	0.6 m
3.3+3.3+3.3 = 9.9 m	0.9 m	1.5 m	1.8 m	0.6 m
3.6+3.6+3.6 = 10.8 m	0.9 m	1.8 m	1.8 m	0.9 m

FIGURE 16-2 (METRIC)
DETECTOR LOCATION DETAILS FOR VARIOUS APPROACH WIDTHS



MULTILANE APPROACH / WITH INDIVIDUAL LANE DETECTION

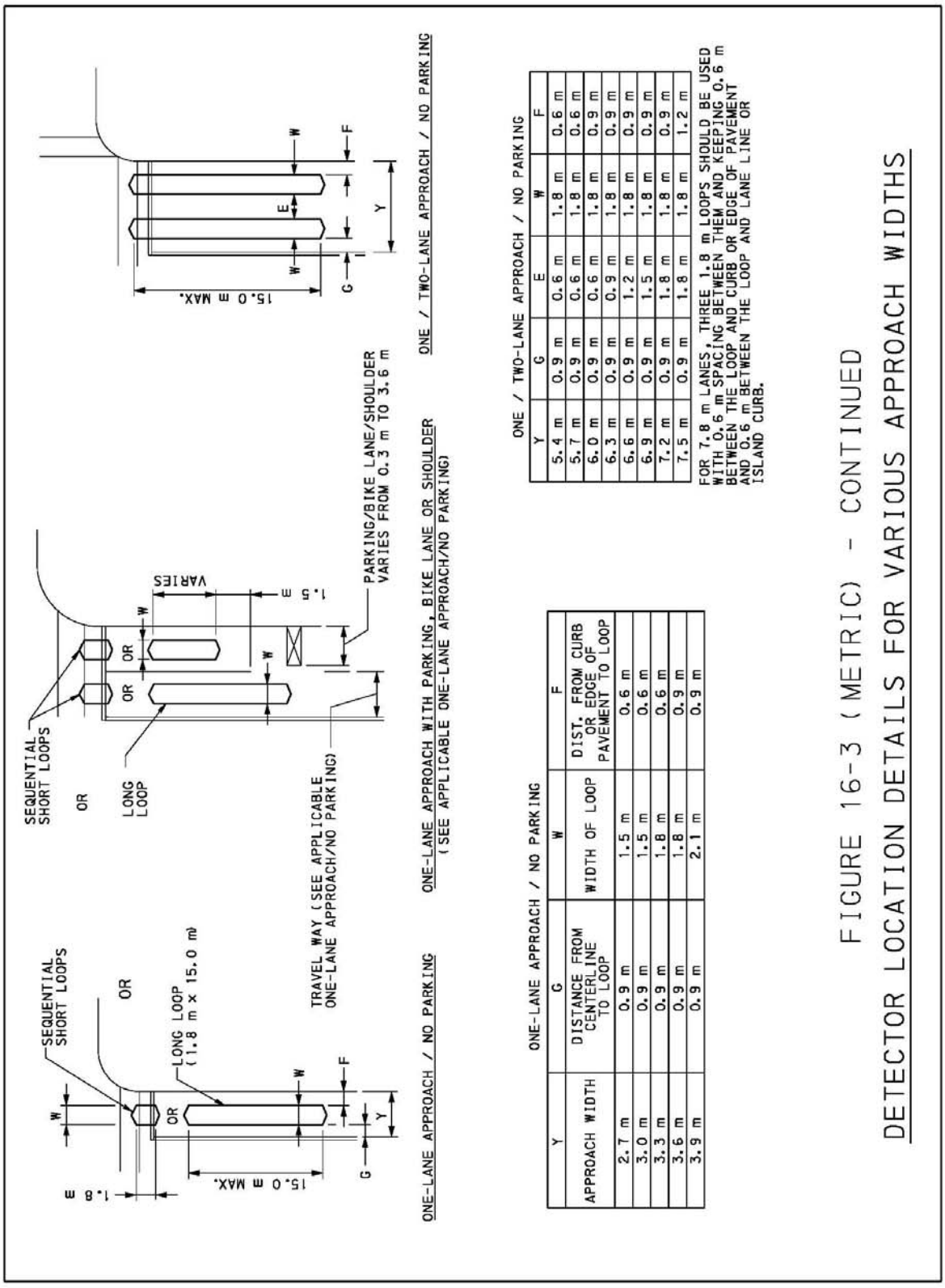
Y	G	E	W	F
APPROACH WIDTH	DIST. FROM CENTERLINE TO LOOP	DIST. BETWEEN LOOPS	WIDTH OF LOOP	DIST. FROM LOOP TO CURB OR EDGE EDGE OF ROAD
10+10+10 = 30'	3'	5'	5'	2'
11+11+11 = 33'	3'	5'	6'	2'
12+12+12 = 36'	3'	6'	6'	3'

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'

FIGURE 16-2 (ENGLISH)

DETECTOR LOCATIONS DETAILS FOR VARIOUS APPROACH WIDTHS



ONE-LANE APPROACH / NO PARKING

ONE-LANE APPROACH WITH PARKING, BIKE LANE OR SHOULDER
(SEE APPLICABLE ONE-LANE APPROACH/NO PARKING)

ONE / TWO-LANE APPROACH / NO PARKING

ONE-LANE APPROACH / NO PARKING

Y	G	W	F
APPROACH WIDTH	DISTANCE FROM CENTERLINE TO LOOP	WIDTH OF LOOP	DIST. FROM CURB OR EDGE OF PAVEMENT TO LOOP
2.7 m	0.9 m	1.5 m	0.6 m
3.0 m	0.9 m	1.5 m	0.6 m
3.3 m	0.9 m	1.8 m	0.6 m
3.6 m	0.9 m	1.8 m	0.9 m
3.9 m	0.9 m	2.1 m	0.9 m

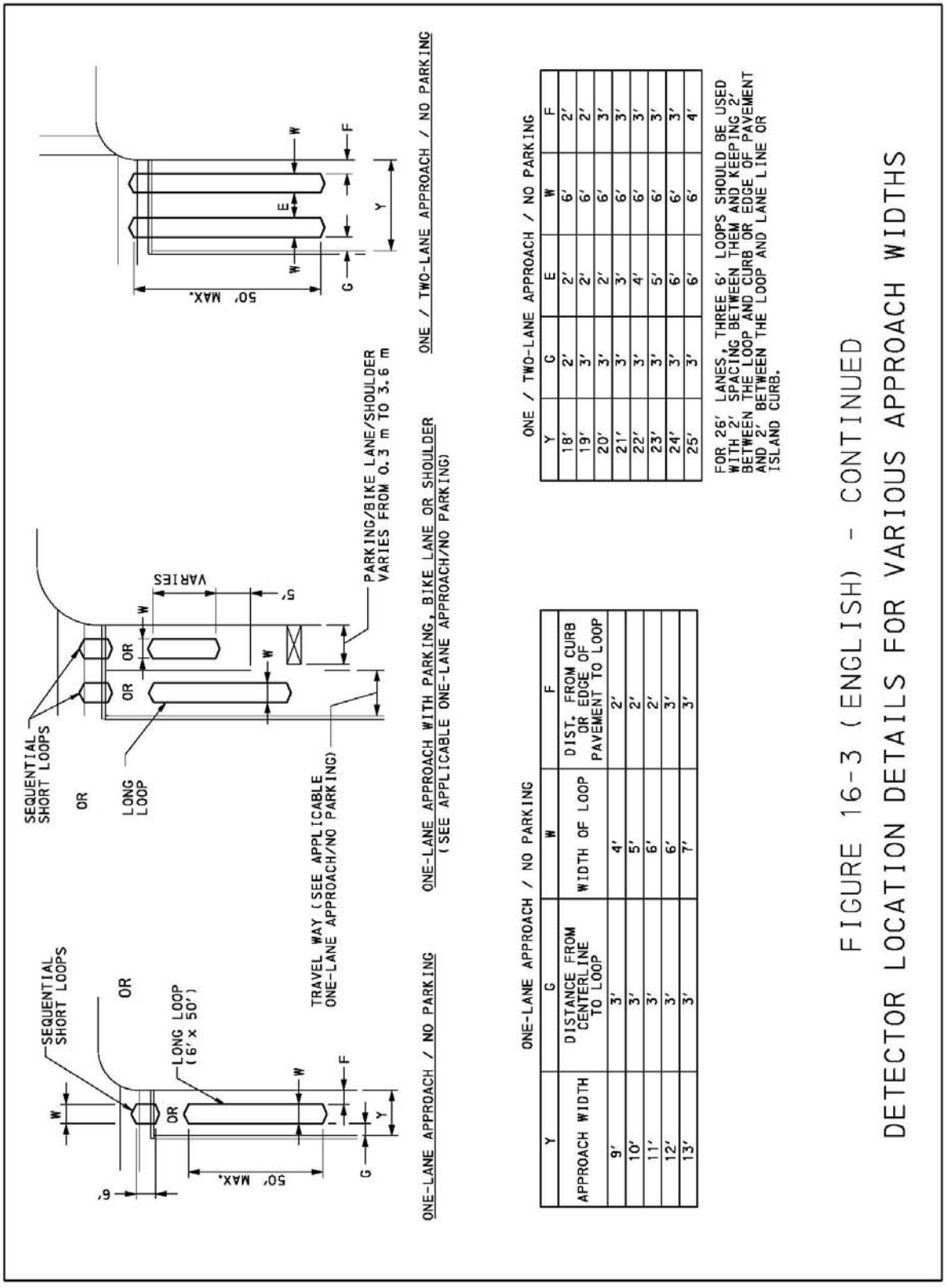
ONE / TWO-LANE APPROACH / NO PARKING

Y	G	E	W	F
5.4 m	0.9 m	0.6 m	1.8 m	0.6 m
5.7 m	0.9 m	0.6 m	1.8 m	0.6 m
6.0 m	0.9 m	0.6 m	1.8 m	0.9 m
6.3 m	0.9 m	0.9 m	1.8 m	0.9 m
6.6 m	0.9 m	1.2 m	1.8 m	0.9 m
6.9 m	0.9 m	1.5 m	1.8 m	0.9 m
7.2 m	0.9 m	1.8 m	1.8 m	0.9 m
7.5 m	0.9 m	1.8 m	1.8 m	1.2 m

FOR 7.8 m LANES, THREE 1.8 m LOOPS SHOULD BE USED WITH 0.6 m SPACING BETWEEN THEM AND KEEPING 0.6 m BETWEEN THE LOOP AND CURB OR EDGE OF PAVEMENT AND 0.6 m BETWEEN THE LOOP AND LANE LINE OR ISLAND CURB.

FIGURE 16-3 (METRIC) - CONTINUED

DETECTOR LOCATION DETAILS FOR VARIOUS APPROACH WIDTHS



ONE-LANE APPROACH / NO PARKING

Y	G	W	F
APPROACH WIDTH	DISTANCE FROM CENTERLINE TO LOOP	WIDTH OF LOOP	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′

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.

FIGURE 16-3 (ENGLISH) - CONTINUED

DETECTOR LOCATION DETAILS FOR VARIOUS APPROACH WIDTHS

17.0 PAVEMENT MARKINGS AND SUPPLEMENTAL SIGNS

17.1 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 PennDOT Publications 46, 111M, 212, and 408.

17.2 SIGNS

Provide signs (such as turn prohibition, lane control, one-way, overhead street name, pedestrian control, and others) required to properly direct and control the flow of vehicular and pedestrian traffic through the signalized intersection.

Signs shall meet the provisions of PennDOT Publications 46, 212, 236M, and 408.

17.3 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 restriction is applicable at specific times.

18.0 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, driveways, pedestrian movements, overhead wiring, etc.

Consult the appropriate utilities and the National Electric Code for clearances from overhead wiring and other facilities.

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.

In areas with curbs and speeds of 60 km/h (35 mph) or less, a minimum clearance of 0.6 m (2 ft) shall be maintained between the face of curb and any part of the signal equipment or fixed supports. Where curbs do not exist or speeds are greater than 60 km/h (35 mph), signal equipment shall have a minimum clearance of 3 m (10 ft) from the edge of the traveled roadway and a minimum of 0.6 m (2 ft) from the edge of shoulder. On rural highways, every effort shall be made to attain the clear roadside concept that will not compromise vehicular safety.

The installation of fixed supports for overhead traffic signals in islands should be avoided, if possible. However, fixed supports may be located in islands when necessary to maintain the effectiveness of the signal display provided the designer can provide a set-back of 2.4 m (8 ft) from all sides of a curbed island or 4.2 m (14 ft) set-back from all sides of an uncurbed island or island with mountable curb.

If the above provisions cannot be satisfied, redesign of the signals or use of guiderail or barrier should be considered. The use of this criteria in conjunction with the provisions in PennDOT Publication 13M (Chapter 12) and PennDOT Publication 72M should provide an acceptable method of determining the use of guiderail or barrier. The criteria in PennDOT Publication 13M (Design Manual Part 2) is a guide and should be supplemented with engineering judgment. For urban-type conditions (low speeds, curbs, parking, pedestrian activity, driveways), guiderail or barrier may be used only in very few cases.

19.0 PEDESTRIAN ACCOMMODATION AT SIGNALIZED INTERSECTIONS

This chapter provides clarification of key issues pertaining to Americans with Disabilities Act (ADA) provisions and pedestrian accommodation at signalized intersections. The objectives of this chapter are to promote statewide uniformity and to provide direction for critical issues.

This chapter shall comply with the Manual of Uniform Traffic Control Devices (MUTCD) as adopted by the Department in PennDOT Publication 212.

19.1 CURRENT ADA CRITERIA FOR SIGNALIZED INTERSECTIONS

The Summary of ADA Title II (28 CFR PART 35) is stated below:

*"**SUMMARY:** This rule implements subtitle A of title II of the Americans with Disabilities Act, Pub. L. 101-336, which prohibits discrimination on the basis of disability by public entities. Subtitle A protects qualified individuals with disabilities from discrimination on the basis of disability in the services, programs, or activities of all State and local governments. It extends the prohibition of discrimination in federally assisted programs established by section 504 of the Rehabilitation Act of 1973 to all activities of State and local governments, including those that do not receive Federal financial assistance, and incorporates specific prohibitions of discrimination on the basis of disability from titles I, III, and V of the Americans with Disabilities Act. This rule, therefore, adopts the general prohibitions of discrimination established under section 504, as well as the requirements for making programs accessible to individuals with disabilities and for providing equally effective communications. It also sets forth standards for what constitutes discrimination on the basis of mental or physical disability, provides a definition of disability and qualified individual with a disability, and establishes a complaint mechanism for resolving allegations of discrimination."*

When it is determined that pedestrians are present and accommodations will be provided, 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 based on the type of pedestrians that are present.

19.2 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. The documentation may be provided with guidance from the Pedestrian Needs Accommodation at Signalized Intersections Checklist on pages 19-8 and 19-9.

19.3 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.

19.3.1 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 Section 19.7. 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 without pedestrians may remain in-place and be maintained until they are no longer functional, at which point they must be removed.

19.3.2 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 PennDOT Publication 13M (DM-2), PennDOT Publication 72M (RC Standards), PennDOT Publication 148 (TC Standards), PennDOT Publication 149M, PennDOT Publication 212, the MUTCD (Section 4E), and ADA requirements.

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:

- Physical restrictions that prohibit pedestrian activity as specified in ADA Title II [i.e., sidewalks less than 0.9 m (3ft) wide or shoulders less than 1.2 m (4 ft) wide].
- Where pedestrian accommodations should not be installed for an approach due to pedestrian crash history or geometrics.

Refer to Section 19.5 for more information regarding pedestrian restrictions.

19.3.3 SIGNALIZED INTERSECTIONS REQUIRING ACCOMODATION 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 national Manual on Uniform Traffic Control Devices (MUTCD) and the Public Rights of Way Accessibility Guidelines (PROWAG).

19.4 ADA AND PEDESTRIAN ACCOMMODATION FOR SIGNALIZED INTERSECTION PROJECT TYPES

A. Maintenance Type Projects. The following examples represent traffic signal projects that include routine maintenance and repair work that generally does not impact, disturb, or modify pedestrian usability. Therefore, these types of work may be completed without other simultaneous modifications to ensure full ADA compliance. For additional examples, refer to PennDOT Publication 13M (DM-2), Chapter 6, Section 6.3. Examples of Maintenance Type Projects include:

- Maintenance and modifications to traffic signal timing and phasing.
- Maintenance, repair, and/or modifications to electrical service equipment.
- Maintenance, replacement, repair, and/or modifications to traffic signal coordination equipment.
- Maintenance, replacement, repair, and/or modifications of traffic signal controllers, controller cabinet assemblies, and related electronic equipment.
- Maintenance, replacement, repair, and/or modifications to pavement markings on the roadway.
- Minor repair and maintenance of pedestrian pushbuttons.
- Minor repair and maintenance of accessible pedestrian signals (APS).
- Maintenance, replacement, and/or repair of circular LED vehicle traffic signal modules.
- Maintenance, replacement, and/or minor repair of LED pedestrian signal head modules or LED countdown pedestrian signal head modules.
- Installation of LED modules to replace incandescent or other light sources.
- Maintenance, replacement, repair, and/or modifications to vehicular detectors.
- Maintenance, replacement, repair, and/or modifications to traffic control signage.
- Maintenance, replacement, repair, and/or modifications to roadway lighting.
- Maintenance, replacement, repair, and/or modifications to video surveillance equipment.
- Maintenance, replacement, repair, and/or modifications to emergency vehicle preemption systems.
- Maintenance, replacement, repair, and/or modifications of junction boxes.
- Maintenance, replacement, and/or relocation to conduit and utility repairs that result in a small portion (less than 30 meters and less than 46 square meters (less than 100 feet and less than 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.
- Maintenance, replacement, repair, and/or modifications of junction boxes outside the pedestrian accessible route.
- Maintenance, replacement, repair, and/or modifications to traffic signal wiring.
- Maintenance, replacement, repair, and/or modifications to traffic signal conduit outside of the pedestrian accessible route.
- Maintenance and minor repair of traffic signal conduit within the pedestrian accessible route.
- Replacement of traffic signal poles.
- All traffic signal preventive maintenance activities.
- Emergency traffic signal pole replacement and other emergency repairs to an existing traffic signal installation.

B. Alteration Type Projects. When an existing pedestrian feature is replaced, 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 examples, refer to PennDOT Publication 13M (DM-2), Chapter 6, Section 6.3. Examples of Alteration Type Projects include:

- 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 30.48 m (100 ft)] of existing accessible route. The newly constructed accessible route will need to meet PennDOT's standards.
- Installation of new pedestrian pushbuttons or accessible pedestrian signals (APS) or relocation of existing pushbuttons.
- Installation of new curb ramps or relocation, repair, and/or modifications to existing curb ramps.
- Relocation of traffic signal poles.
- The addition of pedestrian features to an intersection.
- Minor widening or geometric improvements to an intersection (i.e., the addition of bulb outs).
- The addition of sidewalks at or near the intersection that will generate pedestrian activity at the signalized intersection.

C. Reconstruction and New Construction Type Projects. The following traffic signal projects are typically major projects including new construction, reconstruction, retrofit projects, sidewalk retrofit projects, and community enhancement projects. These traffic signal 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 be expected to provide a complete pedestrian route between logical termini. These projects may require out-of-scope work where feasible and reasonable. For additional examples, refer to PennDOT Publication 13M (DM-2), Chapter 6, Section 6.3. Examples of Reconstruction and New Construction include:

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

19.5 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:

- 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.
- 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.
- Do not use the need for ADA accommodations as the basis to restrict pedestrians, when this otherwise would not be considered.
- 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.
- The "No Pedestrian Crossing Sign" (R9-3A) as shown in PennDOT Publication 236M 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.
- 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.
- ADA compliant curb ramps shall only be placed when the pedestrian need for accommodation is present and pushbutton locations shall be ADA compliant.
- 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.
- If the municipality has not requested APS, the engineering study shall determine if APS is required as outlined in the MUTCD, Sections 4E.06 and 4E.09 and shall include outreach to municipalities, school districts, transit organizations and others.
- All additional guidelines specified in PennDOT Publication 13M (DM-2) and PennDOT Publication 72M (RC Standards) must be followed.
- If pedestrian accommodations are not needed, then an approved engineering study shall document all conclusions.
- 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 without pedestrians may remain in-place and be maintained until they are no longer functional, at which point they must be removed.

19.6 ADA COMPLIANCE DOCUMENTS

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

- PennDOT Publication 13M Design Manual Part 2: Highway Design.
- PennDOT Publication 72M Roadway Construction Standards (RC Standards).
- PennDOT Publication 148 Traffic Standards (TC-7800 Series) Signals.
- 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.
- ADA Accessibility Survey Instructions: Curb Ramps.
- PennDOT District ADA Training Course & Course Materials, Fall 2007.
- *Designing Sidewalks and Trails for Access (Part 2): Best Practices Design Guide*, USDOT, 2001.
- *PEDSAFE: Pedestrian Safety Guide & Countermeasure Selection System*, FHWA-SA-04-003, September 2004.
- Bike/Ped Checklist, Appendix J of Design Manual, Part 1A, PennDOT Publication 10A.
- Technically Infeasible Form in Publication 13M Design Manual Part 2: Highway Design, Appendix A.
- PennDOT Pedestrian Facilities Design Checklist in Publication 13M Design Manual Part 2: Highway Design, Appendix B.

19.7 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

PEDESTRIAN NEEDS ACCOMMODATION AT SIGNALIZED INTERSECTIONS CHECKLIST

Intersection Background Information

DATE: _____
DISTRICT: _____
COUNTY: _____
MUNICIPALITY : _____
INTERSECTION: _____
SUBMITTED BY: _____
STREET ADDRESS: _____
CITY, STATE, ZIP: _____
TELEPHONE: _____

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 the engineering study and engineering judgment, proper documentation shall be made at all new signalized intersections and modifications to existing signalized intersections. This documentation shall be provided with guidance from this checklist.

Project Overview

- ☐ Provide a Detailed Project Description and Scope of the Project.
- ☐ Bike/Ped Checklist Completed

Existing Facility Description

Yes	No	
☐	☐	Are pedestrian facilities present (i.e., curb ramps, crosswalks, pedestrian signals, etc.)?
☐	☐	Are there detailed descriptions of each quadrant of the existing intersection (photos are strongly recommended)?
☐	☐	Are all near-by land uses documented?
☐	☐	Are pedestrian facilities near the intersection (i.e., sidewalks, bus stops, trails, etc.)?
☐	☐	Is there current evidence of pedestrians using the intersection?
☐	☐	Were special accommodations made in the past for pedestrians at the intersection?
☐	☐	Provide all justifications for previous restrictions to pedestrians at the intersection.
☐	☐	Are physical restrictions present?
☐	☐	If pedestrian signals are present, is proper traffic signal timing designated for pedestrians at the intersection?

Proposed Facility Description

Yes	No	
☐	☐	Will the proposed improvements generate new or additional pedestrian traffic?
☐	☐	Does the proposed facility introduce possible additional restrictions for pedestrians?
☐	☐	Are new or existing pedestrian signals proposed at the intersection?
☐	☐	Are sidewalks proposed as part of the project?
☐	☐	Are detailed descriptions of changes to each quadrant documented?
☐	☐	Do near-by land uses change as part of the project?
☐	☐	Are additional pedestrian facilities proposed for the intersection?

Outreach Efforts

Has contact and discussion concerning pedestrian accommodations at the intersection been made with the following?

Yes	No		
☐	☐	Municipality (s)	_____
☐	☐	Transit Organization (s)	_____
☐	☐	School District (s)	_____
☐	☐	Public Meeting (s)	_____
☐	☐	Other (s)	

Pedestrian Determination Using Engineering Judgment

Yes	No	
☐	☐	Has a detailed summary of the pedestrian evaluation of the intersection been completed?(Include all restrictions, reasons for restrictions, and additional pedestrian accommodation recommendations as indicated from the study.)
☐	☐	Will pedestrian signals be required? (If yes, please refer to the Pedestrian Traffic Signals section below.)
☐	☐	If restrictions for pedestrians are present, has the proper documentation been completed?
☐	☐	Is the need for pedestrian access been determined from field observation?
☐	☐	Is the need for pedestrian access been determined from factors identified from the Bike/Ped. Checklist?
☐	☐	Is the need for pedestrian access been determined from local comprehensive planning?
☐	☐	Other Determination Factors _____

Pedestrian Traffic Signals (if applicable)

Yes	No	
☐	☐	Is there proper pedestrian timing established at the intersection?
☐	☐	Is an all-pedestrian phase recommended in the study?
☐	☐	Are the crosswalks in alignment with curb ramps?
☐	☐	Are pedestrian signals visible from the proposed crosswalk/curb ramp locations?
☐	☐	Are countdown pedestrian signals present?
☐	☐	Has the need for Accessible Pedestrian Signals (APS) been determined from the study?
☐	☐	Are pushbuttons proposed to be within the current ADA criteria?
☐	☐	Are all pushbutton locations accessible to all pedestrians?
☐	☐	Do all features satisfy applicable state and federal requirements?

Executive Summary (Engineering Judgment/Recommendations)

District Traffic Engineer Approval	Assistant District Executive Approval
District Traffic Engineer Date	District ADE of Design, Maintenance or Services Date

20.0 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.

20.1 PART A - DESIGN CRITERIA FOR ALL SUPPORT STRUCTURES

(See Section 20.2; Part B, "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.

- Provide base and connection plates as indicated in Publication 148; TC-8801 sheet 7 of 7.
- 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).
- Attach a back-up ring as specified in the AASHTO Specifications (Table 11-2, Detail 11). The backing ring shall be attached to the plate with a full-penetration weld or with a continuous fillet weld around the interior face of the backing ring.
- 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.
- Provide 6 inch complete penetration longitudinal shaft welds at the base plate connection.
- The use of mast arm plate socket connections with fillet welds are prohibited.
- Provide welded connections as shown in Publication 148; TC-8801 sheet 7 of 7.
- The minimum thickness for column and mast materials shall be 3/16 inch or 7 gauges. A non-destructive testing plan is required to be submitted to the

Bureau of Construction Materials for materials less than 5/16 inch.

- 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.

Section 1: Introduction

Section 1.3 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.

e) PENNDOT Publication 408.

Section 2: General Features of Design

2.5 ROADSIDE REQUIREMENTS FOR STRUCTURAL SUPPORTS

2.5.2 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.

Section 3: Loads

3.5 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.

3.6 LIVE LOAD

Delete A3.6.

3.8 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.

Section 5: Steel Design

5.14 DETAILS OF DESIGN

5.14.3 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.

5.15 WELDED CONNECTIONS

The following shall supplement A5.15.

Transverse welds shall not be used to splice pole sections.

5.17 ANCHOR BOLTS

5.17.3 Design Basis

The following shall supplement A5.17.3.

A minimum of six (6) anchor bolts shall be required.

5.17.6.4 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.

5.18 MINIMUM PROTECTION FOR STRUCTURAL STEEL

5.18.1 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).

Section 11: Fatigue Design

11.6 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.

11.7 FATIGUE DESIGN LOADS

11.7.1 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.

11.7.4 Truck-Induced Gust

Delete A11.7.4.

Section 14P: Design Aids

This section shall supplement AASHTO Appendix B.

14.2P STRESSES FOR TUBULAR SECTIONS

The following shall supplement Table 20-2:

Maximum shear stress due to torsion (f_{vt}) 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:

f_{vt}	=	Maximum shear stress due to torsion, lb/in^2
M_z	=	Total torsional moment, in-lb
R	=	Radius at mid-thickness of smaller diameter tube wall, in
t	=	Thickness of smaller diameter tube wall, in
k_t	=	Stress concentration factor due to change in tube diameter (use k_t = 1.20)

Section 15P: Alternate Method for Wind Pressures

This section shall supplement AASHTO Appendix C.

15.2P 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 (V_{fm}) of 80 MPH as shown in Figure C-3.

20.2 PART B - DESIGN CRITERIA FOR STRAIN POLES

(See Section 20.1; Part A, "Design Criteria for All Support Structures," for additional requirements.)

1. 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."

2. 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].

3. 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.

4. 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.

[1] Based on the General Cable Theorem

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.

5. 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.

6. 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.

7. 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 :

$\sqrt{\left(F_x^2 + F_y^2 + F_z^2\right)}$ = 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.)

F_y and F_z 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 Figure B-2:

$$F_{Z1} = R_{Z(L)}$$

$$F_{Z2} = R_{Z(L)} - W_A$$

$$F_{Z3} = R_{Z(L)} - W_A - W_B$$

$$F_{Z4} = R_{Z(R)} - W_E - W_D$$

$$F_{Z5} = R_{Z(R)} - W_E$$

$$F_{Z6} = R_{Z(R)}$$

$$\text{The total length of span wire} = \sqrt{\left(F_x^2 + F_{y1}^2 + F_{z1}^2\right)}\frac{d_{x1}}{F_x} + \sqrt{\left(F_x^2 + F_{y2}^2 + F_{z2}^2\right)}\frac{d_{x2}}{F_x} + \cdots$$

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.

8. 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 PART C - 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.

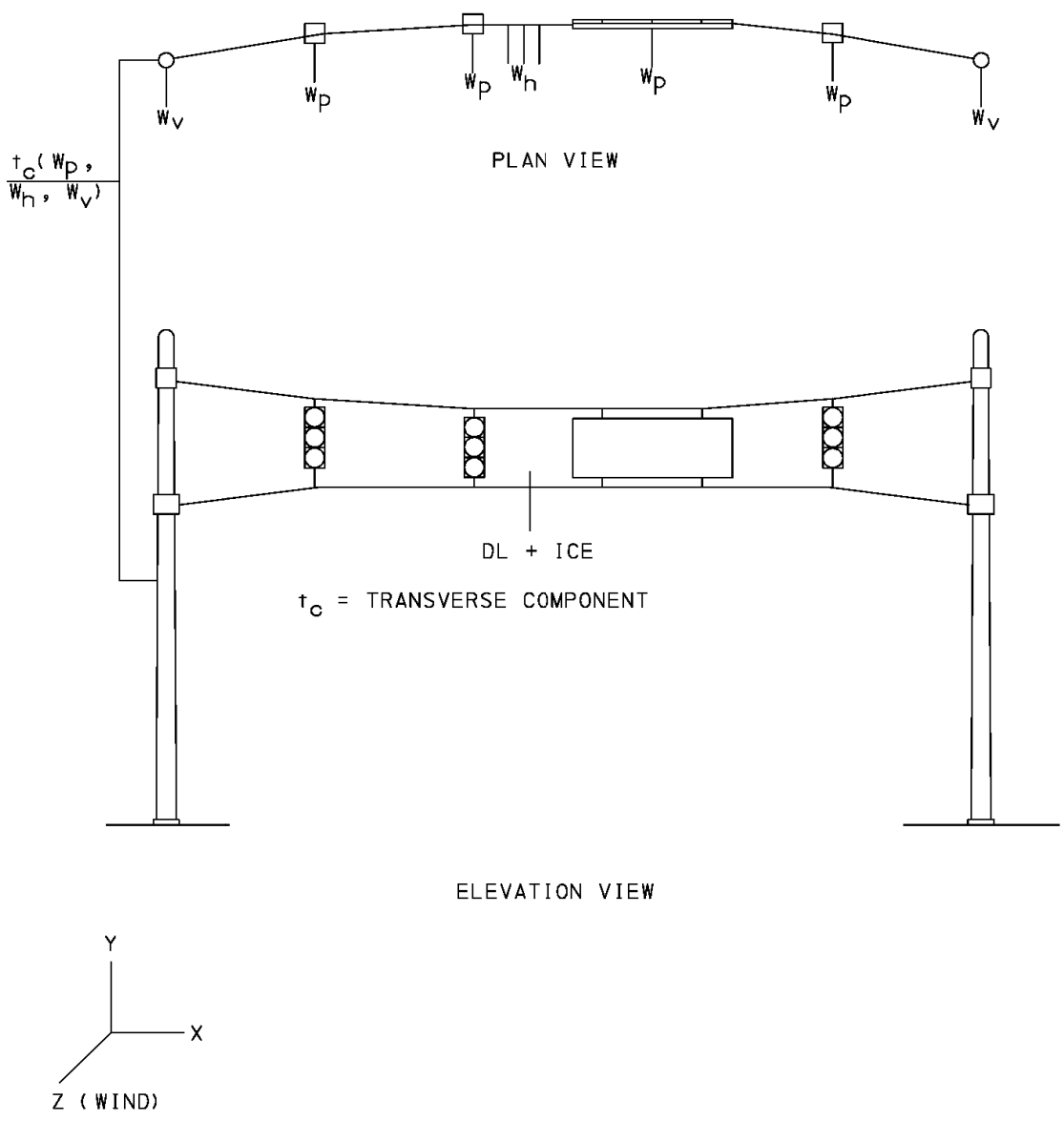


FIGURE 20-1

STRAIN POLE STRUCTURE

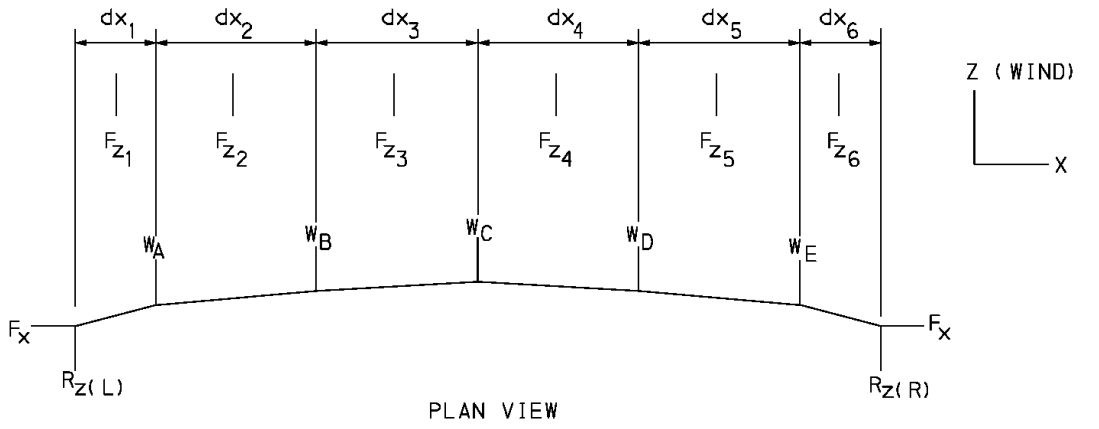
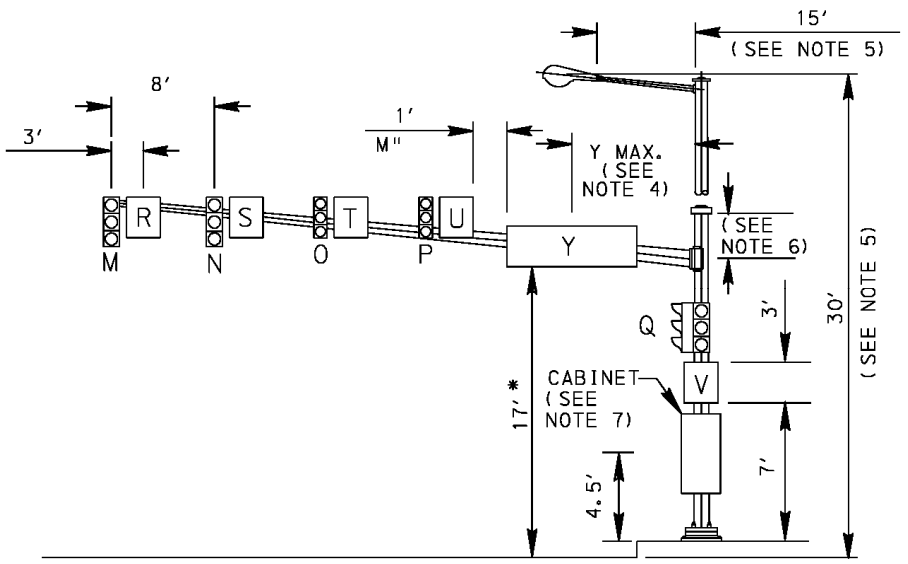


FIGURE 20-2
FORCE DIAGRAM



* 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..

FIGURE 20-3

MAST ARM - STANDARD STRUCTURE LOADING

Table 20-1
MAST ARM - STANDARD STRUCTURE LOADING

MAST ARM LENGTH (ft)		SIGNALS					SIGNS						MAX Y (ft)
		M	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**Y**	
0-10	W	70				123					39	87	5.2
	A	8.76				8.82					7.48	10.50	
>10-15	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	
>15-20	W	97	70			123	39				39	106	6.6
	A	13.89	8.76			8.82	7.48				7.48	21.33	
>20-25	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	
>25-30	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	
>30-35	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	
>35-40	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 (ft)		SIGNALS					SIGNS						MAX Y (ft)
		M	N	O	P	Q	R	S	T	U	V	Y	
>40-45	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	
>45-50	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	
>50-60	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	

W= Load in lb A=Area in ft^2

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 Figure B-3 and Publication 148, TC-8801.

Table 20-2

LOADS AND PROJECTED WIND AREAS FOR TRAFFIC SIGNAL HEADS

LENS SIZE – in ALL SECTIONS	SIGNAL CONFIGURATION (1)	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	3	1	45	2.40	48	5.97	8.79
8	A	4	1	55	3.19	59	7.46	10.69
8	A	5	1	58	3.99	69	9.17	12.46
8	B	3	2	82	2.40	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	17.90
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	17.90
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 Figure 20-4, Traffic Signal Configurations and Designations.

(2) A one-way 8 in lens section is 9 lb without attachment hardware and backplate. A one-way 12 in lens section is 15 lb without attachment hardware and backplate.

(3) The area for an 8 in lens section without backplate is based on a 10 in height by a 11.5 in width, and the area for a 12 in lens section without backplate is based on a 13.5 in height by a 14.8 in width.

(4) The area for a 2-section pedestrian signal assumes a 14.1 in height and a 14.1 in width for each section. The area of a 1-section pedestrian signal assumes a 18.9 in height and a 18.9 in width.

(5) Values in *shaded area* are generally not used.

TRAFFIC SIGNAL
CONFIGURATIONS AND DESIGNATIONS

DESIGNATION	TRAFFIC SIGNAL CONFIGURATION	DIRECTIONS
A		1
B		2
C		2
D		3
E		3
F		4

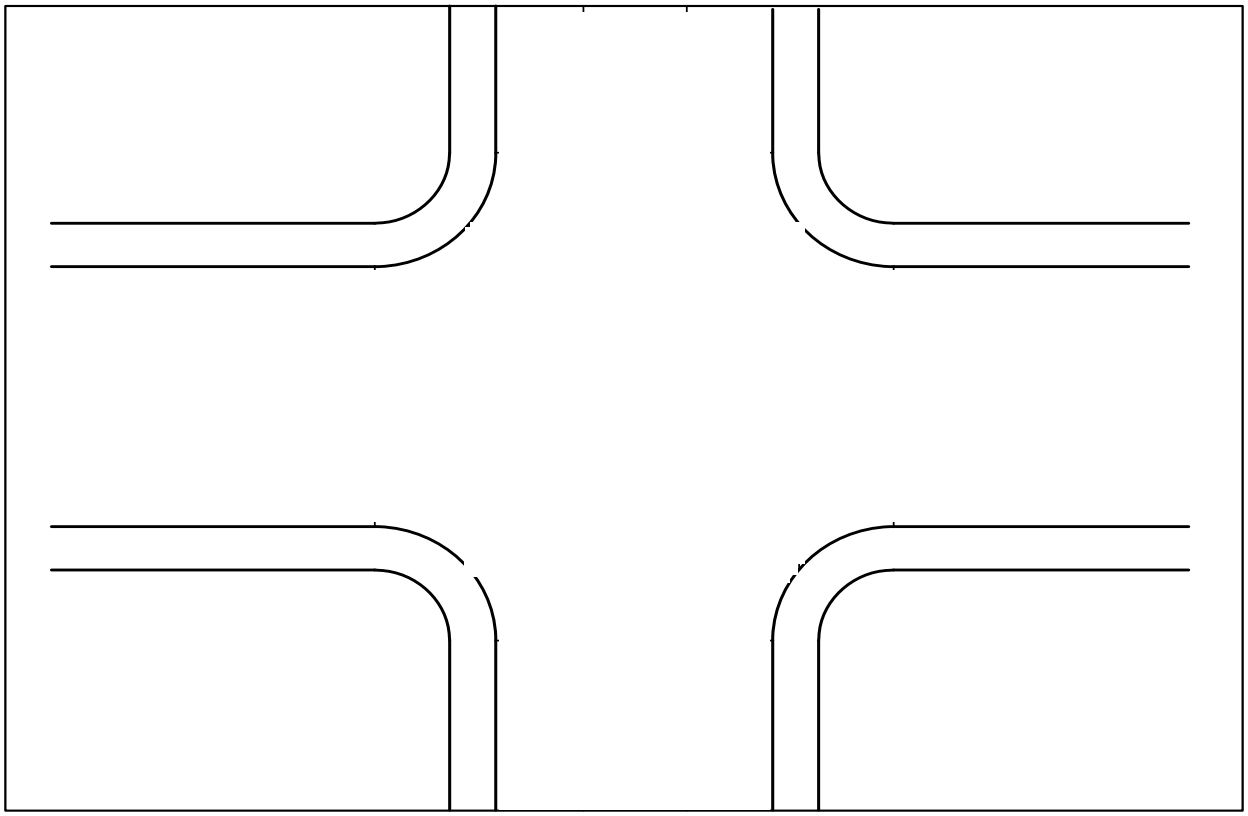
 DIRECTION OF WIND ALL CONFIGURATIONS

FIGURE 20-4
TRAFFIC SIGNAL CONFIGURATIONS

21.0 SIGNAL PLAN PREPARATION GUIDE

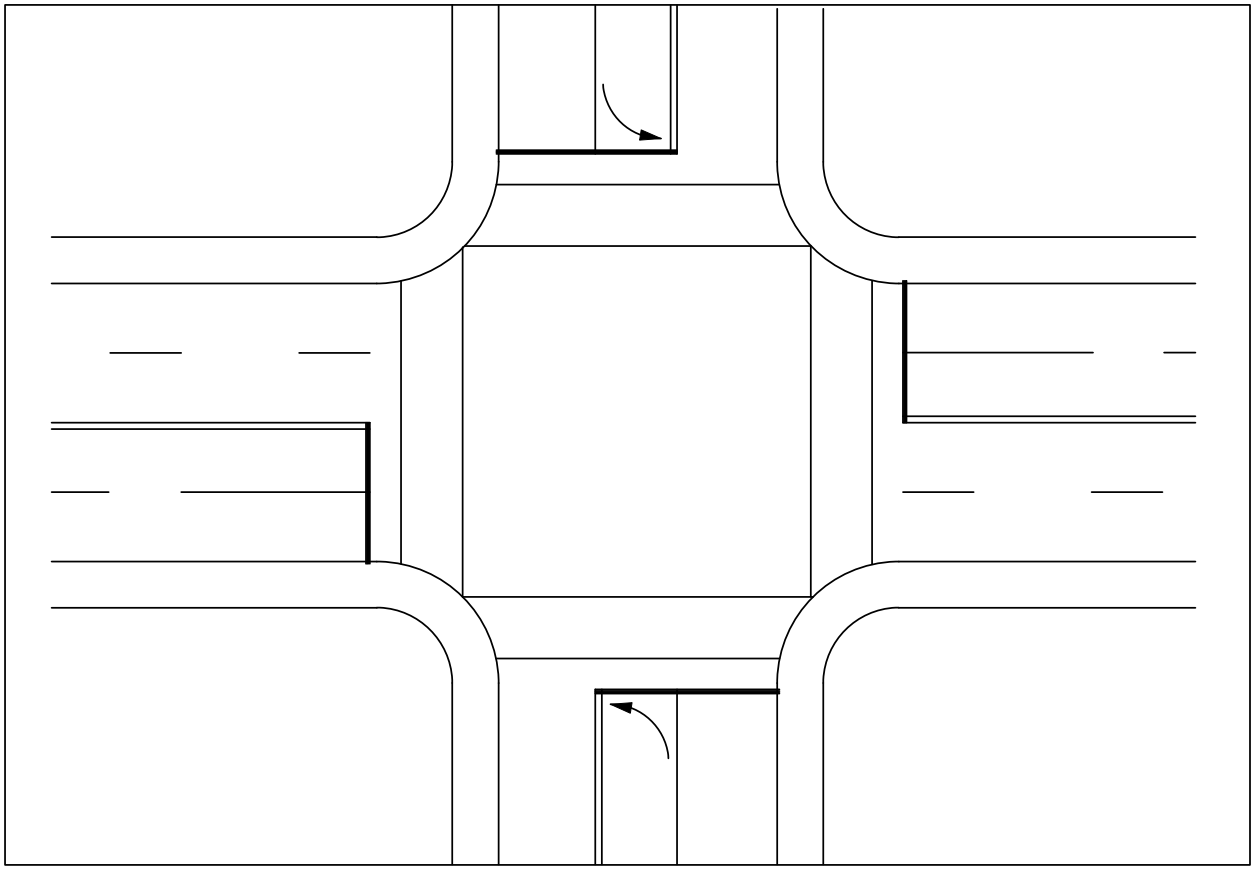
This chapter provides a clear and simple guide which illustrates the procedures to be followed in the preparation of a traffic signal plan for construction projects. Although it may not be possible to strictly comply with the sequence indicated, this chapter will provide a systematic method to be used 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 information in Chapter 22.0 and engineering study findings, helps ensure that the final product is a complete and concise plan for the installation of traffic signals.

STEP 1: Base Plan Preparation



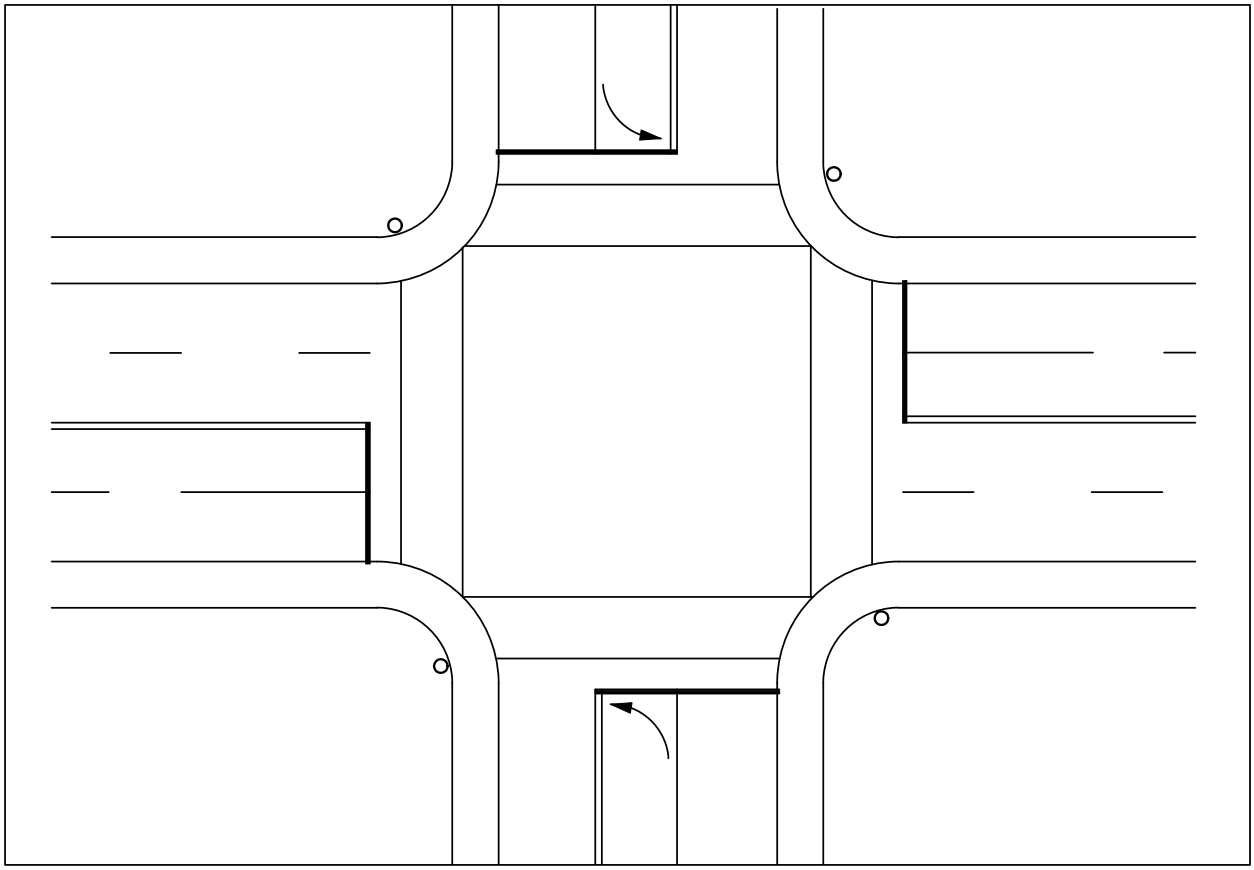
Show curbing, shoulders, curb ramps, sidewalks, islands, and inlets on the base plan. The development of an accurate base plan should include a field survey performed by a surveyor so that the most accurate design can be made. Field verification of the site is strongly suggested prior to continuing the design elements. If the project involves new construction, use care to ensure that the geometrics match those shown on the construction plan.

STEP 2: Pavement Marking Layout



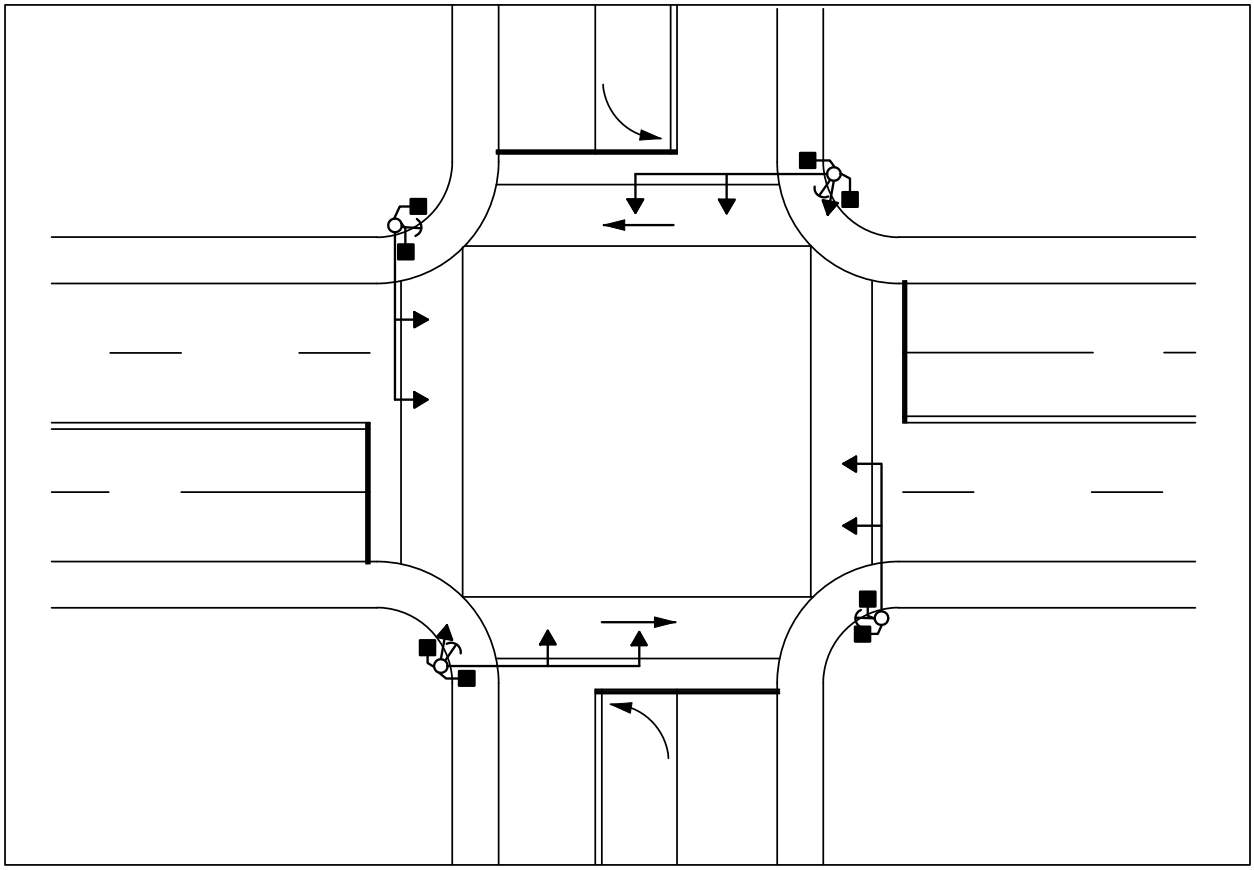
Using the results from a capacity analysis in the engineering study, lay out the lane configuration to allow for the most efficient operation of the intersection. Provide smooth transitions for roadway width reductions and exclusive turn lanes. Curb ramps should be determined through the engineering study taking PennDOT Publication 13M (DM2), Chapter 6 and PennDOT Publication 72M (RC Standards) provisions into account. Crosswalks should be determined once curb ramps are finalized. The pedestrian accessible route should not be obstructed by poles, signs, hydrants, or other street hardware. The crosswalk should be a minimum 0.6 m (2 ft) from the adjacent travel lanes. Pavement marking details shall follow PennDOT Publications 46, 111M, 212, and 408.

STEP 3: Location of Traffic Signal Supports



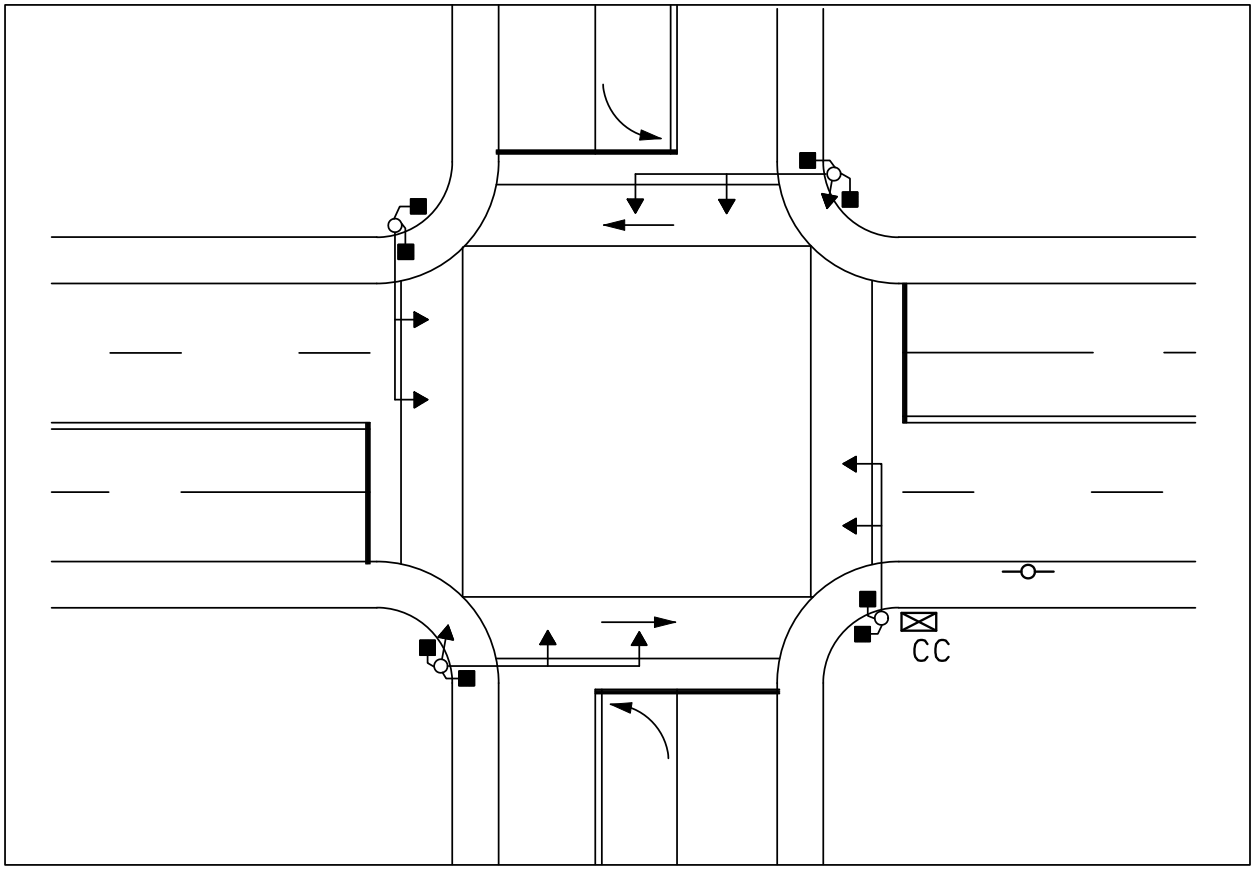
Signal supports should, whenever possible, be located behind the sidewalk area to minimize obstructions to pedestrians and vehicular traffic. Consider right-of-way lines, and select sites that will yield optimum visibility of signals to drivers and pedestrians, and are free from conflicts with utilities and drainage facilities. Due to geometric limitations in urban areas, traffic signal supports may sometimes have to be located near the curb line [minimum of 0.6 m (2 ft) from the edge of the curb to the front face of the traffic signal support]. Traffic signal supports should be located within a tangent section of curb (not in the curb return), and shall be in accordance with PennDOT Publication 13M (DM2), Chapter 6 and PennDOT Publication 72M (RC Standards) provisions.

STEP 4: Signal Heads and Pedestrian Accommodations



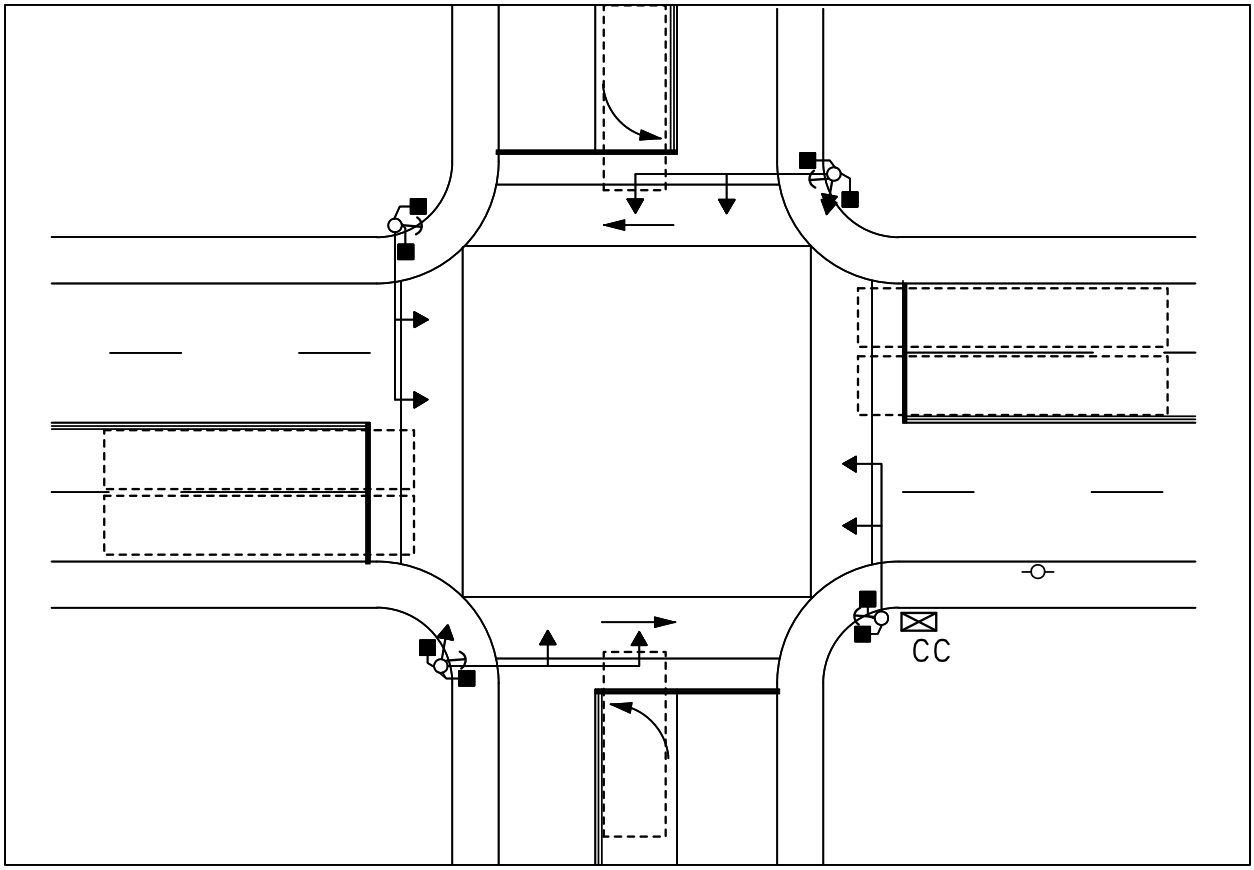
Locate the required positions of traffic signals in conformance with the provisions of the MUTCD and this publication. Provide mast arms, span wire, or pedestals for proper location of the signals. Using the signal templates, make sure the signals fall within the motorist's cone of vision. Adjust the 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 PennDOT Publication 13M (DM2), PennDOT Publication 72M (RC Standards), PennDOT 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.

STEP 5: Location of the Traffic Signal Controller



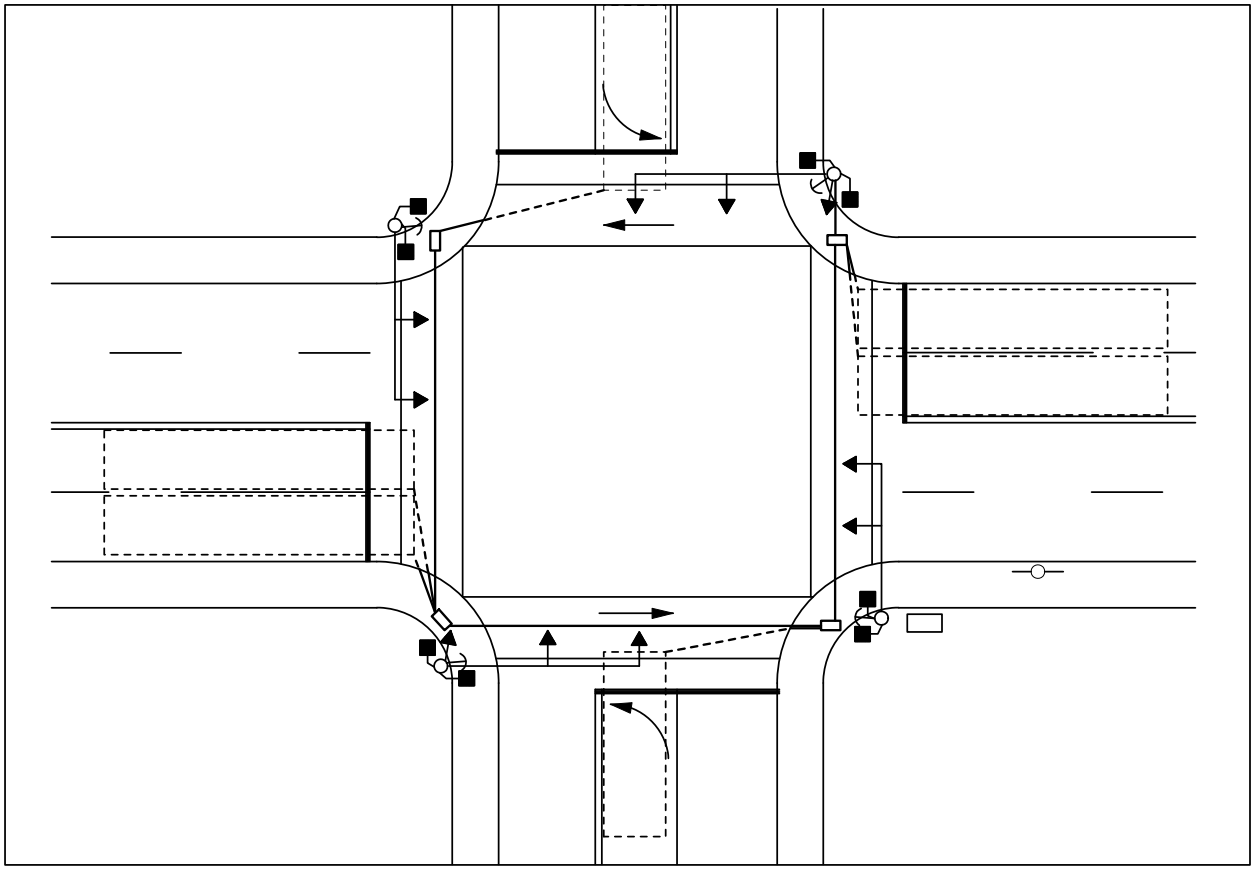
Select a location for the controller. Of prime importance is the prevention of potential damage or knockdown by vehicular traffic. Controllers should not be located near the curb return or on channelization islands. Additional considerations, such as the location of electrical service or communications lines and visibility of signal operations from the controller, may 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 PennDOT Publications 148 and 408.

STEP 6: Location of Detection Areas



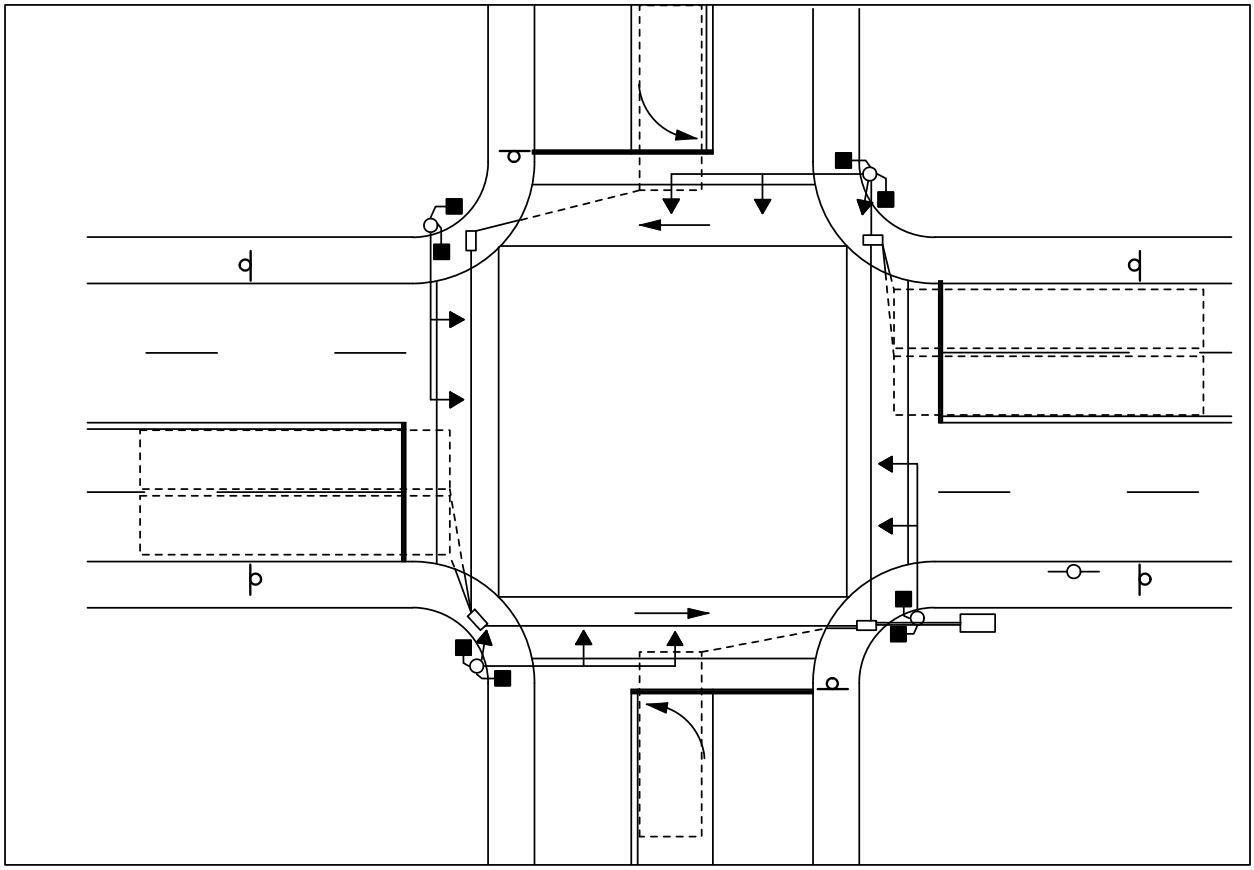
If the traffic signal installation under design is to be actuated, add detection of the sizes and types required in conformance with PennDOT Publication 148, PennDOT Publication 408, and this publication. For example, the detection zone should extend a minimum of 0.90 m (3 ft) beyond the stop line. Detectors should be located a minimum of 0.90 m (3 ft) from the centerline to minimize the possible detection of opposing 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.

STEP 7: Addition of the Electrical Distribution



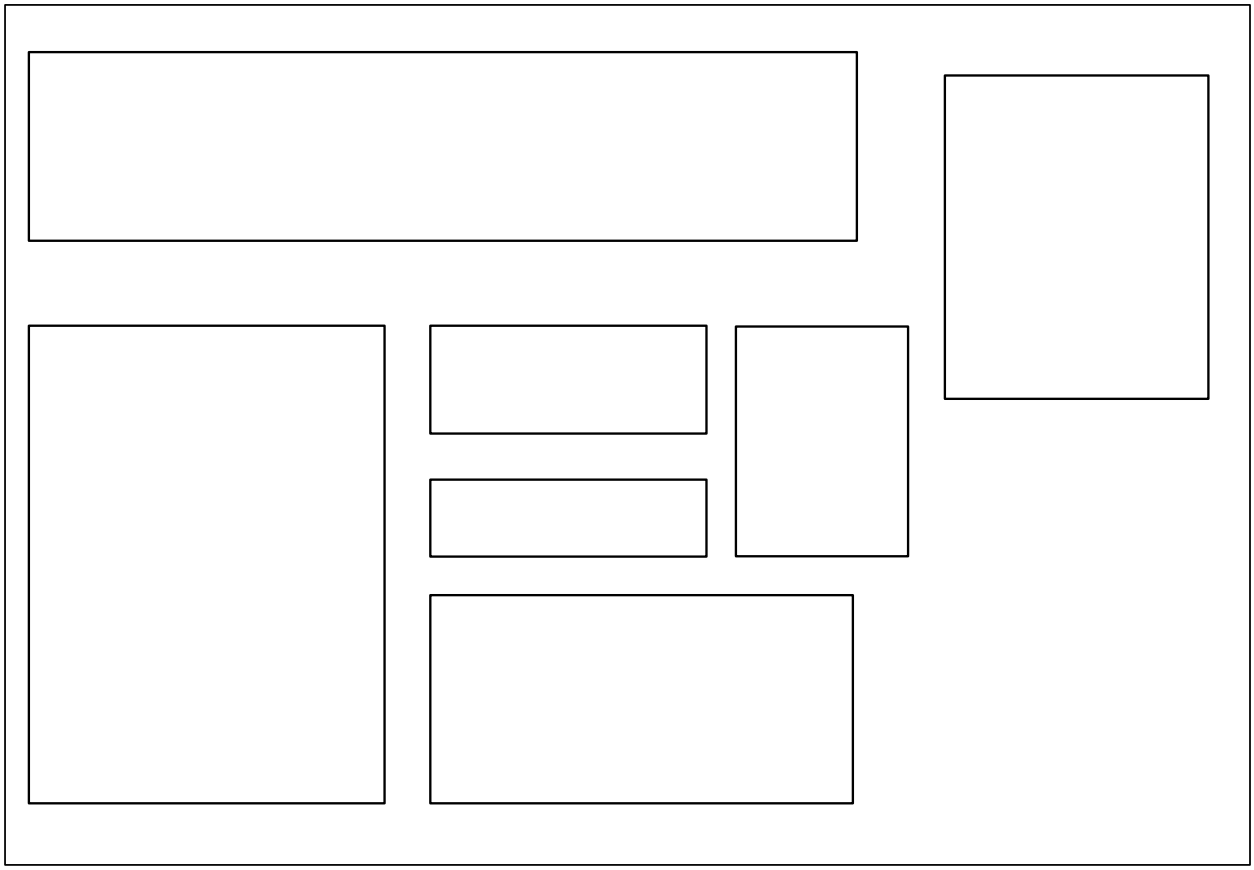
Consult this publication for guidelines regarding the location of junction boxes, conduit, and service conduit. Junction boxes should be placed in sidewalk areas outside of curb ramps. Generally, there should be at least one junction box at each support where wiring runs continue to another location. 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.

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 PennDOT Publications 46, 111M, 212, and 236M. Complete the design sheet 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 an engineering study and engineering judgment. Sketches 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.

STEP 9: Development of a Tabulation Sheet



Complete the various tables on the tabulation sheet in conformance with the guidelines set forth in PennDOT 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.

22.0 PLAN FORMAT CHECKLIST

The following checklist is to be used as a guide to prepare a permit plan sheet and/or the construction plans.

22.1 PLAN SHEET

The information listed below is to be provided on both the permit plan and the construction sheets unless indicated otherwise.

22.1.1 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 PennDOT Publication 236M and actual legend.
- ☐ Size by width and height.

22.1.2 MOVEMENT, PHASING, AND SEQUENCE CHART

☐ Locate on upper left of sheet.

☐ Designate the phases using the numbers 1 through 8. See Appendix A for examples. (NEMA phasing strongly recommended.)

☐ Pictorial representation of movements for respective phase, including pedestrian movements.

☐ Beginning with 1, horizontally list the interval numbers for the cycle.

☐ Add preemption phases.

☐ Vertically list the signal numbers as shown on the plans.

☐ For each interval, show the type of operation by indicating:

G	for Green
R	for Red
Y	for Yellow
W	for “WALKING PERSON” indication or “WALK” indication
DW	for “UPRAISED HAND” indication or “DONT WALK”
FD	for Flashing “HAND” indication or Flashing “DONT WALK” indication
←G-	for Green Arrow indication
←Y-	for Yellow 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, show what signals are flashing and their color. If not flashing, indicate "OFF".

☐ Indicate Emergency Flashing or Flashing (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.

22.1.3 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.

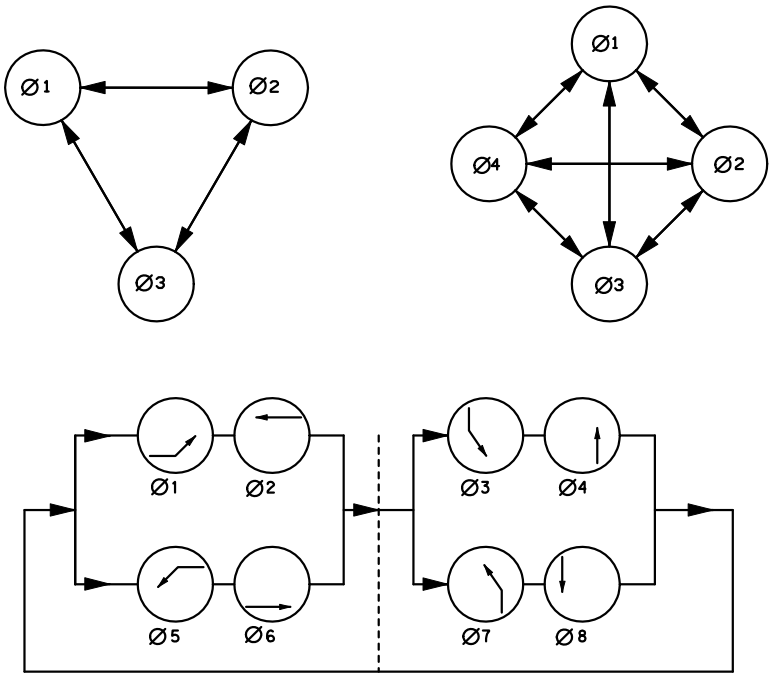


Figure 22-1. Example Phasing Diagram
(use standard NEMA phasing)

22.1.4 SIGNAL IDENTIFICATION

☐ Located at bottom middle of plan.

22.1.4.1 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

☐ Indicate size of signal.

200 mm (8 in) signal

300 mm (12 in) signal

☐ Indicate type of visors.

☐ Indicate if backplates are to be installed.

☐ Indicate louvers (if required).

22.1.4.2 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

☐ Indicate size of message.

22.1.5 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.

22.1.6 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 1:200 (1 in = 20 ft) or 1:250 (1 in = 25 ft).

☐ Professional Engineer's seal (next to title block).

For all of the above, the respective information must be filled in for each project.

22.1.7 NOTES

☐ General notes are located on right hand side of sheet. (permit plan only.)

☐ For construction plan, this area is used only for notes which apply to construction details.

22.1.8 SIGNAL WIRING DIAGRAM (CONSTRUCTION PLAN)

☐ Located on the right-hand side of sheet, below the upper title block.

22.1.9 UPPER TITLE BLOCK

The following items should be located at the top right corner of the sheet, as required.

☐ Project data block (construction plan)

- ☐ District - indicate number.
- ☐ County - indicate county.
- ☐ Route - indicate the routes involved.
- ☐ Section - indicate section number.
- ☐ Sheet - indicate sheet number of contract plans.

☐ Revision block (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.

☐ Permit block (permit plan)

- ☐ 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.
- ☐ Date revised - give date of latest revision.

22.1.10 INTERSECTION

☐ Located in center of sheet using scale of 1:200 (1 in = 20 ft) or 1:250 (1 in = 25 ft).

☐ Plan view of intersection.

☐ North arrow.

(a) Plot the following proposed data on permit plan:

☐ New curbs.

☐ Pavement markings.

☐ Supports.

☐ Signals with #'s.

☐ Pedestrian signals and pushbuttons with #'s.

☐ Controller.

☐ Detectors with dimensions.

☐ Signs with letter designation.

(b) Plot the following proposed data on construction plan.

☐ Existing data as per PennDOT Publication 13M (Design Manual 2).

☐ New curbs.

☐ Pavement markings (only those to be installed by contractor).

☐ Supports with pole #'s.

☐ Signals with #'s.

☐ Pedestrian signals and pushbuttons with #'s.

☐ Controller.

☐ Detectors with #'s.

☐ Signs with letter designation (only those to be installed by contractor).

☐ Junction boxes with #'s.

☐ Conduit.

☐ Service location and type.

22.2 TABULATION SHEET

Prepare the following tabulations only for construction plans.

22.2.1 TRAFFIC SIGNAL SUPPORTS

☐ Location.

☐ Mast arms.

☐ Strain poles.

☐ Sign and signal locations.

☐ Item numbers.

22.2.2 ELECTRICAL AND CONDUIT ITEMS

☐ Location.

☐ Conduit.

☐ Trench.

☐ Signal cable.

☐ Junction box.

☐ Electrical service.

☐ Detector items.

☐ Item number.

22.2.3 DETECTORS

☐ Amplifier.

- ☐ Description.
- ☐ Quantity.
- ☐ Location.
- ☐ Operation.
- ☐ Item Number.

☐ Sensors.

- ☐ Description.
- ☐ Quantity.
- ☐ Size.
- ☐ Location.
- ☐ Item Numbers.

22.2.4 MISCELLANEOUS

☐ Item numbers.

☐ Controller assembly.

☐ Vehicle signal head .

☐ Pedestrian signal head.

- ☐ Systems.
- ☐ Communications.
- ☐ Preemption.

22.2.5 PAVEMENT MARKINGS

- ☐ Item numbers.
- ☐ Quantity.
- ☐ Description.

22.2.6 SIGNS

- ☐ Description.
- ☐ Size.
- ☐ Square meters (feet).
- ☐ Item numbers.
- ☐ Sign Type/Mount.
  - ☐ Type B.
  - ☐ Type F.
  - ☐ Structure-Mounted.

23.0 PERMITS

In accordance with the Pennsylvania Vehicle Code, Section 212.5 of PennDOT Publication 212, and PennDOT Publication 46, local authorities shall obtain written PennDOT approval prior to installing, revising, or removing traffic signals on any highway (State-designated, county, or local), with the following exceptions:

(a) For traffic signals within cities of the first and second class.

(b) For traffic signals on local highways if the local authorities have been granted municipal traffic engineering certification in accordance with 67 PA Code, Chapter 205.

(c) Unless otherwise provided in an agreement with PennDOT.

For each signalized intersection, PennDOT will issue a traffic signal permit that describes the approved design and operation of traffic signal at that intersection.

See Appendix C of this publication for application, permit, and other related forms.

24.0 DEFINITIONS

Consult the MUTCD 2003 Edition for definitions of key words and terms used in this publication.

In addition, the following words and terms, when used in this Handbook, shall have the meanings indicated, unless the context clearly indicates otherwise:

AASHTO – The American Association of State Highway and Transportation Officials.

AASHTO "Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" – Provides guidance for the design and use of traffic signal supports. This document should be used in conjunction with Chapter 20 of this publication.

Accessible route – A continuous, unobstructed path connecting all accessible elements and spaces of a building or facility.

ADA – Americans with Disabilities Act (1990).

Added initial – An increment of time added to the minimum initial portion in response to vehicle actuation.

All-red clearance interval – An interval that follows a yellow change interval and precedes the next conflicting green interval.

Alteration project – A highway alteration project is a change to any portion of an existing facility (space, site, structure, or improvement of a pedestrian or vehicular route) located in the public right-of-way that affects or could affect access, circulation, or use of the facility. Alterations could also affect the structure, grade, function, and use of the roadway.

Breakaway (yielding) – Crashworthy; a characteristic of a roadside appurtenance that has been successfully crash tested in accordance with a national standard such as the National Cooperative Highway Research Program Report 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features."

Capacity – The maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger cars per hour, or persons per hour.

Change and clearance interval – Sum of the yellow change and all-red clearance intervals. Refer to Section 11.5 of this publication for additional information.

Coordinated traffic control (coordination) – The establishment of a definite timing relationship between adjacent controller units.

Conflict Factor (CF) – The product of the left turn volume and the opposing through traffic volume for any one-hour period of a normal weekday.

Countdown pedestrian signal – A pedestrian signal head that displays the number of seconds remaining in the pedestrian change interval.

Curb ramp – A short pedestrian ramp cutting through a curb or built up to a curb from a lower level.

Detector amplifier – A device capable of intensifying the electrical energy produced by a sensor.

Emergency vehicle preemption – The transfer of normal operation of a traffic control signal to a special control mode of operation for emergency vehicles. Refer to Chapter 15.0 of this publication for additional information.

Emitter – A device located in each emergency vehicle to allow activation of emergency vehicle preemption equipment at the intersection, if provided. Refer to Chapter 15.0 of this publication or additional information.

FHWA – The Federal Highway Administration of the United States Department of Transportation.

Fixed supports – Permanent or temporary mounting mechanisms that are not portable and are not designed so that they are easily transported and reused at different locations. Trailers or pedestals that are portable are not fixed supports.

Global Positioning System (GPS) – Technology that uses satellites to obtain key location information to be used at a signalized intersection. Refer to Chapter 15.0 of this publication for additional information.

Green interval timings – The amount of time given for a particular green interval in a phase. Refer to Section 11.7 of this publication for additional information.

Green time-to-cycle time ratio (G/C ratio) – The ratio of the green time to the cycle length.

Highway Capacity Manual (HCM) – Published by the Transportation Research Board, National Research Council.

Initial (minimum) interval – The shortest green time of a phase. Refer to Section 11.7 of this publication for additional information.

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.

Lead/lead left turn phasing – Allows left turn traffic to get an exclusive 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. Refer to Section 10.4.4 of this publication for additional information.

Locking mode – When a particular phase receives a call, and that call will remain until the phase has been serviced.

MUTCD – The Manual on Uniform Traffic Control Devices, as adopted by the Federal Highway Administration (FHWA), and available on the FHWA website.

Mast arm support – A support consisting of an arm in an approximate horizontal position and a vertical pole that together are designed to hold signal heads, small signs, luminaires, and related appurtenances.

Maximum green – The maximum time which a phase may retain the right-of-way. Maximum green starts timing at the beginning of the green period if there is a call on the opposite phase or whenever a call arrives on the opposite phase after the green period has started.

Maximum initial – Used primarily in volume-density operation, it establishes the upper limit of the variable initial period and provides sufficient time to clear the number of vehicles that can be stored between the detector and the stop line. Refer to Section 11.7.5 of this publication for additional information.

Maximum recall – Places a call on a phase and then keeps the phase green for a time equal to the maximum setting. Refer to Section 10.3.2 of this publication for additional information.

Minimum gap – The minimum value the extension will be allowed to shrink between actuations for a phase with a green indication. Refer to Section 11.7.7 of this publication for additional information.

Minimum green – The minimum amount of green time allocated to a particular movement or phase at an intersection.

Minimum recall – Places a call on a phase and then keeps the phase green for at least as long as the initial (minimum) setting. Refer to Section 10.3.1 of this publication for additional information.

NEMA – The National Electrical Manufacturers Association.

Non-locking mode – Allows particular phase calls to be processed, but if that call is dropped during a conflicting phase, the original phase call will be removed from memory.

Optically programmed signals – A type of signal face or signal section designed (or shielded, hooded, or louvered) to restrict the visibility of a signal indication from the side, to certain lane or lanes, or to a certain distance from the stop line. Also known as programmed visibility signals or visibility-limited signal faces or signal sections.

Overlap – A vehicle movement, generally a right turn, which is allowed to run concurrently with two standard phases. Refer to Section 10.5 of this publication for additional information.

Passage time – Provides an additional time increment upon completion of the initial (minimum) interval for each vehicle as it passes the detector. It also determines the length of gap which, if exceeded, permits the right-of-way to be transferred to another phase. Refer to Section 11.7.3 of this publication for additional information.

Peak-hour traffic volume – The highest number of vehicles passing over a section of a lane or a roadway during 60 consecutive minutes of a normal day. The term "peak hours" refers to the peak-hour traffic volume for the morning and the peak-hour traffic volume in the afternoon.

Pedestrian need – Based upon a study, the determination of the accommodations needed for pedestrians taking into account whether or not pedestrians are or will be present, pedestrian volumes, types of pedestrians, and other relevant factors.

PennDOT – The Pennsylvania Department of Transportation; the Department of Transportation of the Commonwealth of Pennsylvania.

Pennsylvania Vehicle Code – Title 75, Pennsylvania Consolidated Statutes having the citation 75 Pa.C.S.

Permitted left turn phasing – Allows a left turn to be made on a circular green indication when there is a sufficient gap in opposing traffic. Refer to Section 10.4.3 of this publication for additional information.

Physical barrier – A physical obstruction (i.e., fence, planter, guiderail, etc.) which prohibits a pedestrian movement. Placement of an intentional physical barrier to deter pedestrian movements must be outside the vehicular line of sight and clear zone.

PROWAG – Public Rights of Way Accessibility Guidelines.

Publication 13M – Design Manual Part 2: Highway Design (Dual Unit).

Publication 35 – Approved Construction Materials (Bulletin 15).

Publication 46 – Traffic Engineering Manual.

Publication 72M – Roadway Construction Standards (Dual Unit).

Publication 111M – Traffic Control-Pavement Markings and Signing Standards, TC-8600 and TC-8700 Series.

Publication 148 – Traffic Standards-Signals, TC-8800 Series.

Publication 191 – Guidelines for the Maintenance of Traffic Signal Systems.

Publication 212 – Official Traffic Control Devices.

Publication 213 – Temporary Traffic Control Guidelines.

Publication 236M – Handbook of Approved Signs.

Publication 408 – Highway Specifications.

Pulse mode – When detection occurs, provides a locking call on the controller until serviced. Refer to Section 16.2.1 of this publication for additional information.

Presence mode – Provides one output pulse for each vehicle passing over the detection area, or an output for each vehicle stopped over the detection area. Does not provide a locking call. Refer to Section 16.2.2 of this publication for additional information.

Protected/permitted 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. Refer to Section 10.4.2 of this publication for additional information.

Protected/prohibited left turn phasing – Motorists can only turn left on the green arrow. Refer to Section 10.4.1 of this publication for additional information.

Recall – An operational mode of an actuated controller whereby a phase, either vehicle or pedestrian, is displayed each cycle whether demand exists or not.

Soft recall – Similar to minimum recall, but phase will discontinue its call for the green interval if there are conflicting phase calls at the intersection by the actual vehicle demand.

Span wire – A cable extended between strain poles used as a horizontal support for signal heads and small signs.

Split phasing – Where two opposing approaches flow in totally separate phases that time consecutively rather than concurrently. Refer to Section 10.5 of this publication for additional information

Strain pole – A vertical support for span wire and related appurtenances.

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, small signs, luminaires, and related appurtenances.

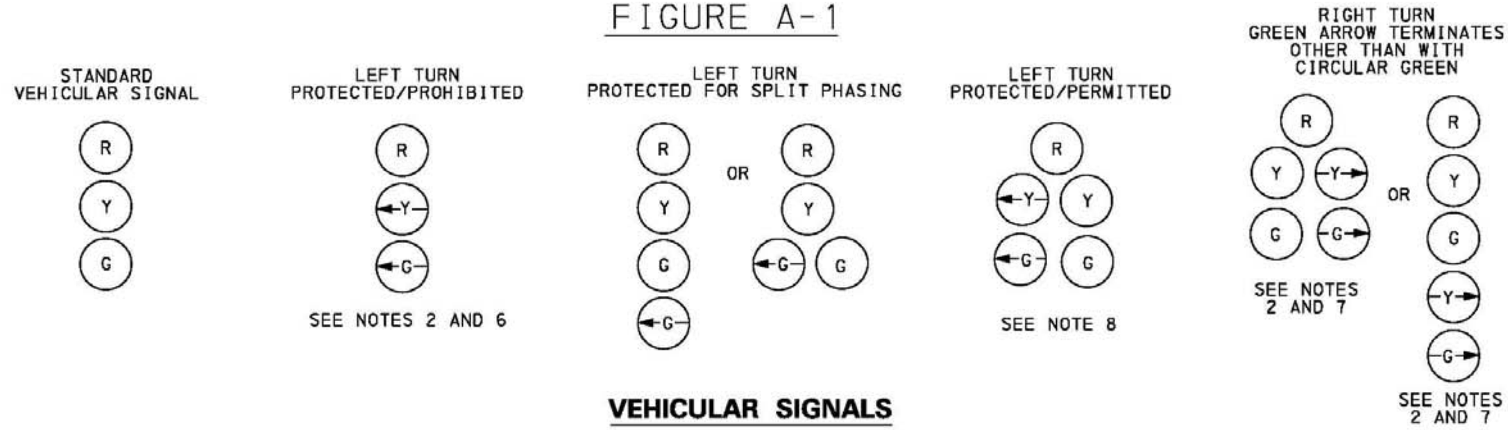
APPENDIX A

SAMPLE DRAWINGS FOR PHASING AND SEQUENCING*

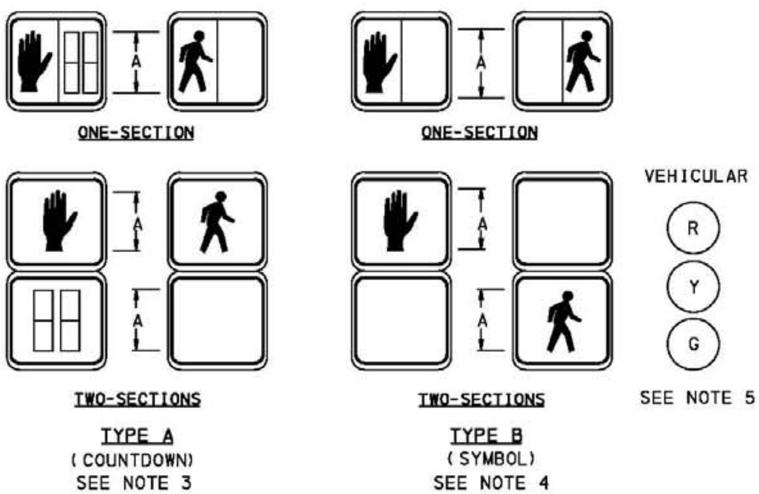
FIGURES

The intent of this Appendix is to help guide the designer when determining "Phasing and Sequencing". The sample figures are not to scale and not all required and desirable signs, pavement markings, pedestrian features, traffic signal timing, and other traffic signal features are depicted. These examples should not be used in place of sound engineering judgment.

FIGURE A-1



VEHICULAR SIGNALS



TYPE	DIMENSION A
A	152 (6") SEE NOTE 3
B	152 (6") SEE NOTE 4

SIGNALS FOR PEDESTRIANS

NOTES:

1. SEE CHAPTER 7.0, SIZE OF SIGNAL LENSES.
2. USE TUNNEL VISORS.
3. COUNTDOWN PEDESTRIAN SIGNALS SHALL CONSIST OF PORTLAND ORANGE NUMBERS THAT ARE AT LEAST 152 mm (6") IN HEIGHT. FOR CROSSWALKS WHERE THE PEDESTRIAN ENTERS THE CROSSWALK MORE THAN 30 m (100') FROM THE COUNTDOWN PEDESTRIAN SIGNAL DISPLAY, THE NUMBERS SHOULD BE AT LEAST 228 mm (9") IN HEIGHT.
4. FOR CROSSWALKS WHERE THE PEDESTRIAN ENTERS THE CROSSWALK MORE THAN 30 m (100') FROM THE PEDESTRIAN SIGNAL HEAD INDICATIONS, DIMENSION "A" SHOULD BE AT LEAST 228 mm (9") HIGH.
5. LOUVER THE APPROPRIATE LENS OR LENSES WHEN IN CONFLICT WITH SIGNALS FOR VEHICULAR TRAFFIC.
6. USE SIGN R10-10L (PUB. 236M) WITH THIS CONFIGURATION.
7. USE SIGN R10-10R (PUB. 236M) WITH THIS CONFIGURATION.
8. USE SIGN R10-12 (PUB. 236M) WITH THIS CONFIGURATION.

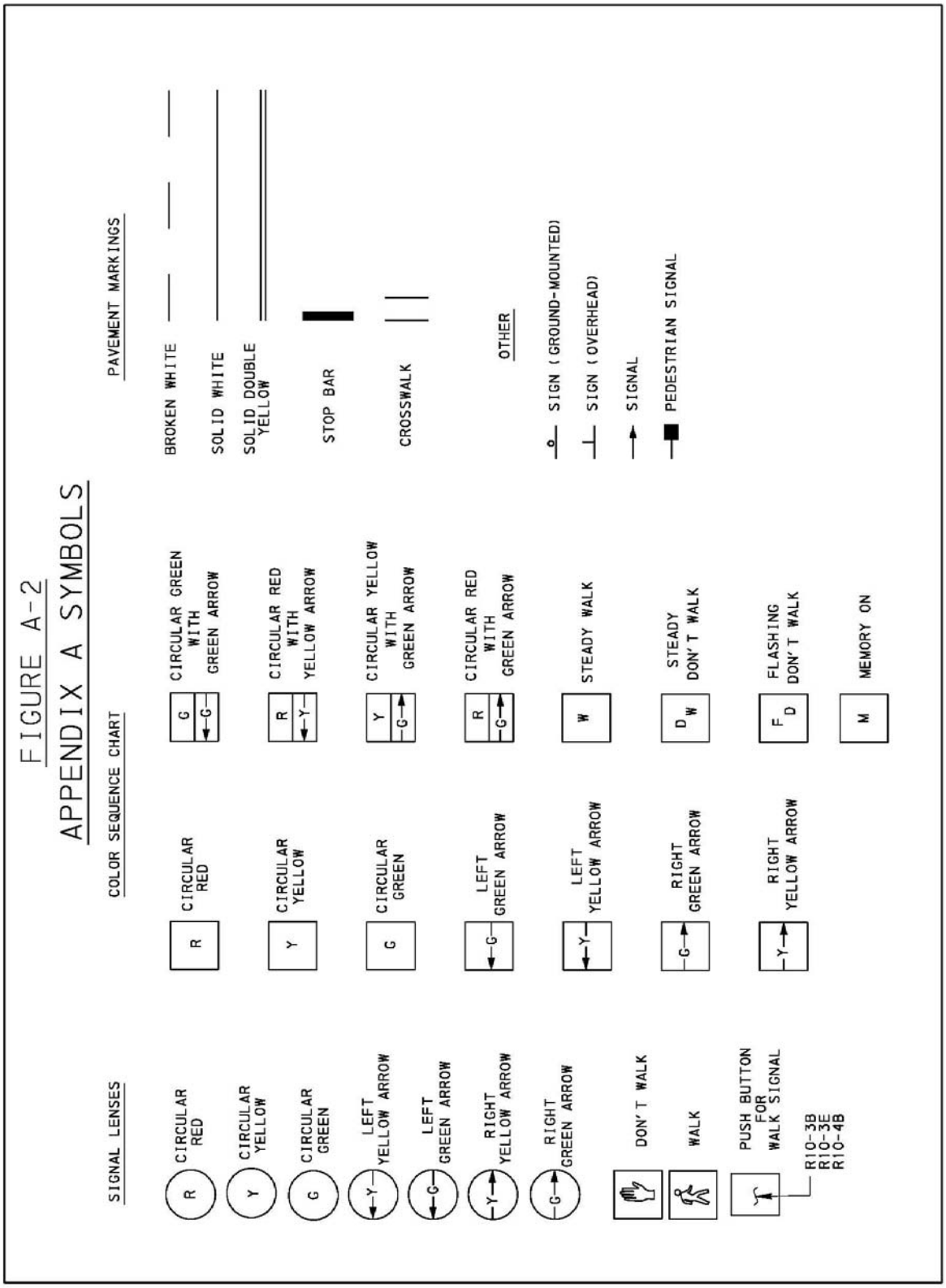


FIGURE A-2
APPENDIX A SYMBOLS
SIGNAL LENSES
CIRCULAR RED
CIRCULAR YELLOW
CIRCULAR GREEN
LEFT YELLOW ARROW
LEFT GREEN ARROW
RIGHT YELLOW ARROW
RIGHT GREEN ARROW
DON'T WALK
WALK
PUSH BUTTON FOR WALK SIGNAL
R10-3B
R10-3E
R10-4B
COLOR SEQUENCE CHART
CIRCULAR RED
CIRCULAR YELLOW
CIRCULAR GREEN
LEFT GREEN ARROW
LEFT YELLOW ARROW
RIGHT GREEN ARROW
RIGHT YELLOW ARROW
CIRCULAR GREEN WITH GREEN ARROW
CIRCULAR RED WITH YELLOW ARROW
CIRCULAR YELLOW WITH GREEN ARROW
CIRCULAR RED WITH GREEN ARROW
STEADY WALK
STEADY DON'T WALK
FLASHING DON'T WALK
MEMORY ON
PAVEMENT MARKINGS
BROKEN WHITE
SOLID WHITE
SOLID DOUBLE YELLOW
STOP BAR
CROSSWALK
OTHER
SIGN (GROUND-MOUNTED)
SIGN (OVERHEAD)
SIGNAL
PEDESTRIAN SIGNAL

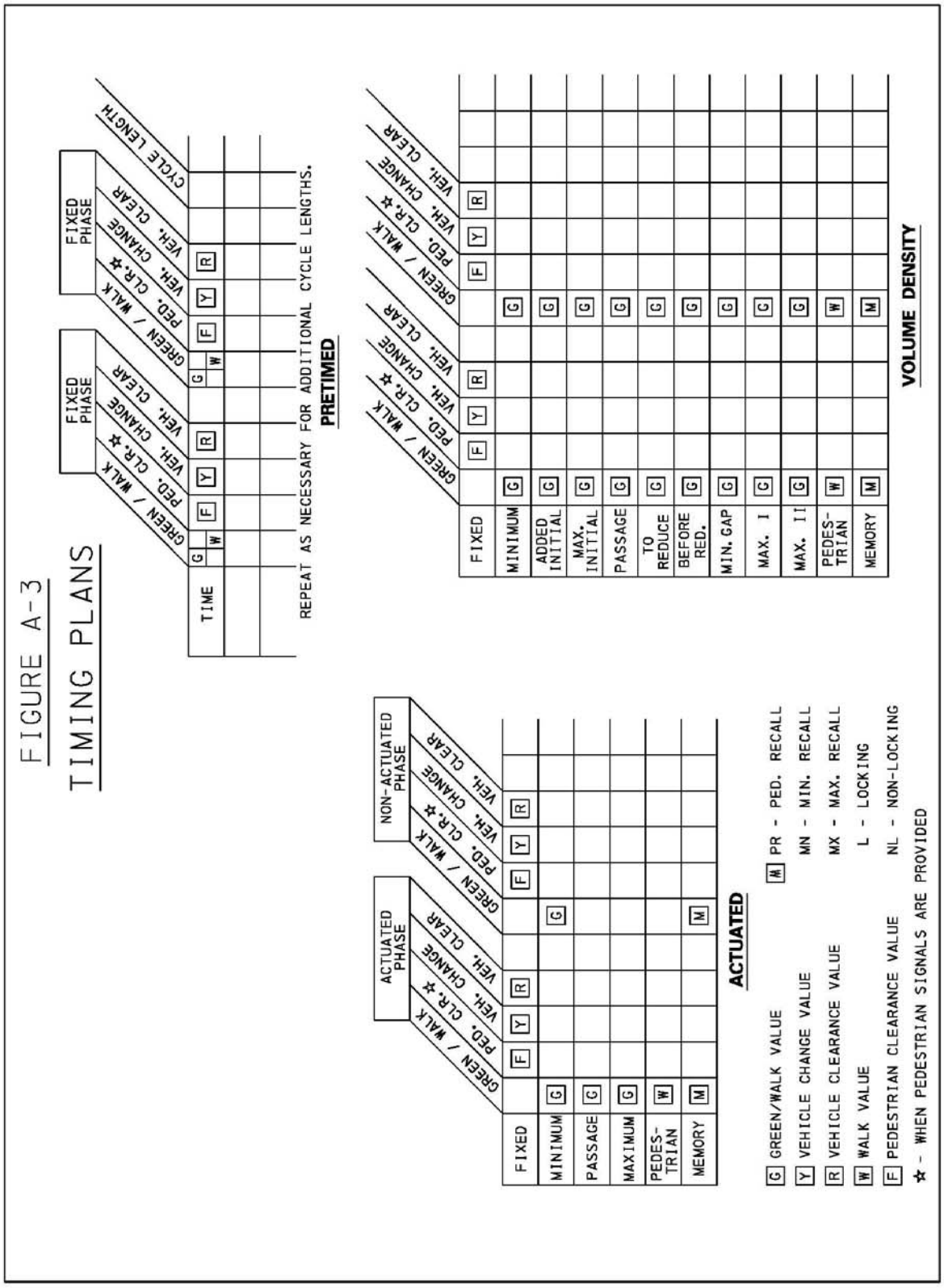


FIGURE A-3
TIMING PLANS
PRETIMED
REPEAT AS NECESSARY FOR ADDITIONAL CYCLE LENGTHS.
TIME
FIXED PHASE
GREEN / WALK
PED. CLR. ☆
VEH. CHANGE
VEH. CLEAR
CYCLE LENGTH
VOLUME DENSITY
FIXED
MINIMUM
ADDED INITIAL
MAX. INITIAL
PASSAGE
TO REDUCE
BEFORE RED.
MIN. GAP
MAX. I
MAX. II
PEDES-TRIAN
MEMORY
ACTUATED
NON-ACTUATED PHASE
ACTUATED PHASE
G GREEN/WALK VALUE
Y VEHICLE CHANGE VALUE
R VEHICLE CLEARANCE VALUE
W WALK VALUE
F PEDESTRIAN CLEARANCE VALUE
M PR - PED. RECALL
MN - MIN. RECALL
MX - MAX. RECALL
L - LOCKING
NL - NON-LOCKING
☆ - WHEN PEDESTRIAN SIGNALS ARE PROVIDED

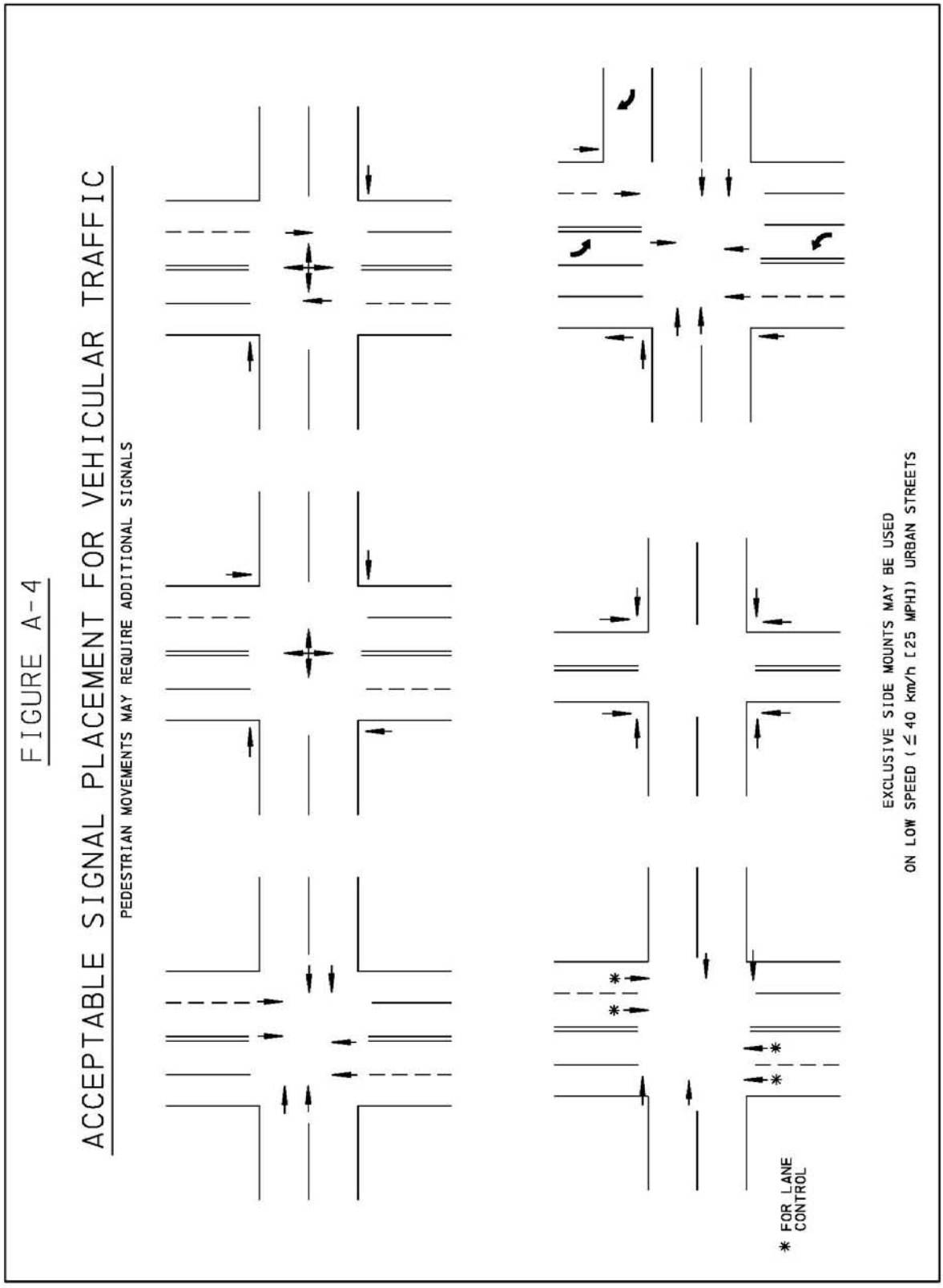
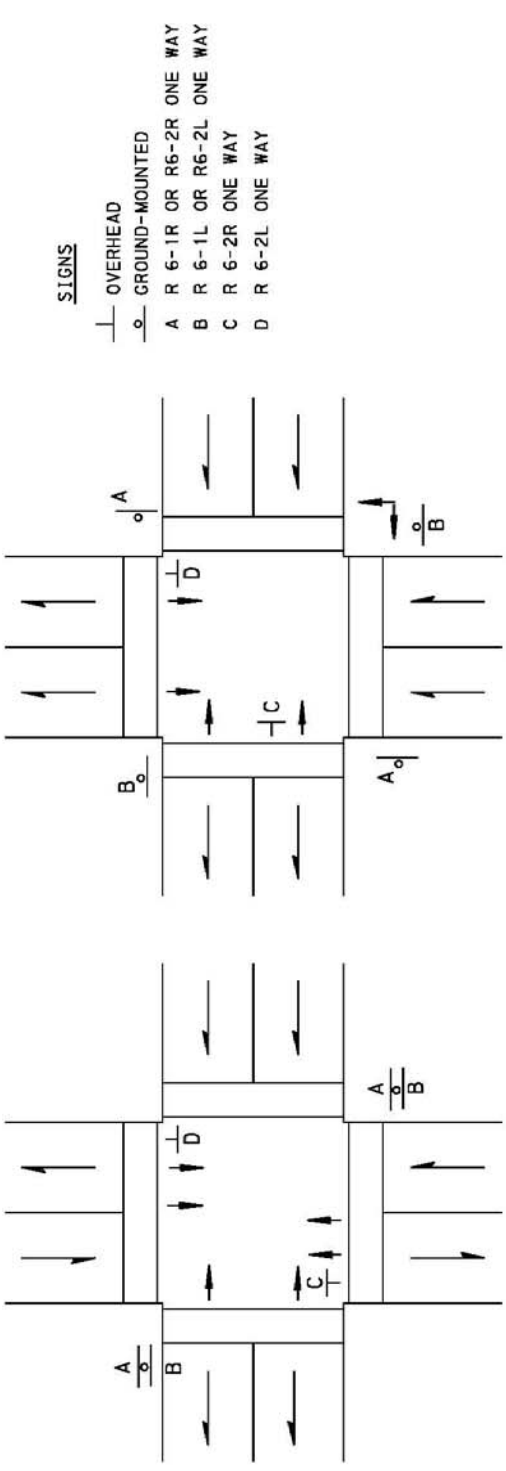


FIGURE A-4
ACCEPTABLE SIGNAL PLACEMENT FOR VEHICULAR TRAFFIC
PEDESTRIAN MOVEMENTS MAY REQUIRE ADDITIONAL SIGNALS
EXCLUSIVE SIDE MOUNTS MAY BE USED
ON LOW SPEED (≤ 40 km/h [25 MPH]) URBAN STREETS
* FOR LANE CONTROL

FIGURE A-5

SAMPLE ONE-WAY INTERSECTIONS
MINIMUM SIGNALS AND SIGNING FOR VEHICULAR TRAFFIC



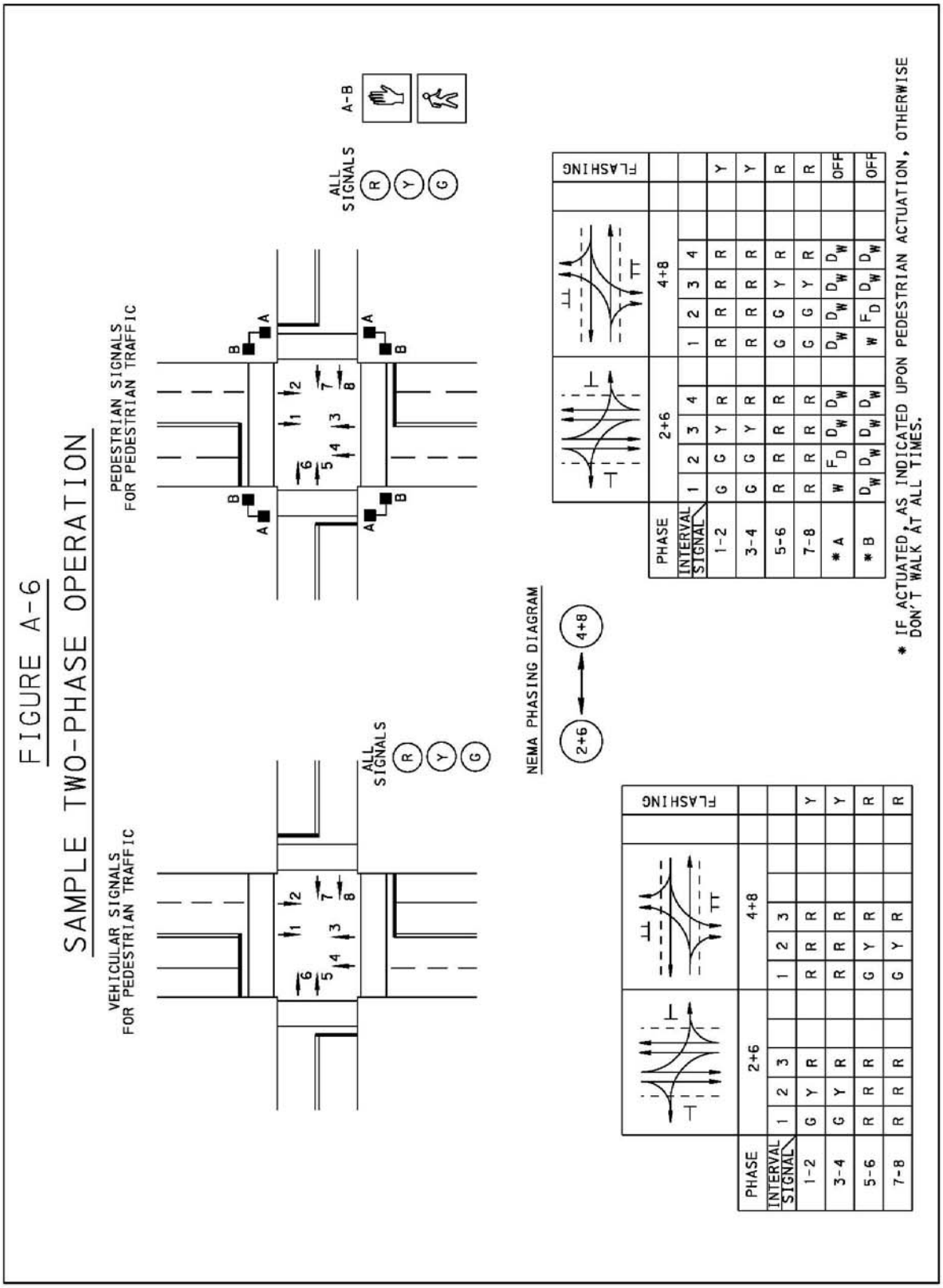


FIGURE A-6
SAMPLE TWO-PHASE OPERATION
VEHICULAR SIGNALS FOR PEDESTRIAN TRAFFIC
PEDESTRIAN SIGNALS FOR PEDESTRIAN TRAFFIC
ALL SIGNALS
R Y G
A-B
NEMA PHASING DIAGRAM
2+6
4+8
PHASE
INTERVAL
SIGNAL
1 2 3 4
1-2 G G Y R
3-4 G G Y R
5-6 R R R G
7-8 R R R G
* A W F_D D_W D_W
* B D_W D_W D_W D_W
4+8
1 2 3
R R R
R R R
G Y R
G Y R
FLASHING
Y
Y
R
R
OFF
OFF
* IF ACTUATED, AS INDICATED UPON PEDESTRIAN ACTUATION, OTHERWISE DON'T WALK AT ALL TIMES.

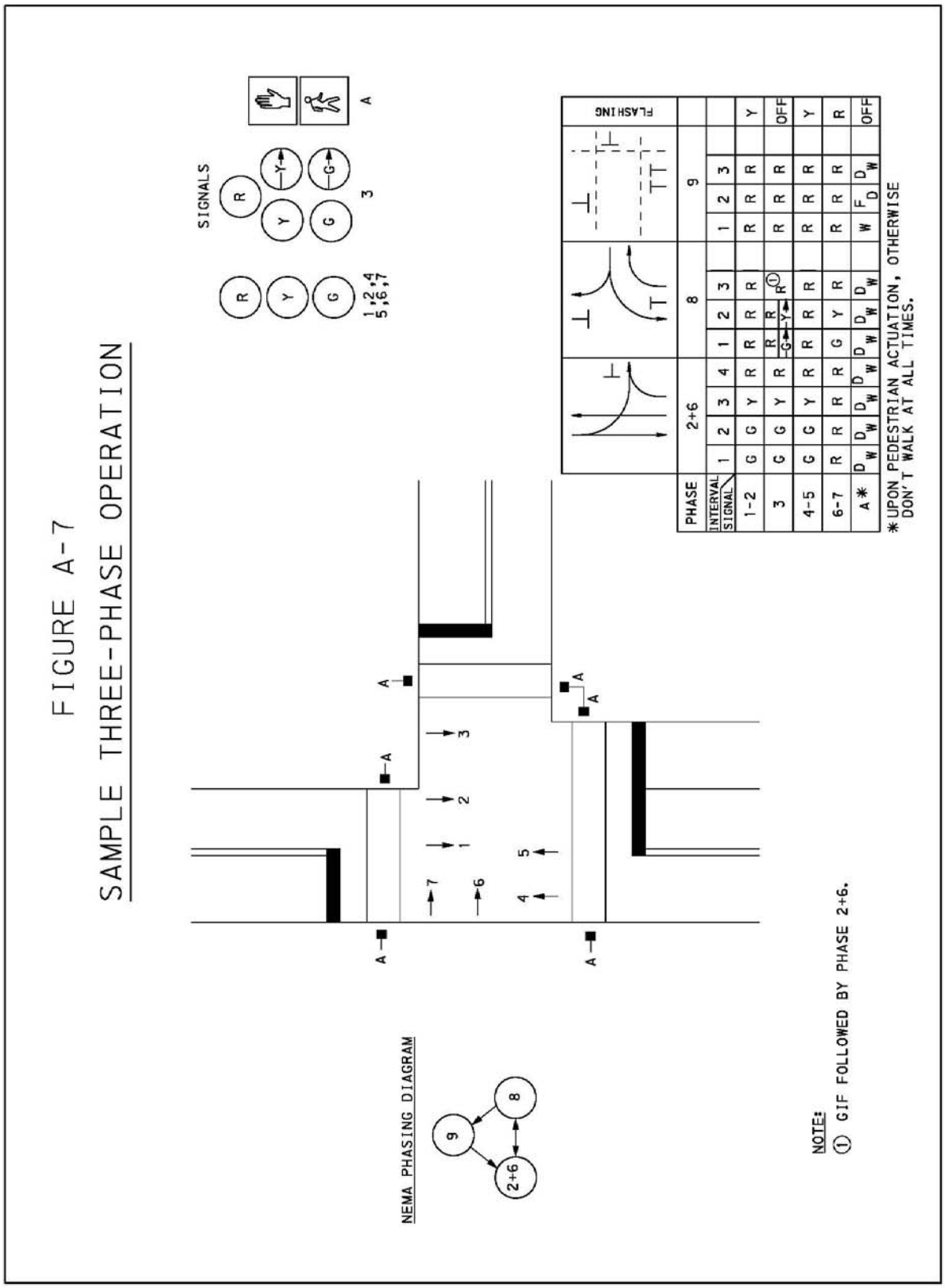


FIGURE A-7
SAMPLE THREE-PHASE OPERATION
SIGNALS
1,2,4
5,6,7
3
A
NEMA PHASING DIAGRAM
9
8
2+6
NOTE:
① GIF FOLLOWED BY PHASE 2+6.
FLASHING
PHASE
INTERVAL
SIGNAL
2+6
8
9
1-2
3
4-5
6-7
A*
OFF
*UPON PEDESTRIAN ACTUATION, OTHERWISE
DON'T WALK AT ALL TIMES.

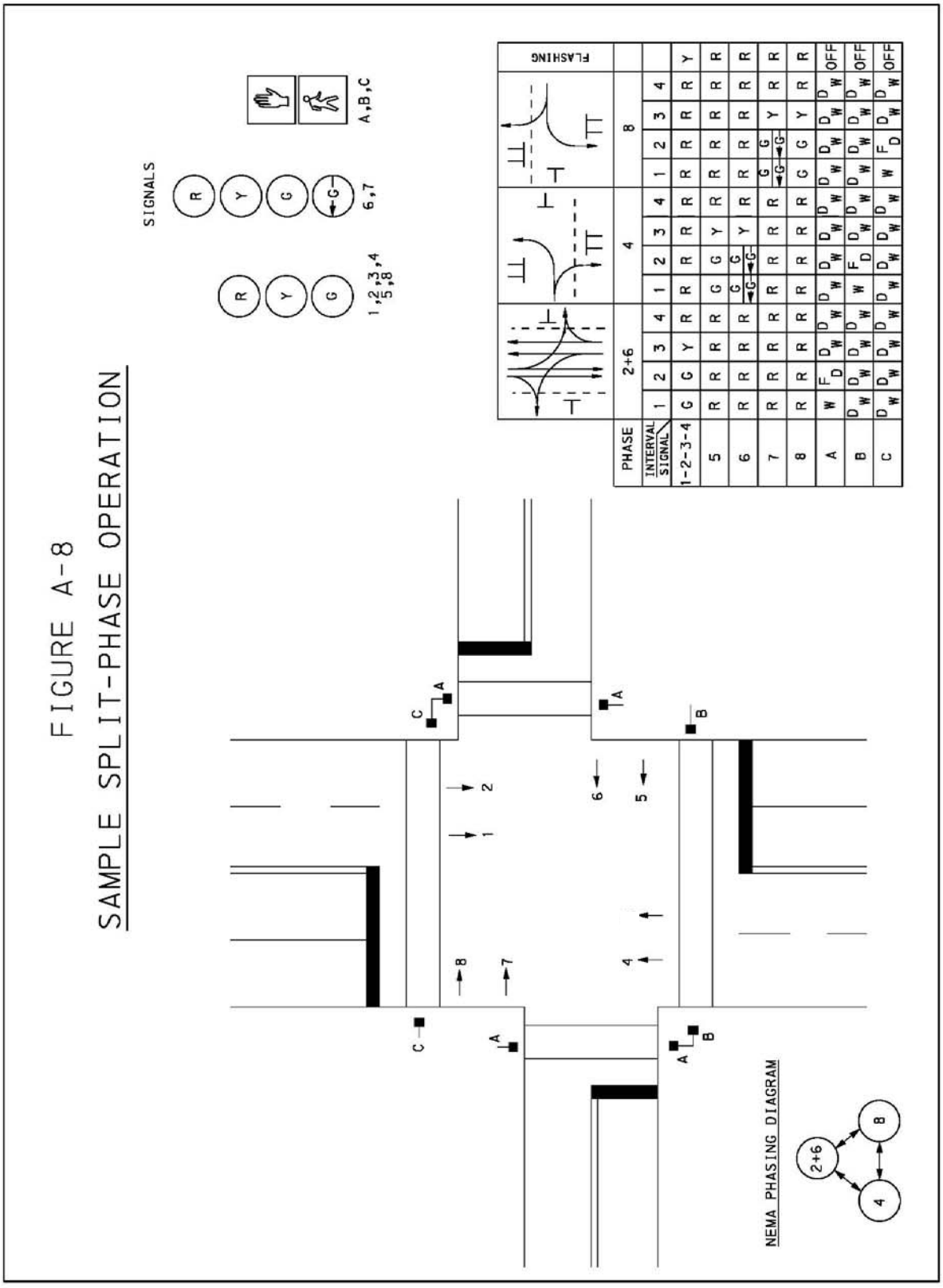


FIGURE A-8
SAMPLE SPLIT-PHASE OPERATION
SIGNALS
A,B,C
6,7
1,2,3,4
5,8
PHASE
INTERVAL
SIGNAL
1-2-3-4
2+6
4
8
FLASHING
NEMA PHASING DIAGRAM

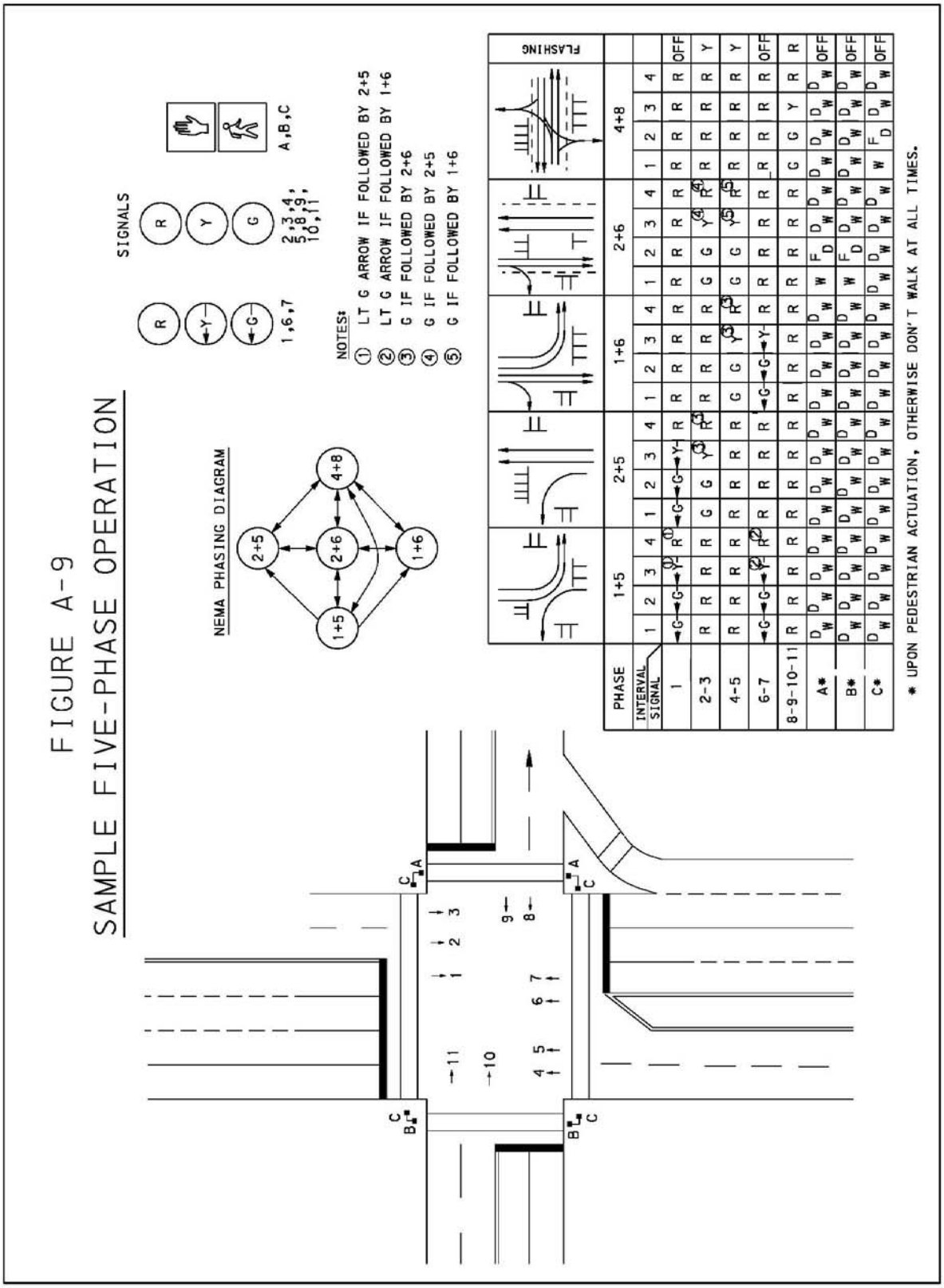
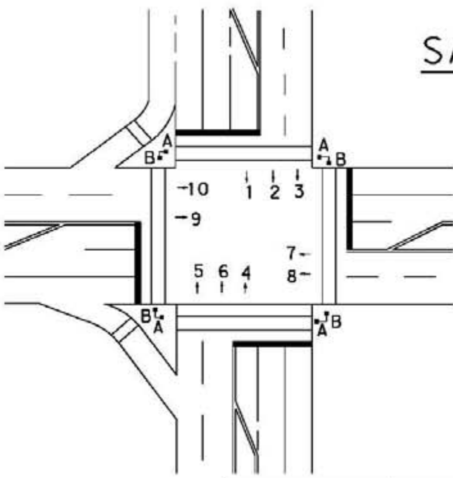
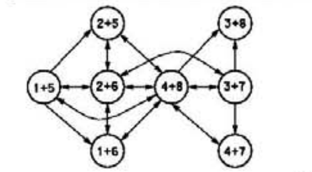
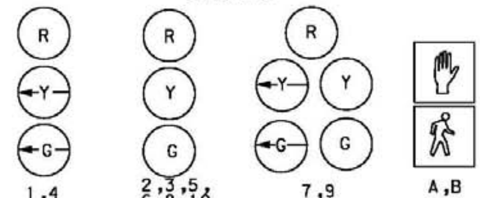


FIGURE A-9
SAMPLE FIVE-PHASE OPERATION
SIGNALS
R
Y
G
1,6,7
2,3,4,
5,8,9,
10,11
A,B,C
NOTES:
① LT G ARROW IF FOLLOWED BY 2+5
② LT G ARROW IF FOLLOWED BY 1+6
③ G IF FOLLOWED BY 2+6
④ G IF FOLLOWED BY 2+5
⑤ G IF FOLLOWED BY 1+6
NEMA PHASING DIAGRAM
2+5
4+8
2+6
1+6
1+5
FLASHING
PHASE
INTERVAL
SIGNAL
1+5
2+5
1+6
2+6
4+8
1
2-3
4-5
6-7
8-9-10-11
A*
B*
C*
OFF
* UPON PEDESTRIAN ACTUATION, OTHERWISE DON'T WALK AT ALL TIMES.

FIGURE A-10
SAMPLE EIGHT-PHASE OPERATION

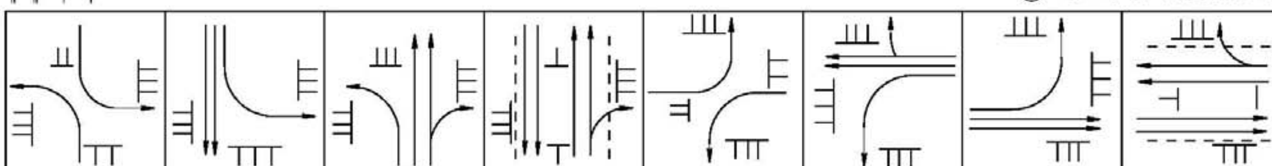






NOTES:

① LT G ARROW IF FOLLOWED BY 2+5
② LT G ARROW IF FOLLOWED BY 1+6
③ G IF FOLLOWED BY 2+6
④ G IF FOLLOWED BY 2+5
⑤ G IF FOLLOWED BY 1+6
⑥ R/←G–IF FOLLOWED BY 3+8
⑦ R/←G–IF FOLLOWED BY 4+7
⑧ G IF FOLLOWED BY 4+8
⑨ G IF FOLLOWED BY 3+8
⑩ G IF FOLLOWED BY 4+7
⑪ G/←G–IF FOLLOWED BY 4+8



PHASE	1+5				1+6				2+5				2+6				3+7				3+8				4+7				4+8				FLASHING
INTERVAL / SIGNAL	1	2	3		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3		1	2	3		1	2	3		1	2	3	4	
1	←G	←Y ①	R ①		R	R	R	R	←G	←G	←Y	R	R	R	R	R	R	R	R		R	R	R		R	R	R		R	R	R	R	OFF
2-3	R	R	R		R	R	R	R	G	G	Y ③	R ③	G	G	Y ④	R ④	R	R	R		R	R	R		R	R	R		R	R	R	R	Y
4	←G	←Y ②	R ②		G	G	Y ③	R ③	R	R	R	R	R	R	R	R	R	R	R		R	R	R		R	R	R		R	R	R	R	OFF
5-6	R	R	R		G	G	Y	R	R	R	R	R	G	G	Y ⑤	R ⑤	R	R	R		R	R	R		R	R	R		R	R	R	R	Y
7	R	R	R		R	R	R	R	R	R	R	R	R	R	R	R	G / ←G	R ⑦ / ←Y			R	R	R		G / ←G	⑧Y / ←Y ⑪	R ⑧		G	G	Y ⑩	R ⑩	R
8	R	R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R		G	Y ⑧	R ⑧		G	G	Y ⑩	R ⑩	R
9	R	R	R		R	R	R	R	R	R	R	R	R	R	R	R	G / ←G	G / ←G			G / ←G	⑧Y / ←Y ⑪	R ⑧		R	R	R		G	G	Y ⑨	R ⑨	R
10	R	R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		G	Y ⑧	R ⑧		R	R	R		G	G	Y ⑨	R ⑨	R
A *	D W	D W	D W		D W	D W	D W	D W	D W	D W	D W	D W	D W	D W	D W	D W	D W	D W	D W		D W	D W	D W		D W	D W	D W		W	F D	D W	D W	OFF
B *	D W	D W	D W		D W	D W	D W	D W	D W	D W	D W	D W	W	F D	D W	D W	D W	D W	D W		D W	D W	D W		D W	D W	D W		D W	D W	D W	D W	OFF

* UPON PEDESTRIAN ACTUATION, OTHERWISE DON'T WALK AT ALL TIMES.

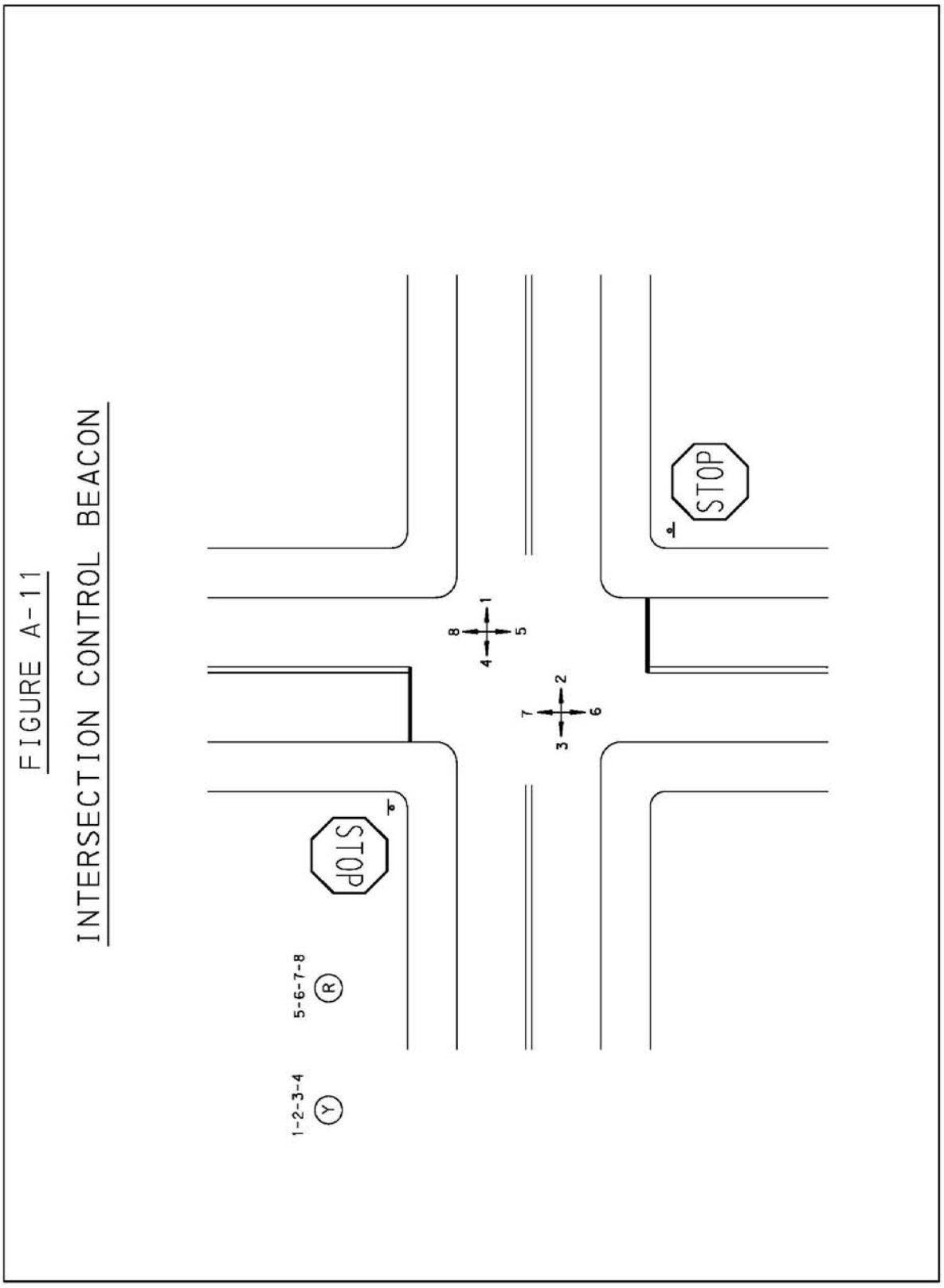


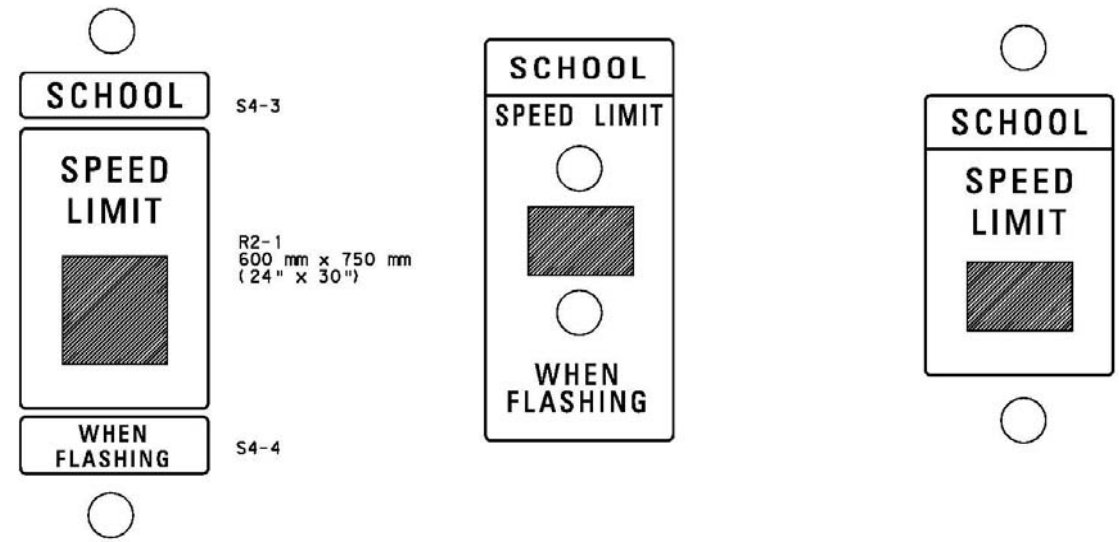
FIGURE A-11

INTERSECTION CONTROL BEACON

APPENDIX B

SCHOOL ZONE SPEED LIMIT SIGN AND FLASHING WARNING DEVICE DETAILS

FIGURES



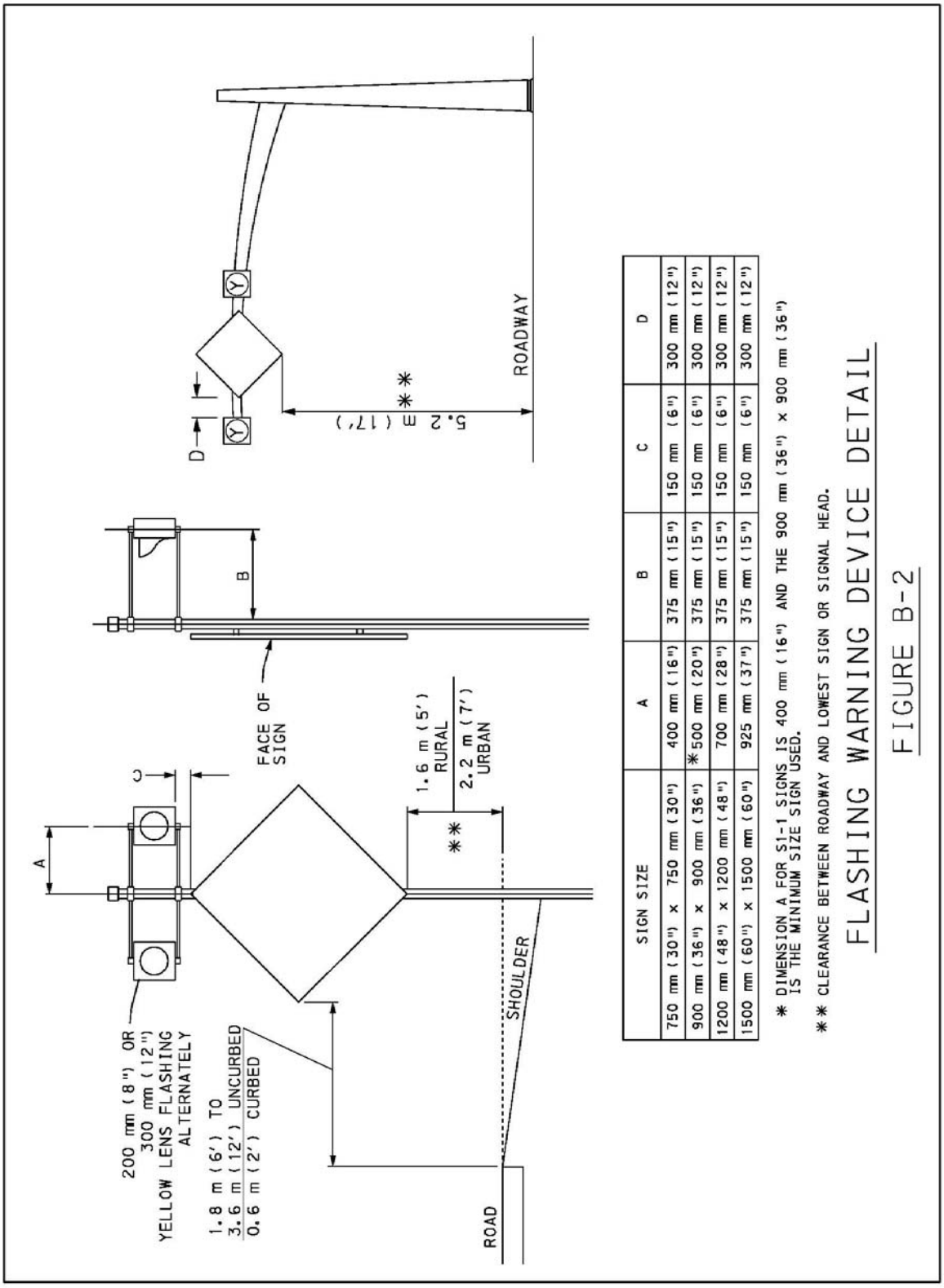
TYPE I **TYPE II** **TYPE III**

NOTES:

1. ANY OF THE ILLUSTRATED TYPES OF SIGNS MAY BE INSTALLED AT THE LOCATIONS INDICATED ON THE PERMIT DIAGRAM.
2. TYPE I IS COMPRISED OF STANDARD SIGNS HAVING THE PENNDOT DESIGNATION NUMBERS INDICATED. IT SHALL HAVE 200 MM (8") DIAMETER SIGNALS MOUNTED EXTERNALLY.
3. TYPE II MUST HAVE A PENNDOT CERTIFICATE OF APPROVAL. THE SIGN SHALL HAVE MINIMUM DIMENSIONS OF 750 MM (30") x 1350 MM (54") WITH 150 MM (6") OR 200 MM (8") DIAMETER SIGNALS MOUNTED INTERNALLY AND A BLANK-OUT SPEED MESSAGE.
4. TYPE III MUST HAVE A PENNDOT CERTIFICATE OF APPROVAL. THE SIGN SHALL BE THE CHANGEABLE MESSAGE TYPE WITH MINIMUM DIMENSIONS OF 600 MM (24") x 950 MM (38") AND 200 MM (8") DIAMETER SIGNALS MOUNTED EXTERNALLY.
5. WHEN THE SIGNALS ARE FLASHED IN TYPES II AND III, THE SPEED MESSAGE ___ SHALL BE VISIBLE.
6. TYPES I AND III SHALL BE INSTALLED WITH THE CLOSEST PART OF THE SIGNAL HOUSING 300 MM (12") FROM THE EDGE OF THE SIGN.

SCHOOL ZONE SPEED LIMIT SIGNS

FIGURE B-1



SIGN SIZE	A	B	C	D
750 mm (30") x 750 mm (30")	400 mm (16")	375 mm (15")	150 mm (6")	300 mm (12")
900 mm (36") x 900 mm (36")	*500 mm (20")	375 mm (15")	150 mm (6")	300 mm (12")
1200 mm (48") x 1200 mm (48")	700 mm (28")	375 mm (15")	150 mm (6")	300 mm (12")
1500 mm (60") x 1500 mm (60")	925 mm (37")	375 mm (15")	150 mm (6")	300 mm (12")

* DIMENSION A FOR S1-1 SIGNS IS 400 mm (16") AND THE 900 mm (36") x 900 mm (36") IS THE MINIMUM SIZE SIGN USED.

** CLEARANCE BETWEEN ROADWAY AND LOWEST SIGN OR SIGNAL HEAD.

FLASHING WARNING DEVICE DETAIL

FIGURE B-2

APPENDIX C

STANDARD FORMS

FORMS

TE-952 (3-09) pennsylvania DEPARTMENT OF TRANSPORTATION	**APPLICATION FOR PERMIT TO INSTALL AND OPERATE TRAFFIC SIGNALS**	DATE _____

WHEREAS, the _____,_____County
(CITY, TOWNSHIP, BOROUGH)

desires to erect, operate and maintain traffic signals on_____

_____, and

WHEREAS, the Vehicle Code requires the approval of the Secretary of Transportation before any traffic signals may be legally erected or reconstructed, and

WHEREAS, the Department of Transportation requires an engineering drawing of the location, the _____ will prepare such a drawing in conformance with the instructions provided by the Department.

NOW, THEREFORE, BE IT RESOLVED, that traffic signals be erected at the above mentioned location, subject to the approval of the Secretary of Transportation, and that his approval is hereby requested, and

BE IT FURTHER RESOLVED, that, in the event a traffic signal permit is approved after proper investigation, the _____
(CITY, TOWNSHIP, BOROUGH)

will be bound by the following provisions:

The traffic signals shall be installed and maintained in accordance with the Vehicle Code and the Regulations for traffic signs, signals and markings of the Department of Transportation, and

Should future highway or traffic conditions, or legal requirements, necessitate alteration of the construction or operation, or hours of operation, or removal of the traffic signals at the above mentioned location, they shall be altered or removed when and as directed by the Secretary of Transportation.

I, _____, Secretary of the _____ do certify that the foregoing is a true and correct copy of the resolution legally adopted at the meeting held, _____.
(DATE)

(SEAL) Signed_____
(SECRETARY)

TE-964 (3-09)

pennsylvania DEPARTMENT OF TRANSPORTATION

TRAFFIC SIGNAL PERMIT

Permit No. _____

Sheet 1 of _____

In accordance with the Vehicle Code, the Secretary of Transportation hereby approves the installation and operation of a traffic signal at the intersection of

_____

_____

in the _____, County of_____

This permit is issued to, and accepted by the_____ hereinafter known as the Permittee, as follows:

This installation shall be in accordance with the Vehicle Code and the Regulations for traffic signs, signals and markings of the Department of Transportation, and shall conform to the following requirements and those contained on the attached sheets.

Type of Controller_____

_____

Type of Signal Mounting_____

_____

Hours of Operation as "Stop" and "Go"_____

_____

Hours of Operation as "FLASHING" _____

_____

Controller Operation _____

_____

_____

_____

_____

_____

_____

_____

All work performed by the Permittee in the erection of the traffic signal shall be under and subject to the direction of the Secretary of Transportation or his authorized representatives. The said Permittee shall use due diligence in the execution of the work authorized under this permit and shall not obstruct or endanger travel along the said road. All operations must be conducted so as to permit safe and reasonable free travel at all times over the road within the limits of the work herein permitted.

The Permittee covenants and agrees to fully indemnify and save harmless the Department of Transportation and assume all liability for damages or injury, occurring to any person, persons or property through or in consequence of any act or omission of anyone working on the construction, or from faulty maintenance or operation of such traffic signal.

The Secretary of Transportation, by law, reserves the right to revoke and annul this permit if the Permittee shall at any time willfully or negligently fail to comply with the conditions contained in this permit, or, upon changes in traffic conditions, fail to make any changes in the construction or operation of this signal, or to remove it, when so ordered by the Secretary of Transportation; of if this installation is not in operation within twenty-four (24) months of the receipt of this permit. The Permittee shall maintain the signal in a safe condition at all times. The Permittee shall not make any change in the construction or operation of this traffic signal without prior written approval of the Secretary of Transportation.

This permit cancels and supersedes all previous permits issued for this location upon completion of the installation specified herein.

DATE _____

APPROVED _____
Secretary of Transportation

BY _____

☐ Director, Bureau of Highway Safety and Traffic Engineering
☐ District Executive

TE -699 (3-09) pennsylvania DEPARTMENT OF TRANSPORTATION

TRAFFIC SIGNAL DESCRIPTION

Municipality _____County _____

Intersection _____

_____ Permit No._____

Type of Mounting: Post Mounted _____Overhead _____ Post Mounted & Overhead _____

No. of Signal Faces _____ 200 mm (8 in) Lenses _____ 300 mm (12 in) Lenses _____

Arrows: Vert. _____ Right _____ Left _____

"WALKING PERSON/HAND" Indications: 152 mm (6 in)_____ 228 mm (9 in)_____

Type of Controller: Pretimed _____Semi-Act. _____ Full Act. _____Vol. Den._____

Other _____

Make of Controller and Model No. _____ PennDOT Approval No. _____

Make of Conflict Monitor and Model No._____

Is Installation: Isolated _____In a system _____Location of master controller_____

_____

Flashing Operation: Emergency _____ Time Clock _____Manual _____

Yellow On _____Red On _____

Make of Flashing Unit and Model No. _____ PennDOT Approval No. _____

Type and number of Detector/s _____ _____ _____ _____ _____ _____ _____

Loop Video Radar Magnetic Sonic Ped. Other

Make of Detector and Model No. _____ PennDOT Approval No. _____

Make of Detector and Model No. _____PennDOT Approval No. _____

Make of Detector and Model No. _____PennDOT Approval No. _____

_____

Does installation & operation conform with permit? _____

Does installation & operation conform to present standards? _____

Have Stop Signs been removed? _____ Date signal placed in operation _____

REMARKS AND RECOMMENDATIONS (Include any additional facts necessary for full description. Use back of form if necessary.)

Signed _____

Date _____

TE -699 (3-09) pennsylvania DEPARTMENT OF TRANSPORTATION

TRAFFIC SIGNAL DESCRIPTION

See Next Page – Guide for Completion of Form T.E. 699

Municipality _____**(1)**_____County _____**(2)**_____

Intersection _____**(3)**_____

_____ Permit No._____**(4)**_____

Type of Mounting: Post Mounted _____**(5)**_____ Overhead ___**(5)**___ Post Mounted & Overhead ___**(5)**___

No. of Signal Faces___**(6)**_____ 200 mm (8 in) Lenses___**(7)**___ 300 mm (12 in) Lenses__**(7)**__

Arrows: Vert. __**(8)**___ Right __**(8)**__ Left __**(8)**_

"WALKING PERSON/HAND" Indications: 152 mm (6 in)___(9)_____228 mm (9 in)____(9)_____

Type of Controller: Pretimed ___**(10)**_____Semi-Act. ____**(10)**___Full Act. ____**(10)**____ Vol. Den. ___**(10)**__

Other _____**(10)**_____

Make of Controller and Model No. _____**(11)**_____ PennDOT Approval No. _____**(11)**_____

Make of Conflict Monitor and Model No. _____**(12)**_____

Is Installation: Isolated _____**(13)**_____ In a system _____ Location of master controller _____**(13)**_____

_____

Flashing Operation: Emergency _____**(14)**_____ Time Clock _____**(14)**_____ Manual _____**(14)**_____

Yellow On _____**(15)**_____Red On _____**(15)**_____

Make of Flashing Unit and Model No. _____**(16)**_____PennDOT Approval No. _____

Type and number of Detector/s _____ _____ _____ **__(17)__** _____ _____ _____

Loop Video Radar Magnetic Sonic Ped. Other

Make of Detector and Model No. _____**(18)**_____ PennDOT Approval No. _____

Make of Detector and Model No. _____ PennDOT Approval No. _____

Make of Detector and Model No. _____ PennDOT Approval No. _____

_____

Does installation & operation conform with permit? _____**(19)**_____

Does installation & operation conform to present standards? _____**(20)**_____

Have Stop Signs been removed? ___**(21)**_____ Date signal placed in operation _____**(22)**_____

REMARKS AND RECOMMENDATIONS (Include any additional facts necessary for full description. Use back of form if necessary.)

(25)

Signed _____**(23)**_____

Date _____**(24)**_____

GUIDE FOR COMPLETION OF FORM TE-699

Item No. **Procedure**

1. List municipality(ies) where signal is located.
2. List county(ies) where signal is located.
3. Include all SRs, TRs, street names, and Township road numbers, if known.
4. Permit number as listed on permit.
5. Check type of mounting.
6. Total number of signal faces including “WALKING PERSON/UPRAISED HAND”. List manufacturer's name, model number, and PennDOT approval number for each type of signal face on back of form.
7. Number of each type of lens.
8. Number of arrow lenses of each type.
9. Number of “WALKING PERSON/UPRAISED HAND” lenses of each type.
10. Check type of controller, not type of operation.
11. Give manufacturer's name, model number, and PennDOT approval number for controller. When applicable , list models with approval number on back of form. If controller is located at another intersection indicate "None" and list the location on back of form.
12. List manufacturer's name and model number for conflict monitor.
13. Check type of installation and show location of master controller.
14. Check type of flashing operation.
15. List streets that have flashing yellow and flashing red, respectively.
16. List manufacturer's name, model number, and PennDOT approval number for flashing unit. If applicable, list this data for additional flashing units on the back of form.
17. Number of each type of detector sensor installed.
18. Give manufacturer's name, model number, and PennDOT approval number for each type

detector unit or amplifier.

19. If answer is "No", list items which do not conform on back of form with an explanation for each item.

20. If answer is "No", list items which do not conform on back of form with an explanation for each item.

21. For new "stop-and-go" traffic signals, do not complete form until stop signs have been removed.

22. Date when new or revised traffic signals were put into operation.

23. To be signed by person making final survey.

24. Date when final survey was made.

25. Use back of form or an additional sheet for other pertinent information. The municipality should be advised of all data included under Items 19 and 20 which do not conform. Other accessory equipment having approval numbers, such as time clocks, preemption equipment, electrically operated signs, etc., should be identified on the back of the form by showing manufacturer's name, model number, and PennDOT approval number.

After completing this report in the field, compare the form with the permit and condition diagram to assure agreement of all items. A copy of the final condition diagram must be attached to this form.