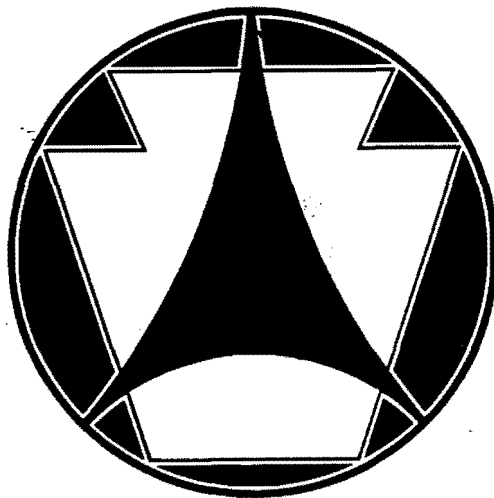


**COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION**

TRAFFIC SIGNAL DESIGN HANDBOOK



Bureau of Maintenance and Operations

Traffic Engineering and Operations Division

TRANSMITTAL
LETTER

Publication 149

DATE

September 1, 1988

SUBJECT:

Publication 149
Traffic Signal Design Handbook, 1988

INFORMATION AND SPECIAL INSTRUCTIONS:

This edition of Publication 149, Traffic Signal Design handbook, establishes guidelines for the design and operation of traffic control signals on all streets and highways in Pennsylvania. It shall be used by Department, county and municipal personnel, consulting engineers or other individuals involved in the design or operation of traffic control signals.

CANCEL AND DESTROY THE FOLLOWING:

1983 Traffic Signal Handbook

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APPROVED FOR ISSUANCE BY:

J. R. Doughty
J. R. Doughty, P.E., Chief
Traffic Engineering
and Operations Division
Bur. of Maintenance & Ops.

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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. As such, it supplements the Regulations of the Department of Transportation. The guidelines established in this Handbook are to be used to design new signals and existing signals which are to be completely reconstructed.

1.1 Traffic Control Signals

Traffic control signals shall operate continuously as "Stop and Go" or "flashing".

All traffic control signal installations shall be provided with electrical flashing mechanism supplementary to the signal timer. A manual switch, and/or where appropriate automatic means shall be provided to actuate the flashing mechanism.

When used as a flashing signal (during emergencies or periods of low traffic flow), it normally flashes yellow on the major street and red on all other streets.

Each vehicular signal face shall have at least three indications, but not more than five. The minimum shall be: red, yellow and green; or circular red, circular yellow and circular yellow. An exception to the above is a single section right green arrow used alone to indicate a continuous movement.

1.2 Intersection Control Beacons

An intersection control beacon is a section of a vehicular signal face having a flashing yellow or red indication. The red shall flash 24 hours a day while the yellow may flash all day or during those hours when the hazard or need for caution exists.

1.3 Pedestrian Signals

Pedestrian signals shall be rectangular or square in shape and shall contain the lettered message "DON'T WALK" on the top, and "WALK" on the bottom if they are of the Two Section Type. The "DON'T WALK" shall be Portland Orange and the "WALK" shall be White in color.

The symbol "Hand" for "Don't Walk" and the "Man" for "Walk" should not be proposed or used.

The pedestrian signals shall be illuminated during "Stop and Go" operation. They shall not be illuminated during Flashing operation. During periods of special preemption they shall generally be steady "Don't Walk".

2.0 MEANING AND APPLICATION OF COLORS AND INDICATIONS

2.1 Circular Red

2.1.1 Meaning

- (a) Vehicular Traffic - Vehicular traffic facing a circular red shall stop at a clearly marked stop line, but 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 follows.)

Unless an official sign is in place prohibiting a turn, vehicular traffic facing a circular red may cautiously enter the intersection to make the turn permitted by law after stopping as provided above. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other vehicular traffic lawfully using the intersection.

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

2.1.2 Application

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

A 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 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 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 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 will be displayed.

2.2.2 Application

A circular yellow shall be displayed 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 - Pedestrians facing a circular green may proceed across the roadway in any marked or unmarked crosswalk unless directed otherwise by an official sign or by pedestrian signals.

2.3.2 Application

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

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/or 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.

2.4.2 Straight-Through Green Arrow

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

A straight-through green arrow on any approach may be displayed alone, or with a circular yellow, but never with a circular red.

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 alone over an exclusive right turn lane, either so designed or signed when accompanied by through movements on that approach.

A right green arrow may be displayed with a circular yellow.

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 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 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 will be displayed.

2.5.2 Application

A yellow arrow may be displayed in a signal face following a green arrow when that face is used exclusively to control a single directional movement.

A yellow arrow may be displayed to indicate the clearance interval following the termination of a green arrow when displayed simultaneously with a continuing circular green in the same signal face.

2.6 Simultaneous Display of Conflicting Indications

The following combinations of signal indications shall not be simultaneously displayed on any one signal face, and shall not be simultaneously displayed in different signal faces on any one approach unless one of the faces is a turn signal controlling only a separately controlled lane and a sign LEFT (or RIGHT) TURN SIGNAL is located adjacent to each such signal face or the signal faces are shielded, hooded, louvered, positioned or designed so that the combination is not confusing.

- (a) CIRCULAR GREEN with CIRCULAR YELLOW.
- (b) Straight-through GREEN ARROW with CIRCULAR RED.
- (c) CIRCULAR RED with CIRCULAR YELLOW.
- (d) CIRCULAR GREEN with CIRCULAR RED.

2.7 Pedestrian Signals

2.7.1 DON'T WALK, Flashing

Pedestrians facing a flashing DON'T WALK shall not start to cross the roadway, but any pedestrian who has partly completed his crossing during the WALK indication shall proceed.

2.7.2 DON'T WALK

Pedestrians facing a DON'T WALK shall not start to cross the roadway.

2.7.3 WALK

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

2.7.4 Application

Pedestrian signals shall be installed in conjunction with vehicular traffic signals already meeting one or more of the traffic signal warrants set forth in the regulations 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 movement in one or more crosswalks with all conflicting vehicular movements being stopped for those crosswalks.
- (c) 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 any volume of pedestrian activity requires use of a pedestrian clearance interval to minimize vehicle-pedestrian conflicts or to assist pedestrians in making a safe crossing.

- (b) When multi-phase or 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.

3.0 FLASHING OPERATION

3.1 Traffic Control Signals

3.1.1 General

Traffic control signals shall be flashed during periods of low traffic volume total volume below 375 vph (urban) or 225 vph (rural) each hour for four or more consecutive hours - unless an engineering and traffic study indicates otherwise. Factors to be considered include sight distance, accident history, or unusual conflicts.

3.1.2. Meaning

Flashing Red - When a flashing red is displayed, 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 flashing yellow is displayed, drivers of vehicles may proceed through the intersection or past such signal with caution.

3.1.3 Application

When a traffic control signal is put on flashing operation, normally yellow should be used for the major street and red for all other approaches. Yellow 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 circular green or green arrow or flashing yellow shall be terminated and immediately followed by a red or flashing red without the display of the yellow change; however, transition may be made directly from a circular green or green arrow to a flashing yellow.
- (c) Stop signs should not be used with traffic control signals during normal flashing operations.

3.1.4 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). 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, all-red interval for the other approaches before changing from flashing yellow or flashing red to green on the major approach.

3.2 Intersection Control Beacon

3.2.1 General

An intersection control beacon is a section of a vehicular signal face, having a flashing circular yellow or flashing circular red indication used only at intersections to control two or more directions of travel.

Intersection control beacons are intended for use at intersections where traffic or physical conditions do not justify conventional traffic signals but where accident records indicate a special problem.

3.2.2 Meaning

The meaning of the flashing circular yellow and flashing circular red indications are as set forth in Section 3.1.2.

3.2.3 Application

Yellow on one street, normally the major roadway and red for the remaining approaches.

Flashing yellow indications shall not face conflicting vehicular approaches.

A stop sign should be used with a flashing red intersection control beacon.

3.2.4 Operation

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

Flashing operation of either signals or beacons shall be such that the indications for an approach shall have simultaneous ON and OFF periods.

3.3 Dimming

If the light output from a 12 inch flashing yellow causes excessive glare during hours of darkness an automatic dimming device should be used to reduce the brilliance during night operation. Consideration for dimming should be done on an approach basis.

3.4 Miscellaneous

A flashing red beacon may be used with a steady green arrow, to emphasize the condition "stop except right turn".

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 150 feet 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 is sufficient to restrict the visibility of the primary signals.
- (d) Other unusual conditions dictate the need.

4.1.2 Vehicular Turn Signals

A single signal face shall be provided for a turning 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.

4.2 Intersection Control Beacon

Two separate sections shall be provided on each approach.

4.3 Pedestrian Signals

Where used, there shall be a minimum of two (2) pedestrian signals visible for each crosswalk (one in each direction) so there is a signal in the line of vision for pedestrians crossing in either direction.

4.4 Mid-Block Signals

At mid-block crosswalks, there shall be at least two vehicular signal faces for each approach.

5.0 LOCATION OF SIGNAL FACES

5.1 Traffic Control Signals

Vehicular signal faces for an approach will preferably be located over the roadway. A minimum of one signal face shall be located over the roadway unless the approach speed limit is 25-mph or less.

5.1.1 Distance from Stop Line

(a) Overhead Signal Faces

Minimum - 40 feet (60 feet desirable) and at least one face, preferably all faces, beyond the center of the intersection.

Maximum - 120 feet. When more than 120 feet use 12 inch lenses, more than 150 feet also provide a supplemental signal face located as close as practicable to the stop line for that approach.

(b) 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 center line extended. When more than 120 feet use 12 inch lenses, more than 150 feet provide a supplemental signal face located as close as practicable to the stop line for that approach.

(c) Mid-Block Signals

There shall be at least one signal face over the roadway for each approach. In other respects, it shall meet the requirements herein for a traffic control signal.

5.1.2 Lateral Placement

(a) 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 can not be avoided.

85 Percentile Speed (mph)	Minimum Visibility Distance (Ft.)
20	175
25	215
30	270
35	325
40	390
45	460
50	540
55	625
60	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 20 degrees to the right of the center of the approach extended, and the other making an angle of 20 degrees to the left of the center of the approach extended. If only one signal is within the cone, it must also be at least 40 feet from the stop line. The center of an approach is considered to be the middle of the approach less any exclusive turn lane and/or parking lane.

(b) Overhead Signals

It is desirable to keep a minimum distance of 2 feet horizontally between any overhead signal and the edge of pavement, curb line or if parking is permitted from the edge of the parking lane. When this distance cannot be attained, the right approach signal should be post mounted.

The left approach signal, except when an exclusive left turn signal is installed, should be located at or to the right of the marked center line of the approach roadway. A minimum distance of 3 feet should be maintained between signal heads for opposing traffic movements to avoid blocking the motorists' view of the indication.

The preferred distance between signal faces is 12 feet, the minimum distance shall be 8 feet measured between centers of signal faces along a line perpendicular to the centerline of the approach.

Lane control signal design shall be avoided except when exclusive left and/or right turns are signalized on an 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.

(c) Post-mounted Signals

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

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

Post-mounted signals on pedestals or poles of yielding, break-away or frangible design may be installed on medians with barrier curbs which are four (4) feet or more in width or on medians with mountable curbs which are eight (8) feet or more in width.

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

If it is an exclusive left turn signal, Section 4.3 must be fulfilled.

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

(a) Overhead

The bottom of a signal face placed over a roadway shall not be less than 15 feet nor more than 19 feet above the pavement but normally should be 16 feet.

Within the above limits, optimum visibility and adequate clearance should be the guiding considerations in deciding signal height. Grades on approaching

streets may be an important factor and should be considered in determining the most appropriate height.

(b) Post Mounted

The bottom of a signal face, not mounted over a roadway, shall not be less than 8 feet nor more than 15 feet 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 40' from the stop line the bottom shall not be more than 12 feet above the sidewalk or pavement grade).

5.2 Intersection Control Beacon

Locate intersection control beacons over head near the center of the intersection where they are continuously visible for the distances provided in Section 5.1.2(a).

The distance between signal faces on an approach shall be as provided in Section 5.1.2(b).

5.3. Pedestrian Signals

5.3.1 Lateral Placement

The pedestrian signal face shall be so positioned and adjusted as to provide maximum visibility at the beginning of the controlled crossing. Pedestrian signals shall otherwise meet the requirements herein for post mounted vehicular signals.

5.3.2 Vertical Placement

Pedestrian signal faces shall be mounted with the bottom not less than 7 feet nor more than 10 feet above the sidewalk level.

The DONT WALK indication shall be mounted directly above or integral with the WALK 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.

6.0 ARRANGEMENT OF LENSES IN VEHICULAR SIGNAL FACES

6.1 Vertical Signal Face

In a vertical signal face, the relative positions of lenses from top to bottom shall be:

- Circular Red
- Circular Yellow
- Circular Green
- Straight Through Green Arrow
- Left turn Yellow Arrow
- Left turn Green Arrow
- Right turn Yellow Arrow
- Right turn Green Arrow

6.2 Horizontal Signal Face

In a horizontal signal face, the relative positions of lenses from left to right shall be:

- Circular Red
- Circular Yellow
- Left turn Yellow Arrow
- Left turn Green Arrow
- Circular Green
- Straight Through Green Arrow
- Right Turn Yellow Arrow
- Right Turn Green Arrow

6.3 Signal Face Cluster

In a cluster, identical signal indications may be repeated in adjacent vertical or horizontal locations within the same signal face.

6.4 Typical Arrangement

Typical design arrangements used in Pennsylvania are shown in Figure 1, Appendix A of this Handbook.

7.0 SIZE OF SIGNAL LENSES

7.1 Vehicular Signals

Lenses for vehicular signals shall be two sizes, 8 inches or 12 inches nominal diameter.

Different size lenses may be used in the same signal face except that an 8-inch red shall not be used with 12-inch circular green or 12-inch circular yellow.

The 8-inch lens is the standard size for vehicular signals, unless an engineering study indicates a need for 12-inch lens or as follows.

12-inch lenses shall be used:

- (a) All arrows.
- (b) Where the nearest signal face is more than 120 feet from the stop line.

12-inch lenses should be considered for use:

- (a) At approaches with 85 percentile speeds exceeding 40 mph.
- (b) At approaches where signalization might be unexpected.
- (c) At approaches where drivers view traffic control and lane use control signals simultaneously.

7.2 Pedestrian Signals

The letters "WALK" and "DON'T WALK" shall be at least three (3) inches high for a crossing where the distance from the near curb to the signal indication is 60 feet or less. For distances over 60 feet the letters shall be 4 1/2 inches high.

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 they are intended.

At intersections where pedestrian signals are not used, 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 4 feet per second. Use the chart "Signal Visibility for Pedestrians" to determine if the signal location is within acceptable limits. If not, install a vehicular signal head that will be visible to pedestrians.

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 tend to make a lens look illuminated when it is not.
- (c) Shield the lens from motorists on other approaches who might be confused were they to see the lens.

8.3 Louvers

Louvers are full circle inserts with one or more built-in fins that restrict the viewing angle of the signal.

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 improve the visibility of signals otherwise impaired by background lighting, sun light, or glare behind the signal face. Backplates should not be used as a design standard but only where an engineering study indicates their need to resolve one of the above problems.

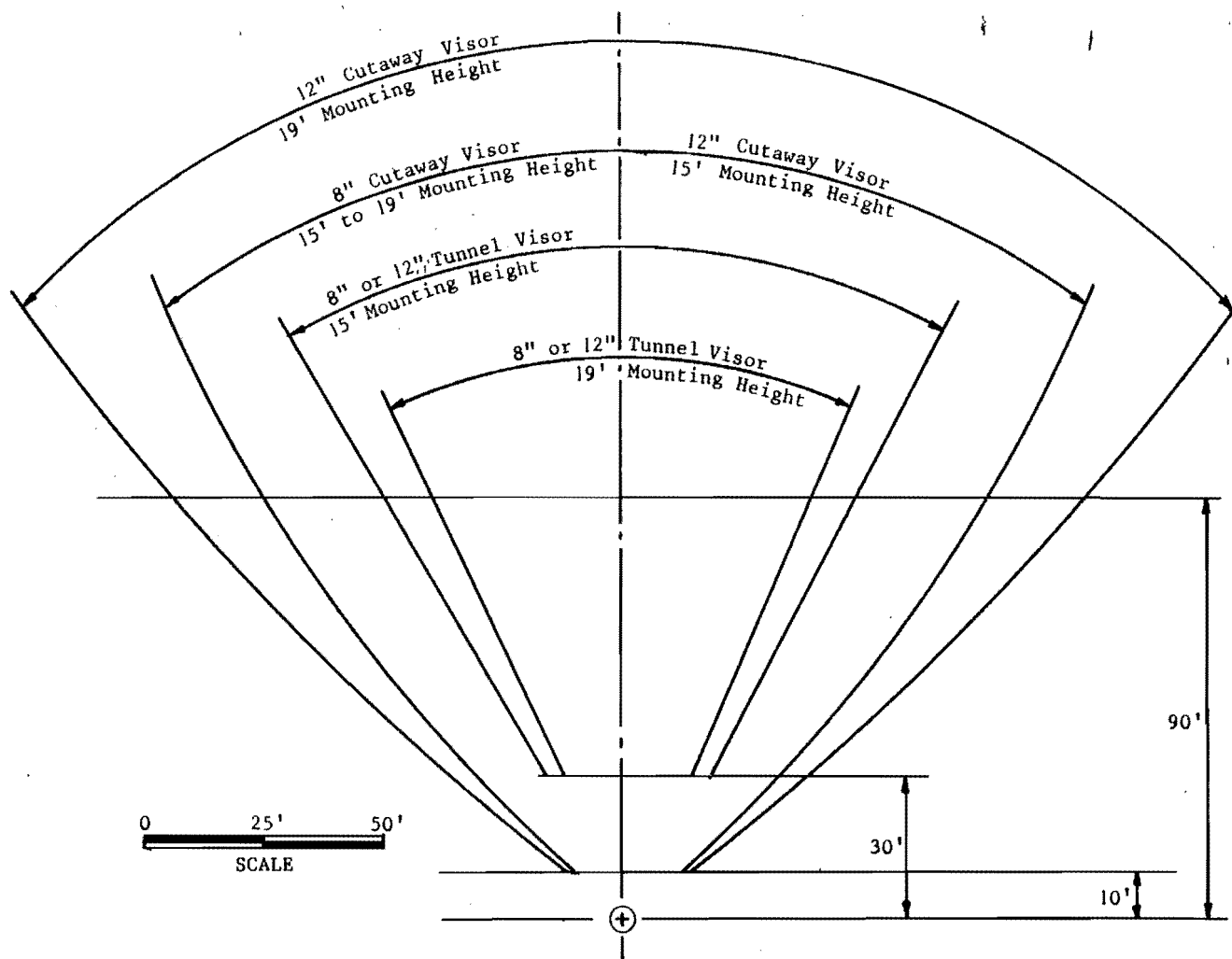
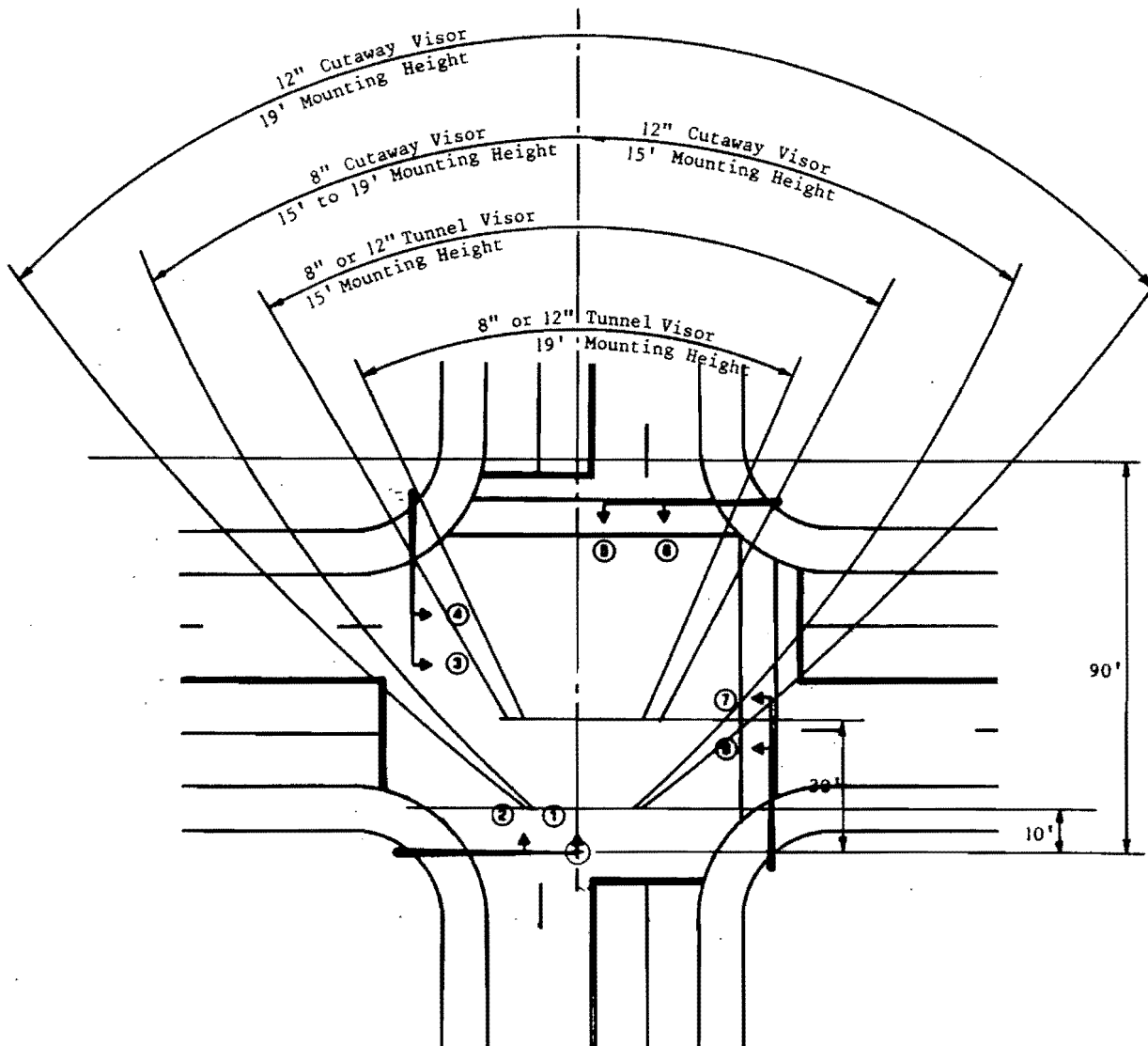


FIGURE 8-1 SIGNAL VISIBILITY FOR PEDESTRIANS

Procedure for use of Figure 8-1 (Signal Visibility for Peds.):

- a) Place overlay such that the $\oplus$ -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 4 feet per sec.) to the center of the farthest traveled lane before opposing vehicles receive a green indication.
- c) In this example, any combination of signal head size, and mounting height can be used except for signals with tunnel visors.



9.0 OPTICALLY PROGRAMMED SIGNAL HEADS

9.1 General

Optically programmed signals, or programmed visibility signals, were 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.

9.2 Location

(a) Lateral Location.

Distance limited visibility. Locate as required herein for standard vehicular signal faces.

Lateral limited visibility. Locate on or within 3 feet of the lane line which separates the controlled lane from the area where the signal should not be seen.

(b) Vertical Location.

Overhead. Locate as required herein for standard vehicular signal faces.

Post Mounted. Locate a minimum of 12 feet above the sidewalk or pavement grade.

All overhead programmed signals shall be rigidly mounted since any movement of the head would alter the area of visibility, thus reducing its effectiveness.

9.3 Installation Design

9.3.1 Lane Control

As indicated, signals which limit the lateral visibility are located on or within 3 feet of the lane line which separates the controlled lane from the lane(s) where the signal should not be seen. In the case of a left-turn lane, for example, assume the signal is placed toward the left edge of the lane. In programming the signal, the light rays from the signal are being aimed not so much at the lane, but the driver's eye height for both high and low vehicles. It is possible that the rays aimed at the high vehicle location could be visible to a motorist in a low vehicle in the adjacent lane, thus reducing the signal's effectiveness. This problem is, in most cases, eliminated by placing the signal along the right edge of the turning lane.

For curved approaches or parallel roadways, the signal location will have to be more carefully determined to achieve the desired results.

9.3.2 Closely Spaced Intersections

When intersections are less than 200 feet apart a motorist may see upstream signal indications and become confused as to which signals control the intersection he 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 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 such that a motorist cannot see the signal display until he 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.

9.3.3 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 farside signals are usually of such a distance from the stop line that the signals 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 problem.

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. 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 crosses the stop line. Thus, the motorist is informed he has the right-of-way to complete his movement.

9.3.4 Pedestrian Signals

Occasionally, there are locations where complex cross-walk 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, shall be provided in such cases.

9.3.5 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 CONTROLLER SELECTION AND PHASING

10.1 Type of Controller

Prior to the design of a signal installation, accurate traffic counts at the design location must be obtained. These should consist of machine counts for a minimum of 24 continuous hours and turning movement counts taken for 2 hours minimum during each of the a.m. and p.m. peak periods. Consideration should be given to the obtaining turning movement counts during midday as well.

Analysis of these volumes, in conjunction with intersection geometrics and proposed lane configurations, will indicate the required phasing and timing during different parts of the day.

The type of control used can have a most 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 which enters from the cross street.

Factors (b) and (c) can be found by studying the manual traffic count sheets 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 any isolated intersection subject to the variations in local conditions.

<u>Factor</u>	<u>Fixed Time</u>	<u>Fully Actuated</u>	<u>Volume Density</u>
(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 20% volume variation is taken as the critical value since with average volumes this variation would require a change in cycle length which, 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 a minimum of two 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, full-actuated and volume-density. Semi-actuated control should be considered only for cases with very light cross street traffic in interconnected systems.

10.2 Number of Phases

10.2.1 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.

The specific number of signal phases required for efficient operation at a particular intersection is dependent upon the physical geometrics 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 installing multiphase signal controllers at intersections to ensure that the multiphase operation is justified. 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 are not 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 which could otherwise be applied to other movements within the intersection.

10.2.2 Two Phase Operation

Two phase signal operation is the simplest form of phasing and is applicable at more intersections than any other phasing. Two phase operation should be used at all locations where the following criteria is satisfied:

- (a) Simultaneous traffic movement in the opposing directions does not present a hazard;
- (b) The intersection has four approaches or less;
- (c) 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 according to capacity analysis procedures or during the vehicular clearance time; and
- (d) The accident experience involving left turn movements does not justify exclusive left turn movements.

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

10.2.3 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; and
- (e) The accident experience has shown 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 geometrics can be simplified to meet the above requirements.

When it is found that the three phase operation is justified exclusively for a minor pedestrian or vehicular movement, the movement shall 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.

10.2.4 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; and,
- (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 shall be actuated.

10.2.5 Five Phase To Eight Phase Operation

Five phase to eight phase operation of traffic control signals may be necessary at locations which cannot be adequately signalized with a four phase installation. The most common application of this phasing is the provision of

exclusive left turn movements 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.

10.3 Left Turn Phases

Determination of the need for advance or exclusive phases for left turning vehicles shall be made as indicated in the Department's policy "Criteria for Signalization of Left Turning Movements". The basis for the analysis shall be the volume of left turning vehicles and opposing through vehicles for the two highest one hour periods of a typical weekday. See Appendix C for this policy.

11.0 CYCLE LENGTH AND TIMING

11.1 General

The full value of any signal installation is realized only when it is operated in a manner consistent with the requirements of traffic. The use of an unduly long cycle or an improper split of a cycle of reasonable length can result in disrespect for and poor observance of signal indications, and a greater accident potential.

11.2 Cycle Length

For pretimed signals, the time cycle is the predetermined time required for the controller to go through one complete set of signal indications. This may vary from 45 seconds to 120 seconds, although the usual cycle lengths are between 60 and 90 seconds. Traffic-actuated signals do not have a constant time cycle since it varies with the changing demands of traffic.

Long cycle length reduces the relative amount of time taken up by the change intervals, and may minimize the number of times that the major street traffic is stopped in each hour. However, under all but the most extreme traffic conditions, a moderate cycle length such as 60 to 90 seconds will prove most efficient in moving traffic with the least delay. This is because on a green signal, the traffic stream - normally "thins out" after the first accumulation of vehicles has started, whereas delay (in vehicle-seconds of waiting time) begins to build up on the stopped approaches.

One of the chief difficulties in signal timing comes from the need to accommodate two or three radically different volume patterns at various times during the period of operation. This may be accomplished either by multi-cycle, multi-split pretimed control, or by traffic actuation.

Some of the factors which must be considered in assigning green time to each of the intersecting streets are:

- (a) Number of traffic lanes and other physical conditions.
- (b) Volume of traffic in the critical lanes.
- (c) Requirements of commercial and public transit vehicles.
- (d) Vehicle headways on the intersecting streets.
- (e) Pedestrian requirements.
- (f) Vehicle and pedestrian clearance requirements.
- (g) Turning movements.

- (h) Clearance and reservoir space for turning vehicles.
- (i) Movement of platoons of vehicles or minimizing overall delay in a network of signalized intersections.
- (j) Grades on approaches.
- (k) Spacing between signals.
- (l) Parking and unparking of vehicles.

The optimum division of the time cycle, or split as it is sometimes called, ordinarily is as important in securing signal efficiency as the selection of the appropriate time cycle 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 roadway capacity.

The time cycle should normally be as short as is practical to handle the traffic requirements of individual intersections. With coordinated system, selection of the time cycle is subject to the spacing of signalized locations and prevailing speeds. Therefore, it will be assumed that the value of the time cycle 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 clearance time.
- (b) Selection of minimum green interval time.
- (c) Proportioning of the green intervals to correspond with traffic flow and efficiency of movement.

11.3 Vehicle Change and Clearance Intervals

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

Yellow vehicle change intervals are in the range of from about 3 to 5 seconds. Excessively long change intervals result in abnormal running of the change and clearance intervals. If an intersection is unusually wide and/or has a documented history of accidents, the yellow change interval may be followed by an all-red vehicle clearance interval of sufficient length to allow vehicles to clear the area before conflicting traffic is released.

The change and clearance intervals should be calculated using the following equation:

$$CCI = t + \frac{1.47V}{2a + 64.4g} + \frac{W + L}{1.47V}$$

Where:

CCI (sec)	=	Change and clearance interval (Y+AR)
Y (sec)	=	3 to 5 (yellow change interval)
AR (sec)	=	CCI minus Y (all red clearance interval)
t (sec)	=	1.0 (perception - reaction time)
V (mph)	=	approach speed (posted speed limit)
a (fps ²)	=	10 (deceleration rate)
g (%/100)	=	grade of approach
W (feet)	=	Width of intersection (from near curb line to center of far lane)
L (feet)	=	20 (length of vehicle)

To speed calculations, the following tables may be used to determine the value of the two terms in the above formula. CCI equals the sum of the two values.

	V Approach Speed	g (Grade of Approach)								
		Uphill					Downhill			
		+4%	+3%	+2%	+1%	Level	-1%	-2%	-3%	-4%
$t + \frac{1.47V}{2a + 64.4g}$	25	2.63	2.68	2.73	2.78	2.84	2.90	2.96	3.03	3.11
	30	2.95	3.01	3.07	3.14	3.21	3.28	3.36	3.44	3.53
	35	3.28	3.35	3.42	3.49	3.57	3.66	3.75	3.85	3.95
	40	3.60	3.68	3.76	3.85	3.94	4.04	4.14	4.25	4.37
	45	3.93	4.02	4.11	4.20	4.32	4.42	4.54	4.66	4.80
	50	4.26	4.35	4.45	4.56	4.68	4.80	4.93	5.07	5.22
	55	4.58	4.69	4.80	4.92	5.04	5.18	5.32	5.47	5.64

	V Approach Speed	W (Width of Intersection)										
		20'	30'	40'	50'	60'	70'	80'	90'	100'	110'	120'
$\frac{W + L}{1.47 V}$	25	1.09	1.36	1.63	1.90	2.18	2.45	2.72	2.99	3.27	3.54	3.81
	30	0.92	1.14	1.36	1.59	1.81	2.04	2.27	2.49	2.72	2.95	3.17
	35	0.78	0.97	1.17	1.36	1.55	1.75	1.94	2.14	2.33	2.53	2.72
	40	0.68	0.85	1.02	1.19	1.36	1.53	1.70	1.87	2.04	2.21	2.38
	45	0.60	0.76	0.91	1.06	1.21	1.35	1.51	1.66	1.81	1.97	2.12
	50	0.54	0.68	0.82	0.95	1.09	1.22	1.36	1.50	1.63	1.77	1.90
	55	0.49	0.62	0.74	0.87	0.99	1.11	1.24	1.36	1.48	1.61	1.73

11.4 Pedestrian Intervals

When pedestrian indications are provided, the minimum length of the WALK interval (Tw) should be based upon the length of time required to start pedestrians who have been waiting for the WALK indication. The length of the interval need not be sufficient to allow a pedestrian to cross the entire roadway (or from, or to a median island) since they may continue to cross on the change interval but should include a reaction time of 3 seconds. However, where pedestrian volumes are heavy, the WALK interval should be as long as practical. Generally, it should be in the range of 7 to 10 seconds

for average conditions. W is the width of roadway from edge of roadway to edge of roadway. Sw is the walking speed of 4 feet per second.

$$T_w = \frac{.5W}{S_w} + .3$$

Minimum 7.0 seconds

The length of the flashing DONT WALK indication (pedestrian clearance interval Tpc) should always provide time for a pedestrian to cross from the curb or edge of shoulder to the center of the farthest traffic lane (L) at a walking speed (Sw) of 4 feet per second, (except near elementary schools and facilities for the elderly where 3 feet per second is a better average speed), before the conflicting vehicular movement receives the green. The length of the vehicular change interval may be included in calculating the length of the flashing DONT WALK interval since the two may overlap.

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

When pedestrian 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 (Tp) to allow pedestrians to cross the roadway at a walking "speed of 4 feet per second, plus additional time (3 seconds) for starting at the beginning of the green.

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

Unless the signal location is completely rural, pedestrian crossing needs should be considered. However, pedestrian timing is usually required only for the two major phases at a multi-phase intersection. At locations where separate pedestrian-actuated timing is provided for a traffic phase, the vehicle minimum timing need not provide for pedestrian crossing.

11.5 Green Intervals

Many highly 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 signals.

After determining the desired proportioning of the green intervals, each green interval must be checked against the allowable minimum green time. Adjustment must be made when necessary, to guarantee the minimum green time for each phase. The resultant timing applies directly where pretimed controllers are used.

For traffic-actuated controllers, the timing thus calculated is used for the maximum green or force-off timing for each phase. With some 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 such 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 time cycle should represent the peak traffic conditions that will be encountered at the signal locations. Fifteen minute peak data, or peak hour data adjusted for the peak-hour factor, is preferred if available. If the different movements at an intersection peak at different times of day, the peak traffic counts from these different times should be allowed to compete with one another for an appropriate portion of the time cycle.

Greatest efficiency is obtained from traffic-actuated equipment only with careful adjustment of the various features provided. This often requires some experimentation after an installation has been made, and it is recommended that only a qualified person make the adjustments.

11.5.1 Minimum (non-actuated)

In semi-traffic actuated equipment the timing for this period determines the 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.

11.5.2 Minimum (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 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 of the detector to move across the detector and place an actuation. This minimum period (TI) normally ranges between 5 to 15 seconds when using impulse type detection. If presence detection is used and the zone of detection extends to the stop line, this period should be set to 0.

$$T_I = 3.7 + 2.1 N$$

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

11.5.3 Passage

Passage time (TU) provides an added time increment during the green interval for each vehicle as it passes the detector. It 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 speed. This feature also determines the length of gap which if exceeded, permits the right-of-way to be transferred to another phase. A value of 3 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 to 3 seconds are normally used.

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

D = distance from detector to stop line

d = distance from stop line to center of intersection

S = Speed of approaching vehicles (feet/sec.)

11.5.4 Maximum

For a semi-traffic-actuated controller, 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 continue to occur. Semi-traffic-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 to 30 seconds for semi-traffic-actuated signals.

For a full-traffic actuated controller, 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 actuations 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 and 60 seconds for major movements and proportionately less for minor movements.

11.5.5 Minimum green, added initial, and maximum initial

For density controllers, the minimum green feature is set at a low value (8 to 12 seconds), and this establishes the shortest green phase possible under extremely light traffic. The initial interval is increased from this value by the added initial feature which adds the time set on the controller for each car which arrives on the red indication. The maximum initial establishes the upper limit of variable initial period. The three adjustments should be set that sufficient green will be available to clear the number of vehicles which can be stored between the detector and the STOP line.

11.5.6 Passage

This feature is the same as the passage discussed above for non-density type controllers. The setting should provide sufficient time (normally 3 to 8 seconds) for a car to travel from the detector to the near curb line at the prevailing speed on the street.

11.5.7 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.

11.5.8 Time Before Reduction

This period begins when the phase is green and there is a servicable conflicting call. During this period the passage time cannot be decreased.

11.5.9 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.

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.

12.1.2 Conduit Layout

The conduit layout should be so designed as 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 must 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 termini 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 2 inch diameter or greater are to be used for purposes of signalization or interconnection. Use of 1 inch diameter conduits will be allowed for the routing of detector leads through the curb into a junction box and for detector lead-in runs to the controller cabinet. One inch 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 is the conduit to 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 compared to the 40 percent fill areas of the conduit. See Figure 12-1 for an example of this analysis.

12.1.4 Method of Installation

(a) Trench. All conduits to be installed in developed areas are to be installed by the open trench method. The trench shall be deep enough to provide a minimum depth of cover of 21 inches.

(b) Jacking. In lightly 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.

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.

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. If in earth areas, it should be 2 to 3 inches 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 450 feet).

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

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 Fig. 13-1 and 13-2, #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 indications to be displayed by the signal.

Each indication requires two conductors, an ungrounded conductor and a grounded conductor (neutral). Neutral returns in a signal head may be spliced together, thus the total number of conductors required equal the number of signal selections 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
DETECT	2/c
Pedestrian Push Button	3/c
Pedestrian Signal	5/c
Three-Section Traffic Signal	5/c
Four-Section Traffic Signal	7/c
Five-Section Traffic Signal	7/c

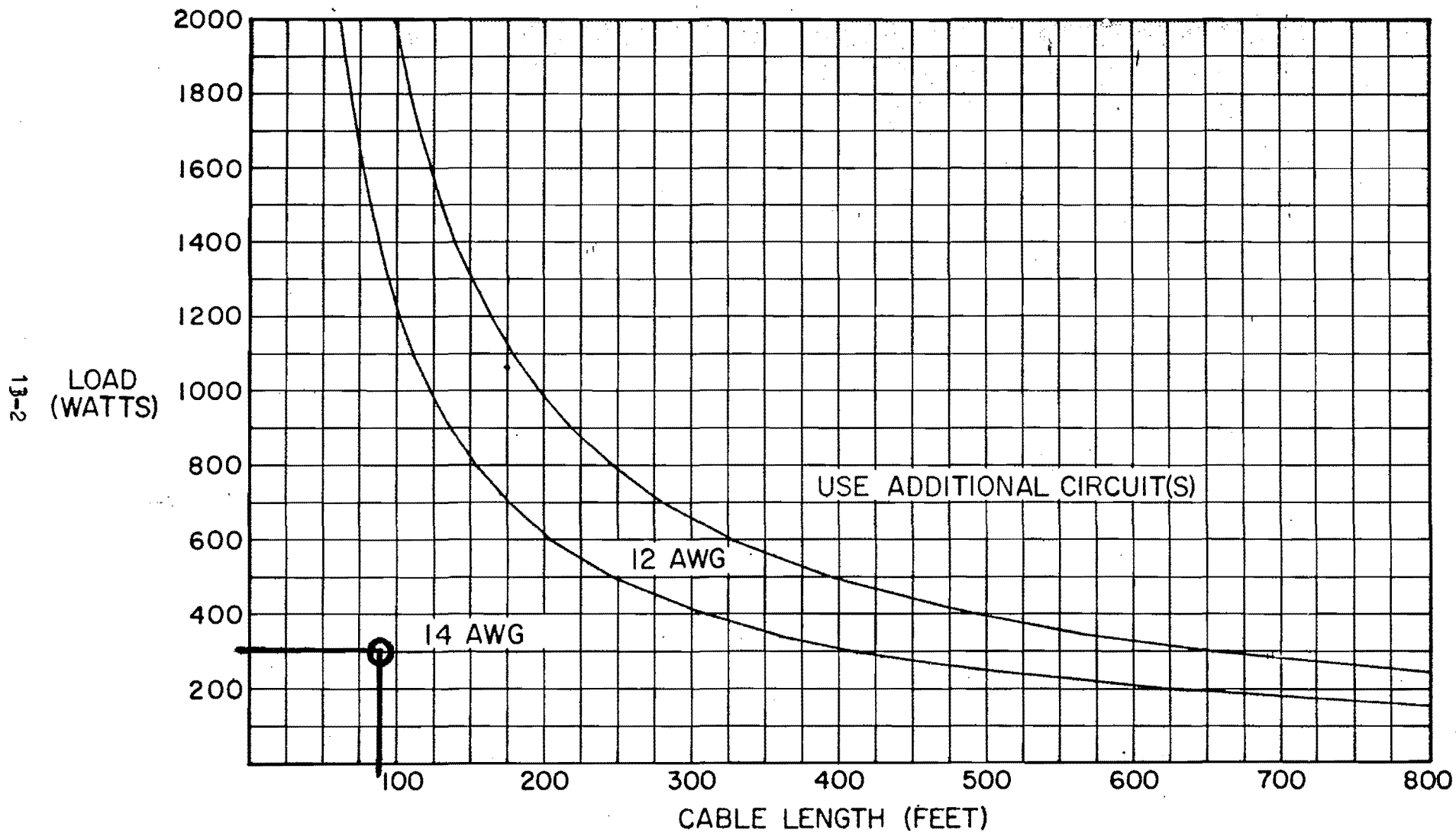
It may be noted that standardizing cable sizes for signal heads will yield at least one spare conductor for each signal. This will:

- (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 turning movements.

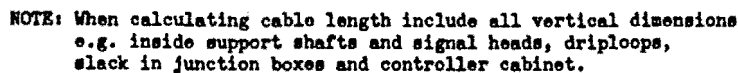
13.4 Wiring Method

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.



CONDUCTOR SIZE - TRAFFIC SIGNAL CABLE



13-3

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 spliced together.

Example - An example of the following wiring method is based on the intersection shown in Figure 13-3.

The conduit from JB-1 to pole 2 contains the wiring for the signal equipment on pole 2 and detectors 8 and 9. Two 3/c cables are provided for the pedestrian push buttons and two 5/c cables for the vehicular signals. Since signal heads 3 and 4 display identical indications at all times, both can operate from one cable from the controller cabinet to the terminal block in signal 4 and a cable from the terminal block in signal 4 to the one in signal 3. Signal head 7 operates differently from the other signals on that pole; therefore, signal 7 requires a separate 5/c cable. This results in two 5/c cables, two 3/c cables for this conduit.

The conduit from JB-1 to JB-3 contains the wiring for the signal equipment on pole 3 and detectors. Two 3/c cables are provided for the pedestrian push buttons and one 5/c cable for the vehicular signal. This results in one 5/c cable, two 3/c cables and one 2/c detector lead-in from detector 5 for this conduit.

As a result of the above the conduit from the controller cabinet to junction box 1 contains the following:

<u>Equipment</u>	<u>Cable</u>
Detectors 1, 2 and 3	1 - 2/c
Detector 5	1 - 2/c
Pushbuttons pole 2	2 - 3/c
Pushbuttons pole 3	2 - 3/c
Signals 3 and 4	1 - 5/c
Signal 7	1 - 5/c
Signal 8	1 - 5/c

Based on the above data conduit sizes can now be determined for the above runs utilizing the information from Table 12-1 and indicated in Figure 12-1.

13.5 Wiring Diagram

A schematic wiring diagram shall be prepared for each traffic signalization design location. This diagram shall show the controller, signal heads, detectors and push buttons, the required number, size and types of wiring, and splices. An example of the diagram is illustrated in the Standard Plan Sheet.

13.6 Color Codes

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

<u>Conductor</u>	<u>Color</u>	
1	Black	Green Ball/Arrow or Walk
2	White	Neutral
3	Red	Red or Don't Walk
4	Green	Reserved
5	Orange	Yellow Ball/Arrow
6	Blue	Green Arrow
7	White/Tracer	Yellow Arrow/Spare

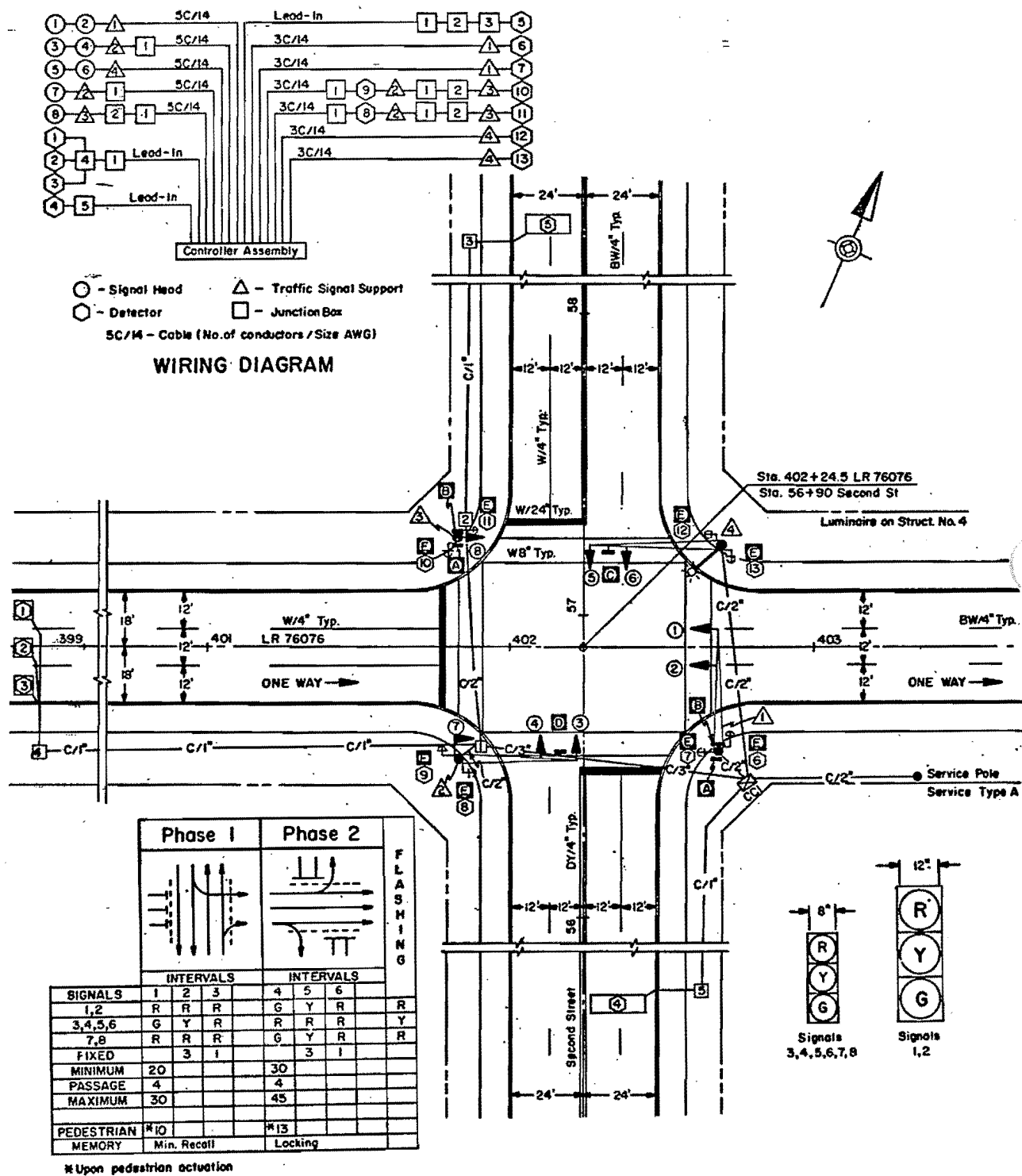


FIGURE 13-3 Intersection Example

14.0 TRAFFIC SIGNALS NEAR RAILROAD OR TRANSIT GRADE CROSSING

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 pre-empted 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.

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 200 feet of a grade crossing must be reviewed by the PUC before a permit for vehicular traffic signals may be issued by the Secretary of Transportation.

15.0 EMERGENCY VEHICLE PREEMPTION

Systems in which traffic control signals are preempted from the approaching emergency vehicle shall be designed and installed so as 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 display is prohibited.

16.0 LOOP DETECTORS

16.1 Loop Detector Theory

The loop detector is comprised of three components:

- (a) An input capacitor in the detector unit or controller;
- (b) A two-wire transmission line; and
- (c) A loop sensor in the roadway surface.

The 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.

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 to 150 milliseconds for each vehicle passing or stopping over the loop.

16.2.2 Presence Mode

When the mode selector switch is in the PRESENCE position, the detector provides one output pulse for each vehicle passing over the loop, or an output for a minimum of 3 minutes for a vehicle stopped over the loop.

16.3 Loop Layout

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 Loop

The short loop may be installed either alone or in conjunction with other short loops to create a large detection area. The criteria for sizing and layout is as follows:

- (a) The length shall be 6 feet.
- (b) The minimum width shall be 5 feet.
- (c) The sides of the loop should be 3 feet 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 70 feet long. The first loop shall be placed such that it extends 3 feet beyond the stop line. The second, third and fourth loops shall be sequentially spaced at 10 feet, 15 feet and 20 feet, respectively.

Short loops may operate in either the pulse or 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. The sizing and layout criteria is as follows:

- (a) The maximum length shall be 50 feet.
- (b) The maximum width shall be 8 feet and the minimum 5 feet.
- (c) The sides of the loop should be 3 feet from either edge of the travel lane.
- (d) The front edge of the loop should extend 3 feet 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 eliminate 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. 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.

16.3.4 Sensor Design

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

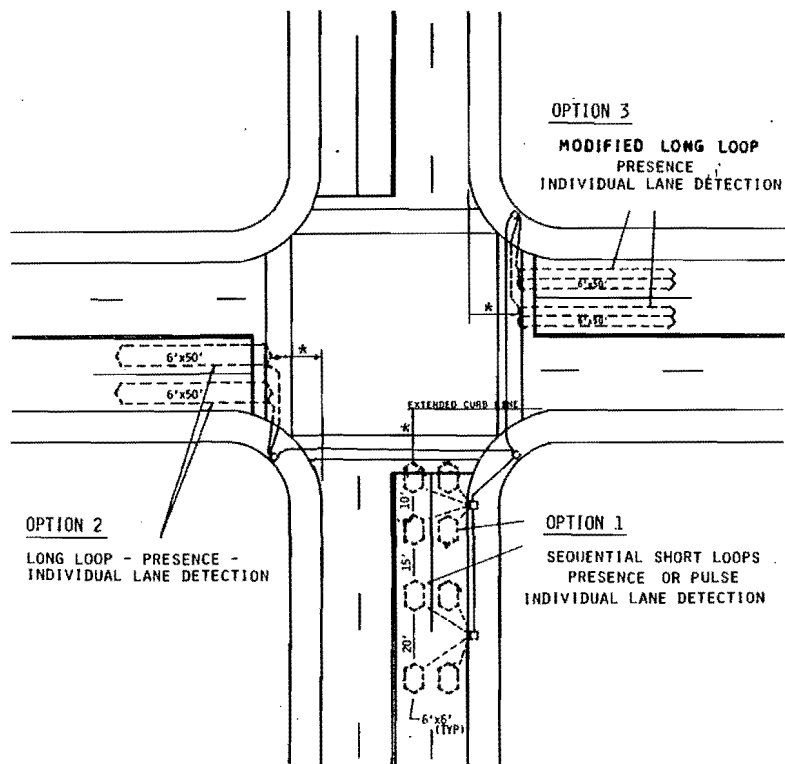
- (d) Option 4 - Consists of one short loop per lane located in advance of the intersection based on normal approach speeds. This option, which operates in pulse mode only, is best suited for providing extension intervals on roads with higher travel speeds. They can also be used for individual lane counting and gap determination.
- (e) Option 5 - Is basically the same as Option 4 except one intermediate loop is used for multi-lane 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 6'x6' 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 pavement is badly cracked or broken, the pavement should be reconstructed prior to installing sensor.

16.3.6 Junction Boxes

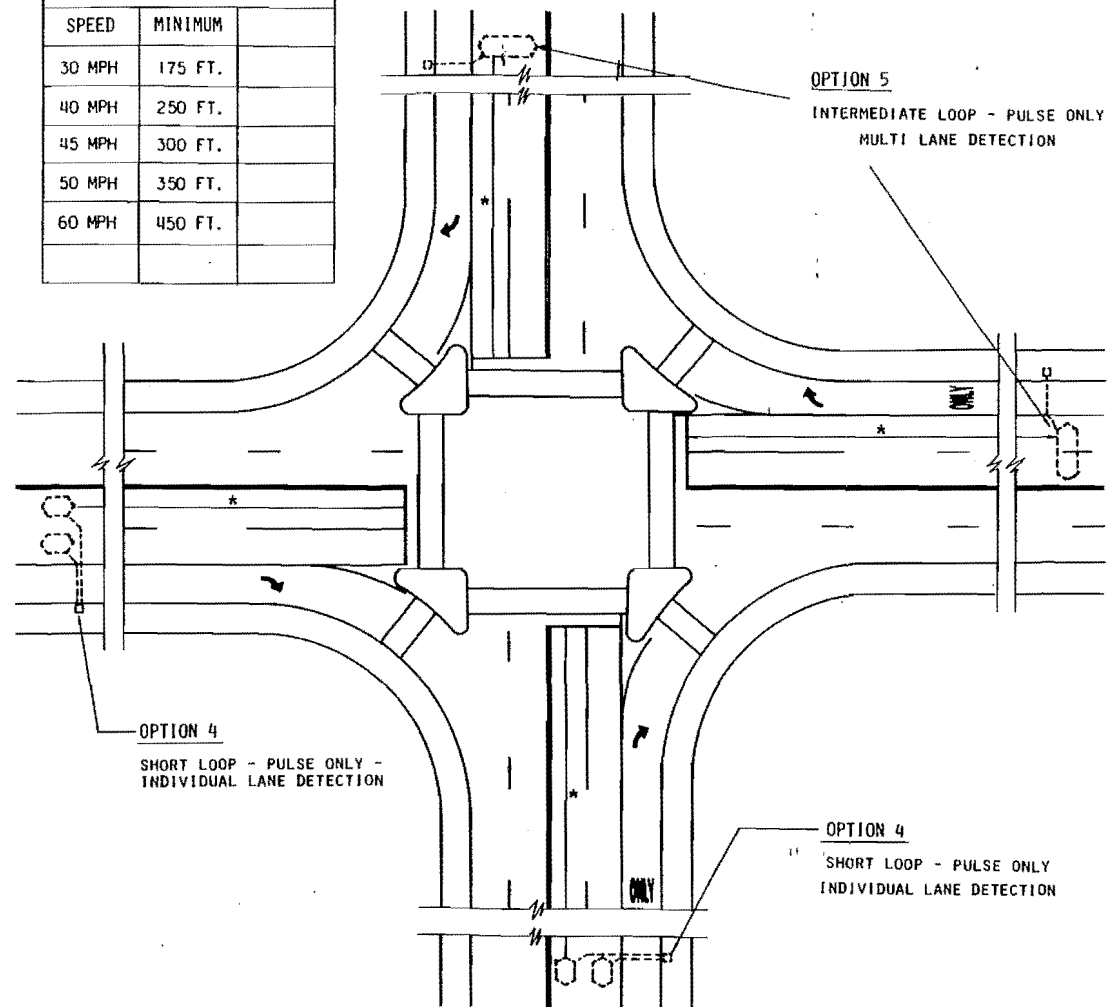
A sensor should have a junction box located in its immediate vicinity out of the roadway area. Sensors shall be provided with a length of 1 inch diameter rigid conduit from the junction box or pole base just beyond the curb or edge of roadway under the finished pavement. The conduit carries the sensor wires from the saw slot in the roadway to the junction box or pole base where the sensor wires are spliced to the lead-in wires.



* DIMENSION VARIES WITH INTERSECTION GEOMETRY & TYPE OF DETECTION

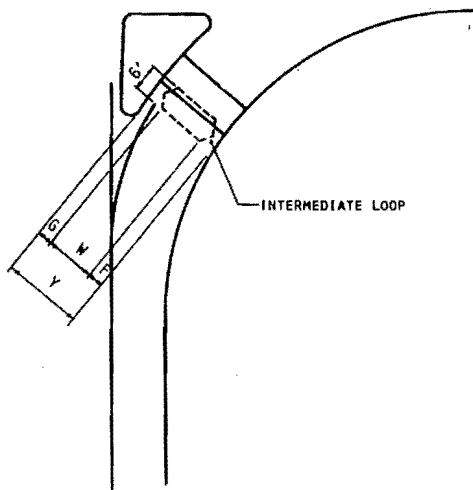
CHART - A
OPTIONS 4 & 5

DISTANCE FROM STOP LINE		
SPEED	MINIMUM	
30 MPH	175 FT.	
40 MPH	250 FT.	
45 MPH	300 FT.	
50 MPH	350 FT.	
60 MPH	450 FT.	

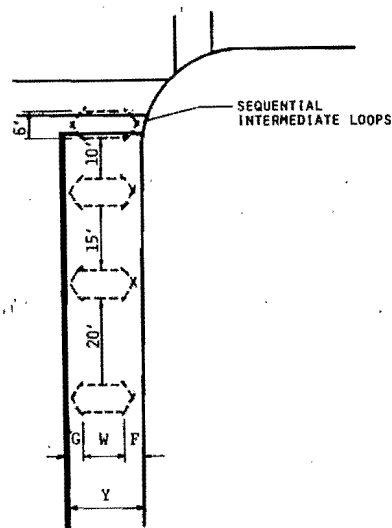


* VARIES WITH SPEED, SEE CHART A

DETECTOR OPTIONS
FOR VARIOUS TYPES OF DETECTION
FIGURE 16-1

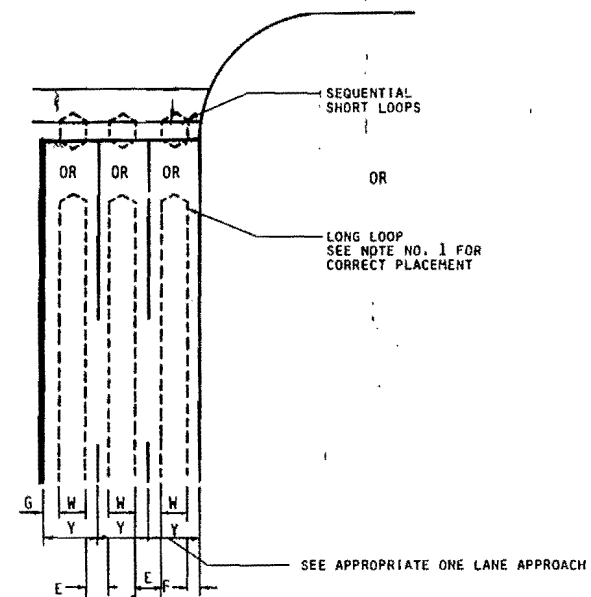


RIGHT TURN LANE/NO PARKING



ONE LANE APPROACH/NO PARKING

(SEE DISTANCES FOR RIGHT TURN LANE/NO PARKING)



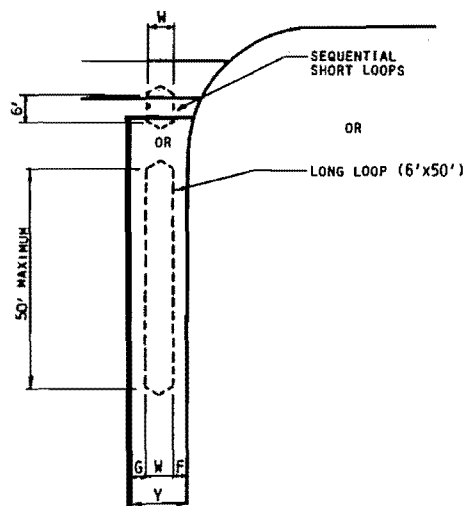
MULTI-LANE APPROACH/WITH INDIVIDUAL LANE DETECTION

Y APPROACH WIDTH	G DIST. FROM LANE LINE OR ISLAND CURB TO LOOP	W WIDTH OF LOOP	F 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'

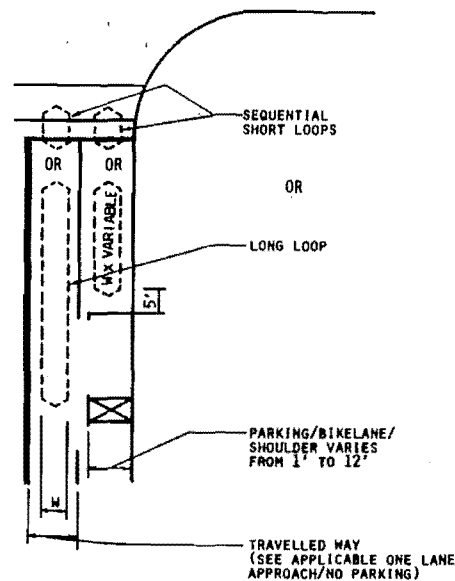
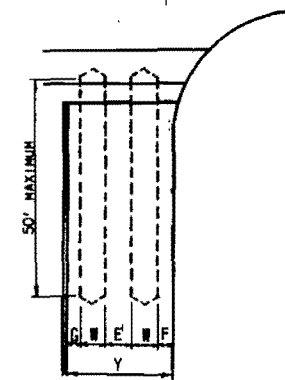
Y APPROACH WIDTH	G DIST. FROM CENTERLINE TO LOOP	E DIST. BETWEEN LOOPS	F DIST. FROM LOOP TO CURB OR EDGE OF ROAD	W WIDTH OF LOOP
10, 10, 10 = (30')	3'	5'	2'	5'
11, 11, 11 = (33')	3'	5'	2'	6'
12, 12, 12 = (36')	3'	6'	3'	6'

DETECTOR LOCATION DETAILS
FOR VARIOUS APPROACH WIDTHS

FIGURE 16-2



ONE LANE APPROACH/NO PARKING

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

ONE/TWO LANE APPROACH/ NO PARKING

Y APPROACH WIDTH	G DISTANCE FROM CENTERLINE TO LOOP	W WIDTH OF LOOP	F DISTANCE FROM CURB OR EDGE OF PAVEMENT TO LOOP
8'	2'	4'	2'
9'	3'	4'	2'
10'	3'	5'	2'
11'	3'	6'	2'
12'	3'	6'	3'
13'	3'	7'	3'

Y	G	E	W	F
18'	2'	2'	6'	2'
19'	3'	2'	6'	3'
20'	3'	3'	6'	3'
21'	3'	4'	6'	3'
22'	3'	5'	6'	3'
23'	3'	6'	6'	3'
24'	3'	6'	6'	4'
25'	3'	6'	6'	4'
26'				

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.

DETECTOR LOCATION DETAILS
FOR VARIOUS APPROACH WIDTHS

17.0 PAVEMENT MARKINGS AND SUPPLEMENTAL SIGNS

17.1 Pavement Markings

Provide pavement markings (such as center line, 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.

17.2 Signs

Provide signs (such as turn prohibition, lane control, one-way, pedestrian control and others) required to properly direct and control the flow of vehicular and pedestrian traffic through the signalized intersection. Do not include signs which are not related to the signal operation.

17.3 Illuminated Signs

Illuminated signs should be used where an engineering study shows that reflectorized signs will not give 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 traffic signal supports requires consideration of many factors, such as, curb radii, roadway cross-section, existing pole locations (lighting, utility, signs, signals), sidewalk width, pedestrian ramps, driveways, pedestrian movements, etc. The importance of the traffic signal as a control device is such that signal display effectiveness should not be compromised.

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 break-away. Moreover, 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. Traffic signal pedestals or poles yielding or break-away design may be used as supports for non-overhead signals and appurtenances. In these cases, the minimum offsets listed below shall be satisfied.

In areas with barrier curbs and speeds of 35 MPH or less, a minimum clearance of 2 feet shall be maintained between the face of curb and any part of the signal equipment or supports. Where barrier curbs do not exist or speeds are greater than 35 MPH, signal equipment shall have a minimum clearance of 2 feet from the edge of the shoulder or 10 feet from the edge of the traveled roadway. On rural highways every effort shall be made to attain the clear roadside concept where it is in effect.

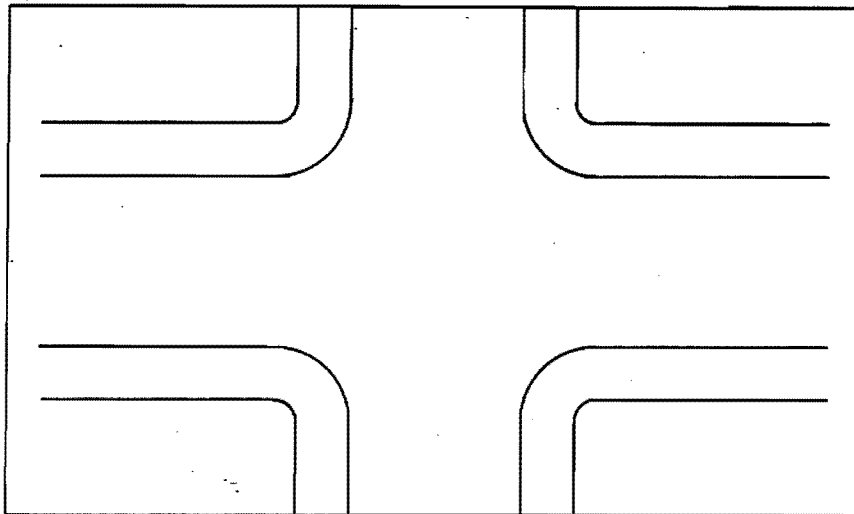
The installation of supports for overhead traffic signals in islands should be avoided. However, supports may be located in islands when necessary to maintain the effectiveness of the signal display provided the designer can obtain a set-back of 8 feet from all sides of a curbed barrier island or 14 feet set-back from all sides of an uncurbed island.

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

19.0 SIGNAL PLAN PREPARATION GUIDE

This section 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 section will provide a systematic method to be used in preparing a plan. This procedure, when used in conjunction with the information in Section 20.0, should ensure the final product is a complete and concise plan for the installation of traffic signals.

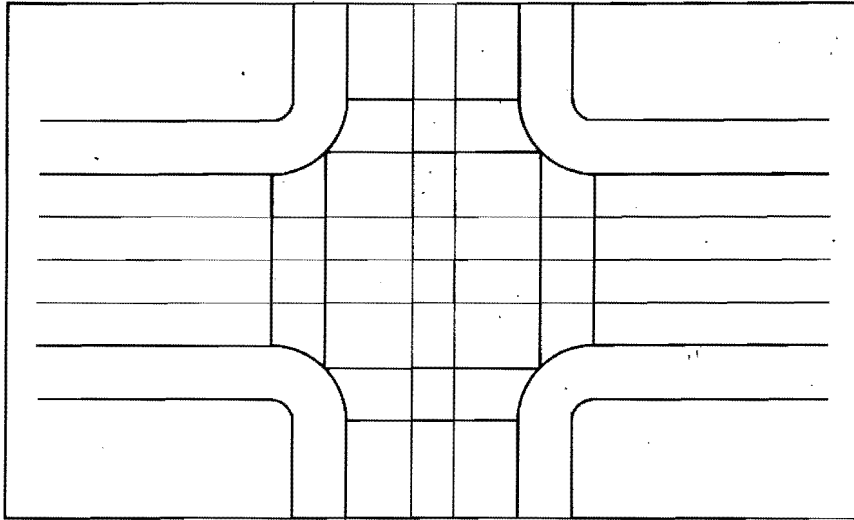
STEP 1



LAY OUT CURBING, SHOULDER AND GEOMETRICS

Show curbing, shoulders, sidewalks, islands and inlets on the base plan. If the project involves new construction, use care to ensure the geometrics match those shown on the construction plan.

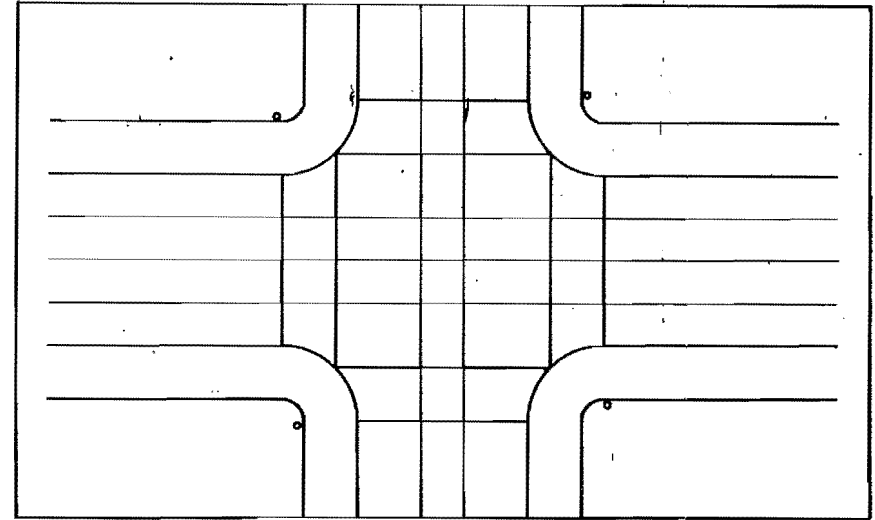
STEP 2



PAVEMENT MARKINGS

Using the results from capacity analysis, lay out the lane requirements so as to provide smooth flow through the intersection. Avoid angular changes in alignment or offsets. Provide smooth transitions for roadway width reductions or exclusive turning lanes. Draw curb ramps and crosswalks. The inside boundary of the crosswalk should be a minimum 2 feet from the adjacent travel lane. Crosswalks shall be located such that they are unobstructed by poles, signs, hydrants or other street hardware. Consult the regulations for additional details regarding the location of lane lines and crosswalks, size and type of lines and their spacing.

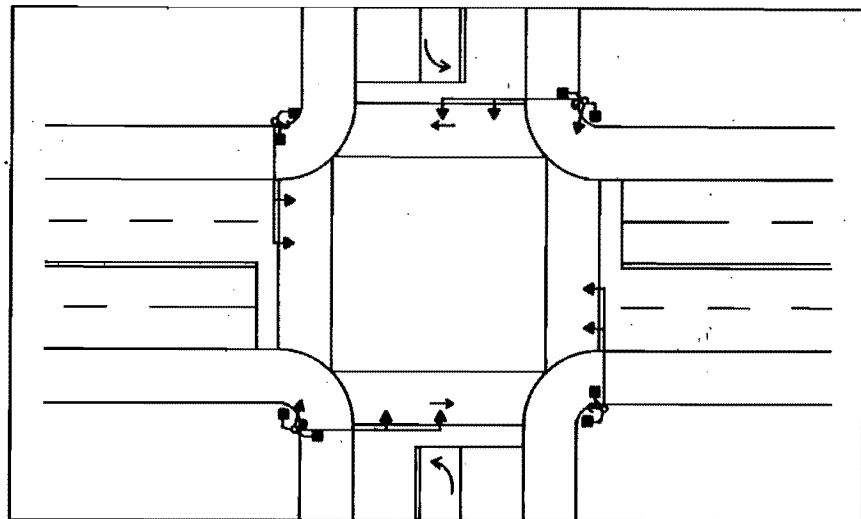
STEP 3



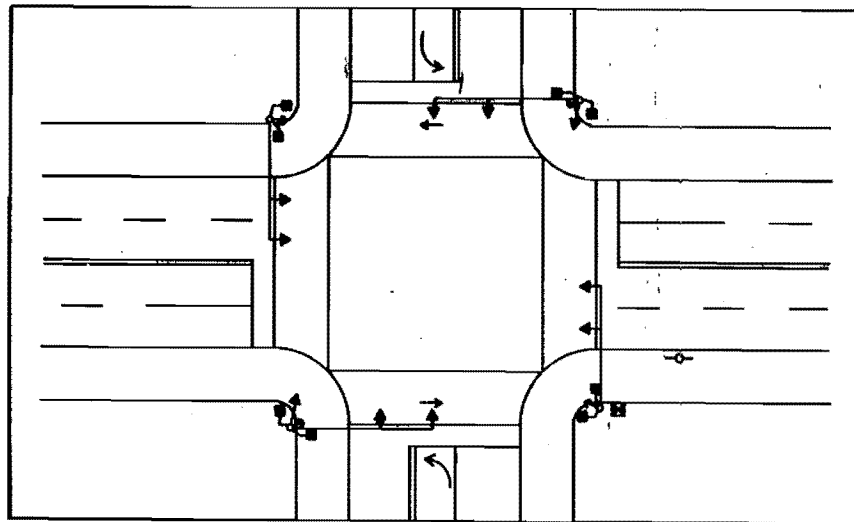
LOCATE SIGNAL SUPPORTS

Signal supports should, whenever possible, be located behind the sidewalk area to minimize the chance of knockdown and obstruction to pedestrians. Select a site that will yield optimum visibility of signals to drivers and pedestrians and is free from conflicts and underground utilities. In some cases, such as in urban areas, it may be necessary to locate the poles near the curb line (minimum offset is 2 feet). Again, conflicts with utilities should be avoided. Poles should be located along a tangent section of curb, not in the curb return, and should not be within the limits of the crosswalks. If necessary, the crosswalk location may be adjusted to simplify pole location.

STEP 4



STEP 5

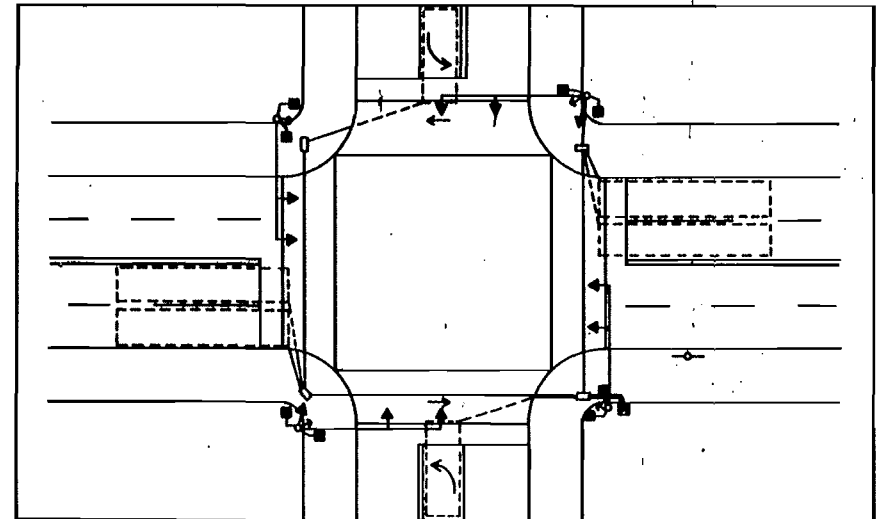
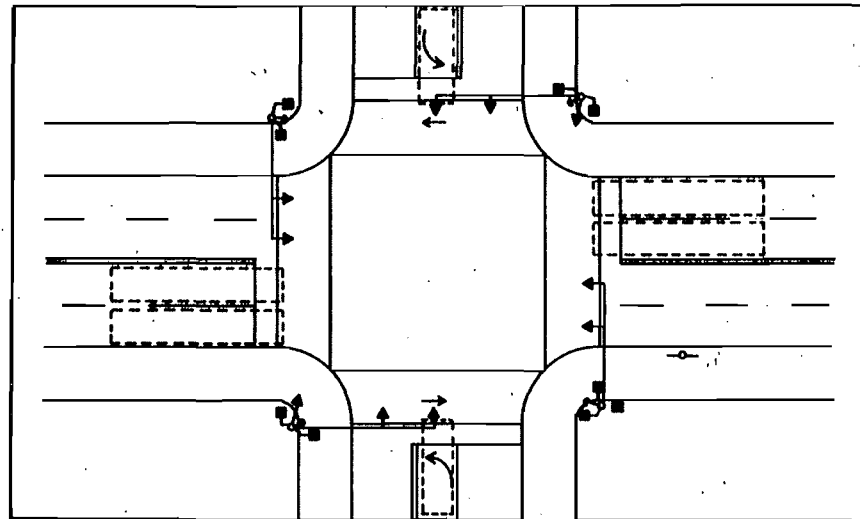


SIGNAL HEADS

Locate the required positions of traffic signals in conformance with the regulations and this manual. 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. Check for signal visibility by pedestrians as described in this Manual. If necessary, provide supplementary signals for pedestrian use or, if warranted, pedestrian signals. When the signal locations are finalized, locate the stop lines and complete the lane striping. Add pavement markings, such as arrows, where required.

LOCATE CONTROLLER

Select a location for the controller. Of prime importance is prevention of possible knockdown. Controllers should not be located near the curb return or on channelization islands. Additional considerations are the location of electrical service or communications lines and visibility of signal operations from the controller. 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 the utility to determine the pole or manhole from which electrical service may be provided and any special design standards that must be met.



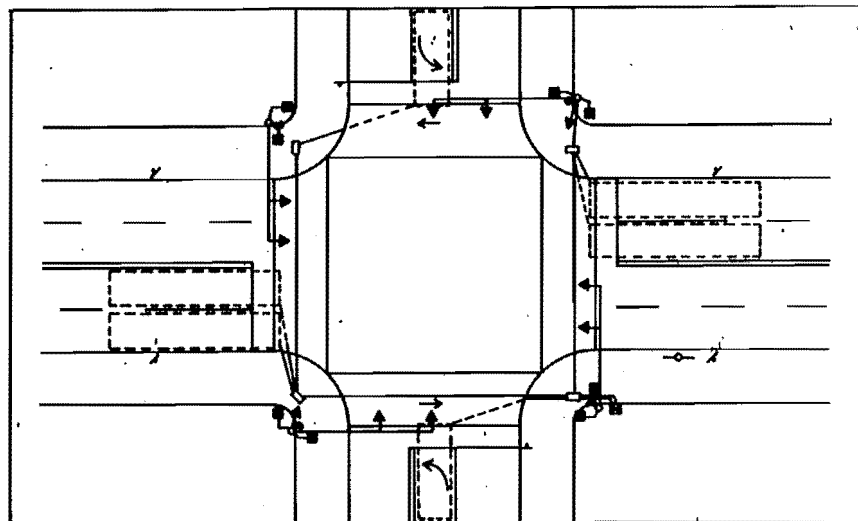
ADD DETECTORS

If the traffic signal installation under design is to be actuated, add detectors of the size and type required in conformance with the detector design criteria. For example, the detection zone should extend a minimum of three feet beyond the stop line. Loop detectors should be located a minimum of three feet 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. Man-holes or other subsurface structures which may affect the operation of the detectors must not be within the loop. A series of smaller loops may be used to avoid subsurface structures and to provide the required area of detection. Locate pedestrian push buttons such that they are easily seen by the pedestrians for which their use is intended. See the traffic signal standards for the location of push buttons and signs.

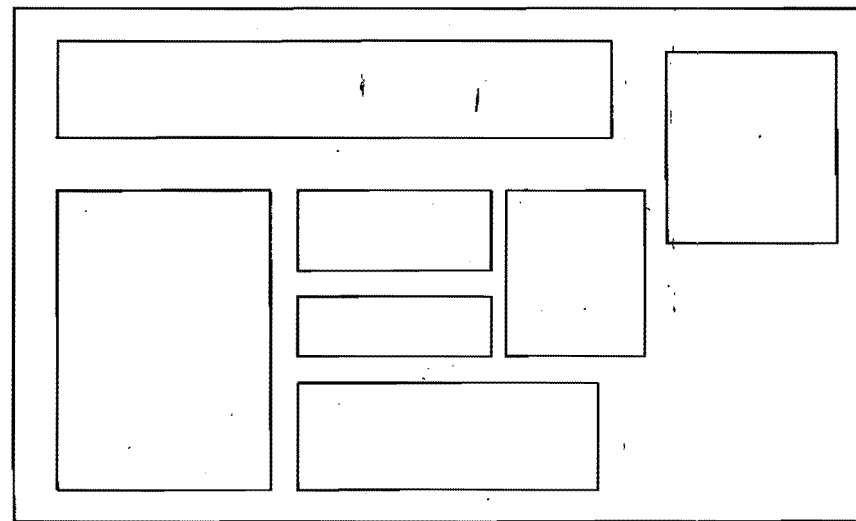
ADD THE ELECTRICAL DISTRIBUTION

Consult this Handbook for the 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 such that 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 diagram to indicate the size and number of conductors in each cable run.

STEP 8



STEP 9



SIGNING AND DETAILING

Add any regulatory and warning signs necessary to complete the design. The signs used must be designed and located in conformance with the regulations. Complete the design sheet by adding items such as dimensions, labeling of signal heads, poles, detectors, paint lines, etc. Add the phasing and timing of signal operation as determined from capacity analysis or other sources. 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.

TABULATION SHEET

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

20.0 PLAN FORMAT CHECKLIST

The following checklist is to be used with the sample plans to prepare a permit plan sheet or the construction plans.

20.1 Plan Sheet

The information listed below is to be provided on both the Permit Plan and the Construction Sheets unless indicated otherwise.

20.1.1 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 number (Ch. 211) and actual legend
 - ☐ Size by width and height

20.1.2 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.
- ☐ Pictorial representation of movements for respective phase including pedestrian movements.
- ☐ Beginning with 1, horizontally list the interval numbers for the cycle.
- ☐ Vertically list the signal numbers as shown on the plans.
- ☐ For each interval indicate type of operation by indicating:

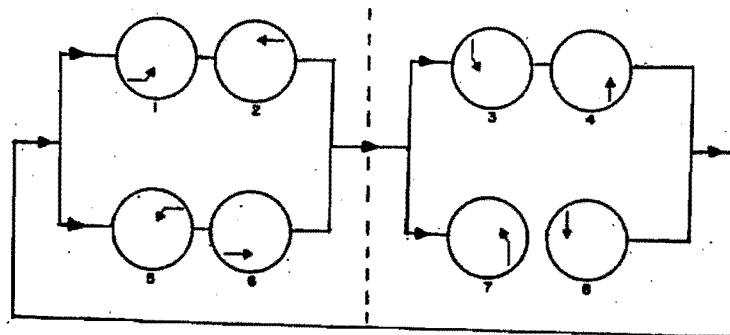
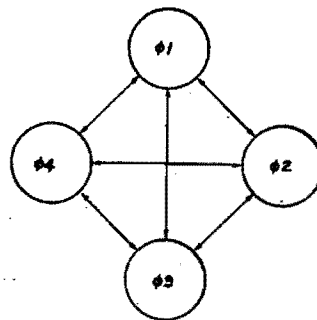
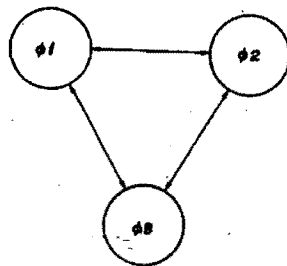
G	for	Green
R	for	Red
Y	for	Yellow
W	for	Walk
DW	for	Don't Walk

FD	for	Flashing Don't Walk
◀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 Fig. 3, Appendix A.
- ☐ On right of chart shown 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 preemption needed, add required phases and appropriate notes.

20.1.3 Phasing Diagram (Required only when sequencing is unusual or needs clarification)

- ☐ Locate at bottom of plan next to phasing chart.
- ☐ 0 symbol for phase
- ☐ ← Indicate sequence of controller with arrows
- ☐ --- Symbol for phase sequence barrier.
- ☐ Number of various phases, using numbers 1, 2, 3 etc. which is the NEMA standard, letters (A, B, C) are not to be used.



20.1.4 Signal Identification

- ☐ Located at bottom middle of plan.

(a) 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.

8 inch signal
12 inch signal

(b) Pedestrian Signals

- ☐ Diagram of signal faces.
- ☐ Show signal numbers as they appear on the plans.
- ☐ Indicate the messages and its location.

Don't
Walk

Walk

- ☐ Indicate size of message.

20.1.5 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.
(See Sample Plan)

20.1.6 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:

☐ Reviewed _____
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"=20' or 1"=25'

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

20.1.7 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.

20.1.8 Signal Wiring Diagram (Construction Plan)

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

20.1.9 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.

20.1.10 Intersection

☐ Located in center of sheet using scale of 1" = 20' or 1" = 25'.

☐ 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 Highway Design Manual

☐ 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

20.2 Tabulation Sheet

Prepare the following tabulations only for Construction Plans.

20.2.1 Traffic Signal Supports

- ☐ Location
- ☐ Mast Arms
- ☐ Strain Poles
- ☐ Sign and Signal Locations
- ☐ Item Numbers

20.2.2 Electrical and Conduit Items

- ☐ Location
- ☐ Conduit
- ☐ Trench
- ☐ Signal Cable
- ☐ Junction Box
- ☐ Electrical Service
- ☐ Detector Items
- ☐ Item Number

20.2.3 Detectors

- ☐ Amplifier
 - ☐ Description
 - ☐ Quantity
 - ☐ Location
 - ☐ Operation
 - ☐ Item Number
- ☐ Sensors
 - ☐ Description
 - ☐ Quantity

- ☐ Size
- ☐ Location
- ☐ Item Numbers

20.2.4 Miscellaneous

- ☐ Item Numbers
- ☐ Controller Assembly
- ☐ Vehicle Signal Head
- ☐ Pedestrian Signal Head
- ☐ Systems
- ☐ Communications

20.2.5 Pavement Markings

- ☐ Item Numbers
- ☐ Quantity
- ☐ Description

20.2.6 Signs

- ☐ Description
- ☐ Size
- ☐ Square Feet
- ☐ Item Numbers
 - ☐ Type B
 - ☐ Type F
 - ☐ Structure Mounted

21.0 PERMITS

Local authorities shall obtain approval from the Department prior to modifying or erecting any traffic signal except as follows;

- (a) In a municipality with a traffic engineer qualified in accordance with Department Regulations (On local streets only). =
- (b) In first and second class cities as outlined in Chapter 201 - Engineering and Traffic Studies, Section 201.4.

22.0 DEFINITIONS

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

Actuated: Identifies type of control which responds to calling signals generated by action of vehicle or pedestrian.

Actuation: The operation of any type of detector.

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

Amplifier: An electrical device, employing solid state components in any oscillator, amplifier, phase detector, memory, decision circuits, and other configurations to sense electrical load changes on an associated sensing element.

Analog Timing: Pertaining to a method of timing that measures continuous variables, such as voltage or current.

Artery: An Arterial or Main Street generally considered to be a thoroughfare with preferential right-of-way.

Auto-Manual Switch: A device which, when operated, discontinues normal signal operation and permits manual operation.

Automatic Time Switch: An electrically operated device for automatic control of the operation of traffic-control signals in any manner prescribed by a predetermined time schedule.

Auxiliary Equipment: Separate devices used to add supplementary features to a controller assembly.

Back Plates: A strip of thin material extending outward parallel to the signal face on all sides of a signal housing to provide a suitable background for the signal indications.

Background Cycle: Term used in coordination systems to identify the cycle length established by coordination unit and master control; takes precedence over intersection control cycle.

Balance Adjuster: A device used in span-wire-mount applications to permit alignment of the point of suspension with respect to the center of gravity of the signal head so that the signal will hang vertically.

Bracket Mount (Side Mount): A signal mounting arrangement where the signal head is mounted approximately parallel to the vertical axis of the pole.

Bus Priority: Cycle by cycle timing of a traffic signal so that beginning and end times of green may be shifted to minimize delay to approaching buses. The normal sequence of signal displays is usually maintained.

Cabinet: An outdoor enclosure for housing the controller unit and associated equipment.

Cable: A group of separately insulated wires wrapped together.

Cable Entrance Adapter: A mounting bracket of tubular construction which is used between the span wire hanger and the signal brackets to provide for passing control cable into the signal head.

Call: A demand for service registered in a controller assembly.

Calling Detector: A detector installed in a selected location to detect vehicles that may not otherwise be detected, and whose output may be modified by the controller unit.

Camshaft: A device to operate the circuit contacts to provide the desired interval sequence.

Center of Approach: The middle of the remaining traffic lanes minus any exclusive turn or parking lanes.

Center Line: A line indicating the division of the roadway between traffic traveling in opposite directions.

Clearance Interval(s): The interval(s) from the end of the right of way of one phase to the beginning of a conflicting phase.

Clock: An accurate timepiece with one or more electrical outputs for function control.

Communication System: The composite of communication links and associated communications equipment which interconnect all the control and surveillance components of a traffic control system.

Conditioned Line: A communications cable specially compensated to provide improved transmission characteristics.

Conflict Monitor: A device used to continually check for the presence of conflicting signal indications and to provide an output of response to the conflict.

Conflicting Phases: Two or more traffic phases which will cause interfering traffic movements if operated concurrently.

Controller Assembly: A complete electrical mechanism mounted in a cabinet for controlling the operation of a traffic control signal.

Controller Interface Unit: The piece of equipment inserted between the local intersection communication terminal and the intersection controller to translate the instructions from the computer into commands that are recognized and responded to by the controller.

Controller Memory: The retention of an actuation for future utilization by the controller unit.

Controller Unit (Timer): That part of the controller assembly which performs the basic timing and logic functions.

Coordination: The establishment of a definite timing relationship between adjacent controller units.

Coordinator: A device used to relate the timing of one controller unit to others.

Critical Intersection Control (CIC): An algorithm employed to dynamically control the split at signalized locations where heavily traveled streets intersect and where the traffic patterns are such that special control, responsive to changing conditions, is needed. Control strategies for such intersections require input from detectors on each approach so that the split may be varied cycle to cycle.

Critical Lane Detection: A system or hardware and software designed to provide data on traffic flow for a selected lane, usually the heaviest volume lane of an approach to a signalized intersection.

Cycle: The total time required to complete one sequence of signalization at an intersection.

Decoder: A device used in a coordination communication system to interpret signal inputs into specific selections or actions at the receiving point (intersection).

Delayed Output: The ability of a detector to delay its output for a predetermined length of time during an extended actuation.

Density: A measure of the concentration of vehicles, stated as the number of vehicles per mile. $\text{Density} = \text{Volume} \div \text{speed}$.

Detector: A device for indicating the presence of vehicles or pedestrians desiring the right-of-way. Includes the amplifier, sensor and other related devices.

Detector Amplifier: A device capable of intensifying the electrical energy produced by a sensor.

Detector Mode: A term used to describe the duration of detector output when a detection occurs.

- a. Pulse - The ability of a detector to produce a pulse that has a predetermined duration regardless of the length of time a vehicle is in the field of influence.
- b. Controlled Output - The ability of a detector to produce a pulse that has a predetermined duration regardless of the length of time a vehicle is in the field of influence.
- c. Presence - Detector output continues if any vehicle (first or last remaining) remains in the field of influence.
- d. Limited-Presence Detector output continues for a limited period of time if vehicles remain in field of influence.

Detection Zone (Sensing Zone): That area of the roadway within which a vehicle will be detected by a vehicle detector.

Dial Disconnect: The process of interrupting the connection between the dial pulsing circuit and the signal cam shaft rotational device in some types of intersection controllers.

Dial Supervision: The technique for allowing the dial to dwell for an adjustable period of time in one or more of the phases comprising the cycle. This permits the computer to independently extend the duration of each phase beyond its preset minimum.

Digital Controller Unit: A controller unit employing digital timing techniques.

Digital Timing: Pertaining to a method of timing that operates by counting discrete units.

Directional Detector: A detector capable of being actuated only by vehicles proceeding in one specified direction.

Disconnect Hanger (Jack Box): A mounting device for span wire or mast arm mount that contains a terminal block for a plug and socket and a means of readily attaching or detaching the signal head to and from the hanger.

Double Dial Timer: A timer equipped with two timing dials, mechanically or electrically inter-related so that it is possible to set up and select, manually or remotely, either of two timing programs.

Dual-Ring Controller Unit: A controller unit containing two interlocked rings which are arranged to time in a preferred sequence and to allow concurrent timing of both rings, subject to the restraint of the Barrier (Compatibility Line).

Dummy Interval: A redundant interval in the cam switching mechanism incorporated so as to allow the total number of intervals in the cycle to correspond integrally with the total number of intervals provided on the cam switching mechanism.

Duplex: Two-way communication on a single communication link. (See Half Duplex, Full Duplex).

Electromechanical Device: A device which is characterized by electrical circuits utilizing relays, step switches, motors, etc.

Electronic Circuitry: Circuitry involving non-mechanical devices, i.e., vacuum tubes, resistors, condensers, inductors, etc. A condenser charging through a resistor, as contrasted to a mechanical timing circuit which may involve a motor or clock-like device.

Emergency Vehicle Preemption: The transfer of the normal control of signals to a special signal control mode for emergency vehicles.

Encoder:

- 1) A device which converts data into a form for transmission over the communication link between two points in a system.
- 2) A circuit to transform data from one form to another; i.e., convert discrete decimal characters into binary characters.

- 3) A system which converts signals which have been fed into it individually into combinations of outputs.

Extensible Portion: That portion of the green interval following the initial portion.

Extension Detector: A detector arranged to register actuations at the controller only during the green interval for that approach so as to extend the green time for the actuating vehicles.

Extension Limit: The maximum time of the extensible portion for which actuations of any traffic phase may retain the right of way after actuation on an opposing traffic phase.

Extension Unit: The timing interval during the extensible portion which is resettable by each detector actuation. The green right-of-way of the phase may terminate on expiration of the unit extension time.

Field Terminals: Devices for connecting wires entering the controller assembly.

Fixed Initial Portion: A preset initial portion that does not change.

Flasher: A device used to open and close signal circuits at a repetitive rate.

Flasher Controller Assembly: A complete electrical mechanism for operating a hazard identification beacon or intersection control beacon.

Flasher Switch: A switch located inside the control cabinet or on the police panel which, when operated, discontinues normal signal operation and causes the flashing of a pre-determined combination of signal indications.

Force Off: A command that will force the termination of the right-of-way.

Frequency Division Multiplexing (FDM): Involves the use of different frequencies (tones) to represent different message channels. For example, on a typical telephone communication link of voice grade quality (Series 3000), up to 16 different message channels can be transmitted. Each channel can also be multiplexed further by Time Division Multiplexing.

Frequency Shift Keying (FSK): A form of digital frequency modulation employing discrete frequencies for specific signals, e.g. marking signals. The transmitter is changed from one frequency to another, i.e., keyed to represent a different information character.

Full Duplex: A communication facility providing simultaneous transmission and reception.

Full Traffic Actuated Controller Assembly: A type of traffic-actuated controller assembly in which means are provided for traffic actuation on all approaches to the intersection.

Gap Reduction: A feature whereby the "unit extension" or allowed time spacing between successive vehicle actuations on the phase displaying the green in the extensible portion of the interval is reduced.

Hold-On Line Signal: A signal to intersection controller commanding it to remain under computer control.

Hold Signal: A signal to intersection controller commanding it to retain the specified phase even in the presence of conflicting demands.

Inboard Signal: The mast arm mounted signal nearest to the signal post or mounted on the signal post.

Infra-Red Detector: A detector that senses radiation in the infra-red spectrum.

Initial Green Portion: The first part of the green interval which is timed out or separately controlled by a traffic-actuated controller before the extendible portion of the interval takes effect.

Interconnect: The communication network usually consisting of electrical cable connecting the system master with local control stations; e.g. intersection controllers.

Interface: A common boundary at which two separate systems or portions of each join or interact. An interface can be mechanical, as in adjoining hardware surfaces, or it can be electrical, as in signal level transformation points. Moreover, it can also refer to human and machine interface and the interaction between man and computer.

Interval: That part of the signal cycle during which signal indications do not change.

Interval Sequence: The order of appearance of signal indications during successive intervals of a cycle.

Interval Timing: The passage of time which occurs during an interval.

Isolated Controller Assembly: A controller assembly for operating traffic signals not under master supervision.

Jack Mounted Relay: A relay which may be removed or replaced without the use of tools and without disturbing any wiring.

Lamp: That part of the optical unit which, when energized, electrically provides the optical unit light source.

Lane Line: A line separating two lanes of traffic traveling in the same direction.

Lane-Use Control Signal: A highway traffic signal which is erected to control the direction of vehicular traffic movement in an individual lane.

Lens: That part of the optical unit through which light from the light source and reflector passes and, in so doing, is redirected into a prescribed pattern and is filtered to a prescribed color.

Light-Sensitive Detector: A detector utilizing a light-sensitive device for sensing the passage of an object interrupting a beam of light directed at the sensor.

Limited-Presence Mode: Detector output continues for a limited period of time if vehicles remain in field of influence.

Local Offset Unit, Coordination Unit or Local Supervisory Mechanism: An auxiliary synchronous device applied to a non-synchronous controller to keep in step with a control frequency, which may be the a.c. power frequency. May have multi-offset capabilities.

Locking Memory: An operational mode of an actuated controller which requires detector memory.

Loop Detector: A detector that senses a change in inductance of its inductive loop sensor caused by the passage or presence of a vehicle near the sensor.

Magnetic Detector: A detector that senses changes in the earth's magnetic field caused by the movement of a vehicle near its sensor.

Magnetometer Detector: A detector that measures the difference in the level of the earth's magnetic forces caused by the passage or presence of a vehicle near its sensor.

Major Street: At an intersection, the roadway approach or approaches normally carrying the major volume of vehicular traffic.

Manual Operation: The operation of a controller assembly by means of a hand-operated device(s) (i.e., pushbutton).

Manual Switch: A switch, generally located on the panel board or on the police panel of a traffic controller, which, when moved to its manual position, permits the controller to be operated by a hand-operated switch or push button. Moving this switch to the manual position normally prevents normal controller operation by the timing mechanism.

Mast Arm Mount: A signal head mounting supported from a rigid arm extended over the roadway for the purpose of supporting the signal head.

Master Controller Assembly: A controller assembly for supervising a system of secondary controllers.

Master-Secondary Controller Assembly: A controller assembly operating traffic signals and providing supervision of other secondary controllers.

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 Portion: The limit of the added initial portion.

Microprocessor: A device which uses the flexibility of computer electronics on a limited scale. Microprocessors are basically microminaturized CPU's.

Minimum Gap: The minimum to which the time between vehicles on a phase with right-of-way can be reduced because of vehicles waiting on another phase.

Minimum Green Interval: The shortest green time of a phase. If a time setting control is designated as "minimum green," the green time shall be not less than that setting.

Minimum Period: In semi-traffic actuated controllers, the shortest time for which the right-of-way shall be given to the approaches not having detectors.

Minor Movement Timer: A device that can be added to a controller assembly to provide additional actuated intervals.

Minor Street: The roadway approach or approaches at an intersection normally carrying the minor volume of vehicular traffic.

Mode: 1. In detection, refers to the pulse width generated by a vehicle actuation.

2. Also used to identify certain logic conditions in control that permit predetermined operation.

Modular Design: A design concept such that functions are sectioned into plug-in units which can be readily exchanged with similar units.

Mounting Brackets: A grouping of parts used to fix a signal head in the operating position.

Movement: The term used to identify the direction of travel and the approach of a vehicle at an intersection. (See Phase).

Multiplexing: A communications technique in which a single channel of communication is subdivided into independent frequency bands (FDM) or into time slots (TDM) which allows more than one item of information to be transmitted or received at essentially the same time. This technique is employed when more economical than establishing duplicate channels.

Nonconflicting Phases: Two or more traffic phases which will not cause interfering traffic movements if operated concurrently.

Nondirectional Detector: A detector capable of being actuated by vehicles proceeding in any direction.

Nonlocking Memory: An operational mode of actuated controller which does not require detector memory.

Non Actuated: Refers to a control type generally in the pretimed category, but can be one phase in any control which does not employ a vehicle call.

Offset: Offset is the time relationship, expressed in seconds or percent of cycle length, determined by the difference between a defined interval portion of the coordinated phase green and a system reference point.

Offset Dial: A calibrated dial by which it is possible to set any desired offset of the major phase signal indication.

Offset Selection: Choosing one of several possible offsets manually or automatically either by time-of-day or in response to some directional characteristic of traffic flow.

Operating Speed: The highest overall speed, exclusive of stops, at which a driver can travel on a given highway under prevailing conditions, without at any time exceeding the design speed.

Operational Delay: This is delay caused by interference between components of traffic, that is, the delay due to influences of other traffic. One type of operational delay is caused by other traffic movements that interfere with the stream flow (side frictions). This includes parking or unparking vehicles, pedestrians, stalled vehicles, double parking, and cross traffic. A second type of operational delay is caused by interferences within the traffic stream (internal frictions), this includes congestion due to high volumes, lack of roadway capacity, and merging or weaving maneuvers.

Optical Unit: An assembly of a lens, reflector, light source, and other components, if required, with the necessary supporting parts to be used for providing a signal indication.

Outboard Signal: The signal head mounted nearest to the end of the mast arm.

Overlap: A right-of-way indication that allows traffic movement when the right-of-way is being assigned to two or more traffic phases.

Passage Detection: The ability of a vehicle detector to detect the passage of a vehicle moving through the detection zone and to ignore the presence of a vehicle stopped within the detection zone.

Passage Period: The time allowed for a vehicle to travel at a selected speed from the detector to the nearest point of conflicting traffic.

Pavement Markings: Markings set into the surface of, applied upon, or attached to the pavement.

Peak-Hour Traffic: The highest number of vehicles found to be passing over the section of a lane or a roadway during 60 consecutive minutes. This term may be applied to a daily peak hour or a yearly peak hour.

Pedestrian: Any person afoot.

Pedestrian-Actuated Controller Assembly: A controller assembly in which intervals, such as pedestrian WALK and clearance intervals, can be added to or included in the controller cycle by the actuation of a pedestrian detector.

Pedestrian Clearance Interval: The first clearance interval following the pedestrian walk indication, normally flashing "Don't Walk."

Pedestrian Detector: A detector capable of sensing manual operation by a pedestrian.

Pedestrian Indication: A vehicular or pedestrian signal which is erected for the exclusive purpose of directing pedestrian traffic at signalized locations.

Pedestrian Phase: A traffic phase allocated to pedestrian traffic.

Pedestrian Signal: A pedestrian signal lens or an equivalent device.

Permissive Period: Relates to selected periods during coordinated operation in which a call from the opposing phase can be acknowledged.

Phase: A part of the traffic signal time cycle allocated to any combination of traffic movements receiving right-of-way simultaneously during one or more intervals.

Phase Green Control: A scheme for controlling an intersection controller whereby a control circuit causes the controller to dwell in Phase Green Intervals until released by the Master Control Unit. Minimum green times and all fixed intervals are timed by the local controller; offset, split and cycle length are controlled by the Master Controller.

Phase Modular Controller: A controller constructed so that each timing module is associated with only one independent phase. The addition or removal of modules associated with one phase will not affect the operation of the controller with respect to the other phases.

Phase Omit (Special Skip, Force Skip): A command that causes omission of a selected phase.

Phase Sequence: A predetermined order in which the phases of a cycle occur.

Phase Shift Keying (PSK): A modulation method employed to transmit data. The technique of differentially coherent phase modulation is generally used as it eliminates the difficulty of deriving a reference phase. In such a system, each signal element is stored one element at a time and the phase change between successive elements provides system coherence and the desired reference.

Phase Overlap: Refers to a phase which operates concurrently with one or more other phases.

Point Detection: The detection of a vehicle as it passes a point or spot on a street or highway.

Portion: A discrete subdivision of an interval during which the signals do not change.

Post Mounted Signals: Any signal head mounted directly to or on top of the signal post.

Power Failure Feature and Indicator: A relay mechanism which operates in case of power failure and, upon restoration of power, causes the illumination of a power failure indicator. The indicator can be a pilot lamp mounted on or in the controller cabinet which, when illuminated, indicates that power has been off and that the controller requires manual in-time resetting.

Preemption: The transfer of the normal control of signals to a special signal control mode.

Presence Detection: The ability of a vehicle detector to sense that a vehicle has appeared in its field whether moving or stopped.

Pressure-Sensitive Detector: A detector capable of sensing the pressure of a vehicle passing over the surface of its sensor.

Pretimed Controller Assembly: A controller assembly for operating traffic signals in accordance with a predetermined fixed-time cycle.

Probe: The sensor form commonly used with a magnetometer-type detector.

Programmable Read Only Memory (Prom): A device that stores data which cannot be altered by computer instructions. Data is stored ("burned") into this device externally by an electronic process. Some PROM's can be erased and programmed through special physical processes.

Progression: Refers to coordination method based upon offsets between intersections along an artery.

Pulse Detection: Detector produces a short output pulse when detection occurs.

Radar Detector: A detector capable of sensing the passage of a vehicle through its field of emitted microwave energy.

Radio Interference Suppressor: A device inserted in the power line in the controller assembly (cabinet) that minimizes the radio interference transmitted back into the power supply line, which interference may be generated by the controller or other mechanisms in the cabinet.

Read Only Memory -- ROM: A storage device not alterable by computer instructions, e.g., magnetic core storage with a lockout feature or punched paper tape. ROM requires a masking operation during production to permanently record programs or data patterns in it. Synonymous with nonerasable storage, permanent storage and read-only storage.

Recall: An operational mode of an actuated controller whereby a phase, either vehicle or pedestrian, is displayed each cycle whether demand exists or not. (Minimum, Maximum, Pedestrian).

Recall Switch: A manual switch which causes the automatic return of the right of way to its associated phase.

Red Clearance Interval: A clearance interval which may follow the yellow change interval during which both the terminating phase and the next right of way phase display red.

Reflector: A contoured reflective surface which re-directs the light from the light source toward the lens.

Relay: An electromagnetic switching device, having multiple electrical contacts, energized by electrical current through its coil. It is used to switch other electrically independent circuits.

Reset: An adjustment mechanism applied to a dial type traffic-signal controller to cause the dial units at different locations to establish its synchronous operation, i.e., for all the dials to have a pre-determined fixed relation to one another so that the offset at each controller can be established and maintained.

Reset Interrupter: A device which will automatically distribute the time lag resulting from resetting of dial type fixed-time controllers over a period of time varying from one to several cycle lengths.

Responsive Mode: A system operation wherein the selection of signal timing programs is based on current traffic data as input by vehicle sensors within the network.

Rest: The state in which a controller unit rests until called out of that phase.

Rigid Mast Arm Signal: A mast arm mount where the signal head is rigidly affixed to the mast arm to prevent any relative movement between the signal and the arm.

Sampling Detector: Any type of vehicle detector used to obtain representative traffic flow information.

Secondary or Local Controller: A controller for operating the traffic-control signals at an intersection. Such a controller may or may not be under the supervision of a master controller.

Semi-Traffic Actuated Controller Assembly: A type of traffic-actuated controller assembly in which means are provided for traffic actuation on one or more but not all approaches to the intersection.

Sensor: The sensing element of a detector.

Sequence: The order in which signal intervals are displayed around an intersection on a pretimed control or with calls all around on an actuated control.

Side Fire Detector: A vehicle detector with its sensor located to one side of the roadway.

Signal Circuit Contact: A device arranged to energize or de-energize signal light circuits during a specified interval.

Signal Face: A combination of sections each capable of displaying its indication in one direction.

Signal Head: An assembly containing one or more signal faces.

Signal Indication: The illumination of a traffic-signal lens or equivalent device or a combination of several lenses or equivalent devices at the same time.

Signal Installation: All of the equipment and material involved in the control of traffic at one intersection by a traffic control signal.

Signal Lens: That part of the optical unit through which light from the light source and reflector passes and, in so doing, is redirected into a prescribed pattern and is filtered to a prescribed color.

Signal Network: Any two or more intersecting signal systems employing the same cycle length. The basic requirement for coordinating signal systems is that a common cycle must be employed.

Signal Section: The optical unit and housing capable of displaying one indication.

Signal Shut-Down Switch: A manual switch to discontinue the operation of traffic control signals without affecting the power supply to other components in the controller cabinet.

Signal System: Two or more signal installations operating in coordination.

Single-Ring Controller Unit: A controller unit containing two or more sequentially timed and individually selected conflicting phases so arranged as to occur in an established order.

Skip Phasing: The ability of a controller to omit a phase from its cycle of operation in the absence of demand or as directed by a master control.

Slave: A local control device whose interval timing and sequence of operation is controlled by a submaster in a distributed system.

Socket: That part of the optical unit which supports the lamp and is so arranged as to fix the position of the light source with reference to the focal point of the reflector.

Solid-State Circuitry: Solid-state circuitry is electronic circuitry in which the active elements are transistors instead of vacuum or gaseous tubes. Solid-state power control involves the use of Silicon Controlled Rectifier switches or Triacs instead of power relays. Devices specified as solid-state contain no electromechanical moving parts of any sort and likewise contain no hot or cold cathode types of tubes.

Solid-State Device: A device characterized by electrical circuits the active components of which are semiconductors to the exclusion of electro-mechanical devices or vacuum tubes.

Span Wire Hanger (Span Wire Clamp): A mounting bracket for supporting a signal head by clamping onto a span wire.

Span Wire Signal: A signal head suspended over the roadway on cable.

Split: A division of the cycle length allocated to each of the various phases (normally expressed in percent).

Split Selection: The process by which a split is selected or calculated by the computer based on a measurement and comparison of directional demand as detected by system sensors or predetermined by time of day clock.

Stop Line: A line which indicates where vehicles should stop when directed by a traffic officer or traffic control device.

Submaster: A control unit capable of supervising a group of local control units (slaves) according to commands from the central computer master. Submasters are normally employed in distributed systems.

Sonic Detector: A vehicle detector which emits sound type energy from a transducer at a higher frequency than can be detected by the normal human ear (above 19KH), and is capable of sensing reflection of this energy off of a vehicle in its field.

Synchronous Controller Unit: A controller unit in which the timing mechanism is controlled by and dependent on a suitable frequency standard such as the frequency of the primary alternating-current power.

Through Band Or Green Band: The time in seconds elapsed between the passing of the first and last possible vehicle in a group of vehicles moving in accordance with the designed speed of a progressive traffic-control system.

Timer: The timing unit in a controller. In a fixed-time controller, the timer generally includes dials, flashing mechanism, motors, gears, cam-shaft, etc. In an actuated controller, timer is normally meant as the unit performing the timing function, but not the light relays, SCR's external flasher, etc.

Time Clock: A device for the automatic selection of modes of operation of traffic signals in a manner prescribed by a predetermined time schedule.

Time Division Multiplexing-TDM: A technique for transmitting several different messages over one communication channel by dividing a fixed interval of time into several time slots in which a discrete message is sent in each time slot.

Time Reference Point: In the signal system for any one street, the time-space diagram is normally expressed in terms of the offset between each signal in the system, and one particular signal which services as the time reference signal. The start of green of the time reference signal on this street is defined as the time reference point.

Timing Dial: A calibrated dial or similar mechanism on a timer equipped with adjusting devices by which it is possible to divide the time cycle into the required number of intervals and set up the offset and interlock.

Tone: An audio frequency signal.

Traffic Actuated Controller Assembly: A controller assembly for supervising the operation of traffic control signals in accordance with the varying demands of traffic as registered with the controller by detectors.

Traffic Adjusted Controller: A local intersection controller whose cycle length is directly under the control of a cycle generator at the master controller, and whose offset and split are also controlled by the master controller.

Traffic Adjusted System: A system in which an analog computer controls cycle length at special local controllers. Changes are based on threshold levels as sensed by vehicle controller.

Traffic Signal Pedestal (Post): A vertical support on top of which the signal or controller is mounted.

Traffic Signal Span Structure: The structural member suspended between two or more supports.

Traffic Signal Support: The physical means whereby a signal head is supported in a particular location.

Traffic Responsive System: A system in which a master controller (analog or digital) specifies cycle and offset based on the real-time demands of traffic as sensed by vehicle detectors.

Train Approach Signal: A highway Traffic Signal which indicates to highway traffic, the approach and passage of railroad trains at a railroad highway grade crossing.

Triple Automatic Reset: A reset by which it is possible to automatically select any one of three offsets.

Triple Dial Timer: A timer equipped with three timing dials, mechanically or electrically inter-related so that it is possible to set up and select, manually or remotely, any one of three timing programs.

Unit Extension: The timing interval during the extensible portion which is resettable by each detector actuation. The green right of way of the phase may terminate on expiration of the unit extension time. (See "Extinction Limit.")

Vehicular Phase: A traffic phase allocated to vehicular traffic.

Visor, Cutaway: A visor which encircles approximately 300 degrees around the lens, the lower half of which is cut away or contoured.

Visor, Full Circle: A visor which encircles the entire lens.

Visor (Hood): That part of a signal section which protects the lens face from direct ambient light.

Visor Tunnel: A visor which encircles the entire lens except a segment equal to approximately two inches of circumference at the bottom of the lens.

Yellow Change Interval: The first interval following the green right-of-way interval in which the signal indication for that phase is yellow.

Yield: The action of allowing a semi-actuated controller, or an actuated controller operating in the semimode, to terminate the main street phase so as to begin satisfying existing cross street demand.

APPENDIX A

TYPICAL DRAWINGS FOR
PHASING AND SEQUENCING

FIGURE A-1

**STANDARD
VEHICULAR SIGNAL**

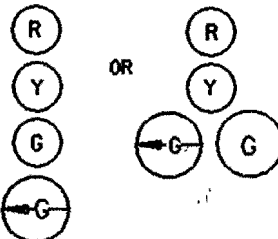


**LEFT TURN
PROTECTED/PROHIBITED**

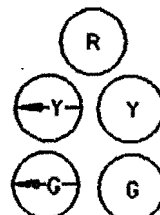


*

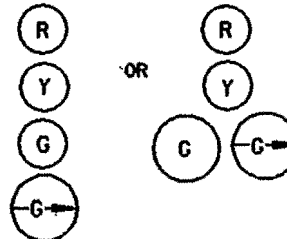
**LEFT TURN
PROTECTED/PERMITTED**



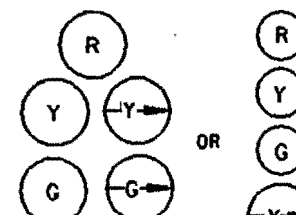
**LEFT TURN
PROTECTED/PERMITTED**



**RIGHT TURN
CONTINUOUS**



**RIGHT TURN
GREEN ARROW TERMINATES
OTHER THAN WITH
CIRCULAR GREEN**



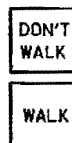
*



*

VEHICULAR SIGNALS

PEDESTRIAN



**

VEHICULAR



PEDESTRIAN SIGNALS



MAY BE 8" OR 12" LENSES



SHALL BE 12" LENSES

* TUNNEL VISORS

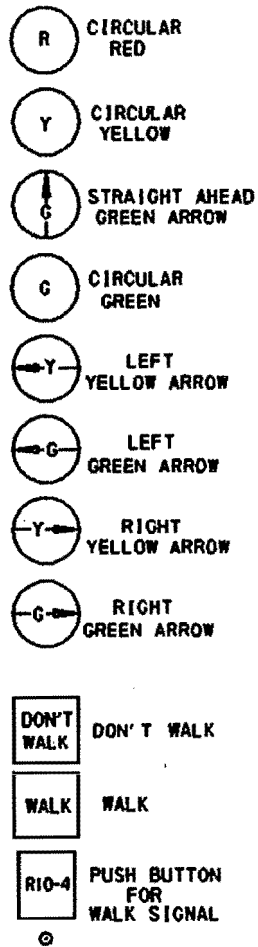
** 3" LEGEND WHEN DISTANCE FROM NEAR CURB TO SIGNAL IS 60' OR LESS.
4 1/2" LEGEND WHEN DISTANCE IS GREATER THAN 60'.

*** LOUVER THE APPROPRIATE LENS OR LENSES WHEN IN CONFLICT WITH SIGNALS FOR VEHICULAR TRAFFIC.

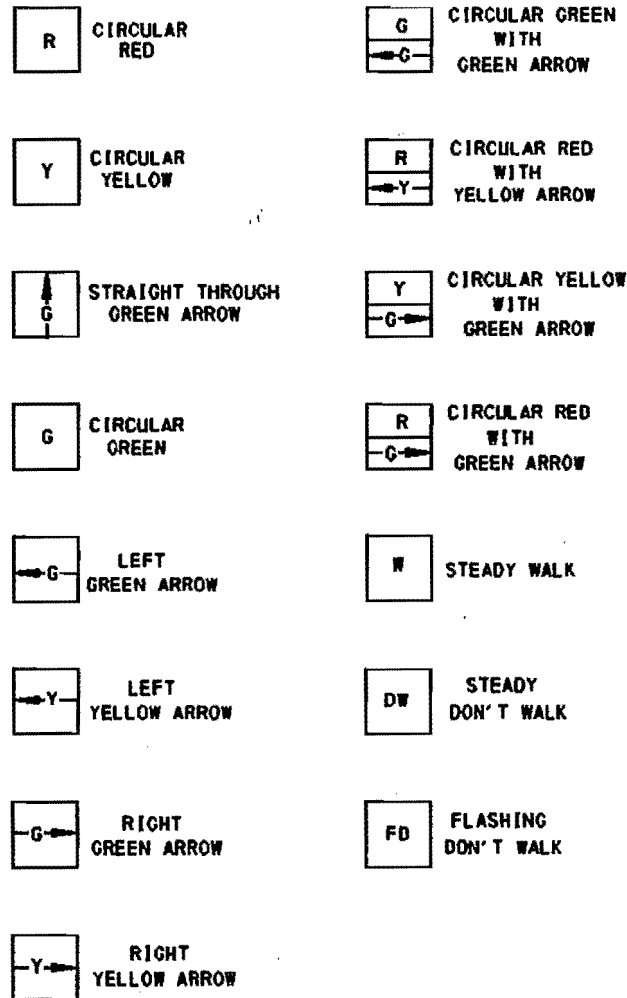
FIGURE A-2

SYMBOLS

SIGNAL LENSES



COLOR SEQUENCE CHART



TRAFFIC LINES

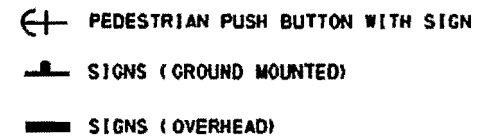
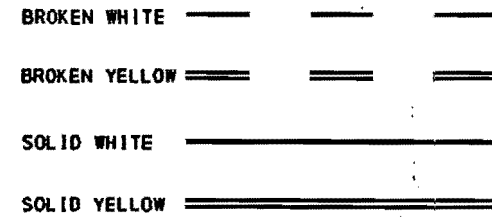


FIGURE A-3

TIMING PLANS

TIME	GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR					GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR					CYCLE LENGTH
	G	W	F	Y	R	G	W	F	Y	R	
% CYCLE TIME/CYCLE	30		15	5	3	21		18	5	3	100
DIAL SETTING	30		45	50	53	74		92	97	00	

REPEAT AS NECESSARY FOR ADDITIONAL CYCLE LENGTHS.

PRETIMED
ELECTROMECHANICAL

TIME	GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR					GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR					CYCLE LENGTH
	G	W	F	Y	R	G	W	F	Y	R	

REPEAT AS NECESSARY FOR ADDITIONAL CYCLE LENGTHS.

PRETIMED
SOLID STATE

	ACTUATED PHASE GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR					NON-ACTUATED PHASE GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR				
	F	F	Y	R		F	Y	R		
FIXED										
MINIMUM	G					G				
PASSAGE	G									
MAXIMUM	G									
PEDESTRIAN	W									
MEMORY	M					M				

ACTUATED

G SEE SECTION 11.5

Y SEE SECTION 11.3

R SEE SECTION 11.3

W SEE SECTION 11.4

F SEE SECTION 11.4

M PR - PED. RECALL

MN - MIN. RECALL

MX - MAX. RECALL

L - LOCKING

NL - NON-LOCKING

☆ - WHEN PEDESTRIAN SIGNALS ARE PROVIDED

	GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR					GREEN / WALK PED. CLR. ☆ VEH. CHANGE VEH. CLEAR				
	F	F	Y	R		F	Y	R		
FIXED										
MINIMUM	G					G				
ADDED INITIAL	G					G				
MAX. INITIAL	G					G				
PASSAGE	G					G				
TO REDUCE BEFORE RED.	G					G				
MIN. GAP	G					G				
MAX. I	G					G				
MAX. II	G					G				
PEDESTRIAN	W					W				
MEMORY	M					M				

VOLUME DENSITY

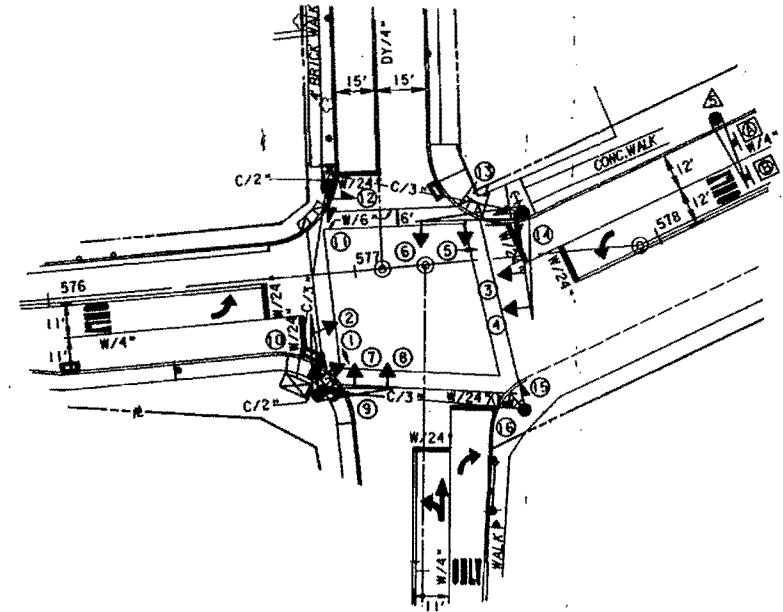
FIGURE A-4

	PHASE 1			PHASE 2			PHASE 3			PHASE 4 *			FLASHING	
SIGNAL	INTERVAL			INTERVAL			INTERVAL			INTERVAL				
	1	2	3	4	5	6	7	8	9		10	11	12	
①	G	G	G	G	Y	R	R	R	R		R	R	R	Y
②	G	G	G	G	Y	R	R	R	R		R	R	R	Y
③ ④	G	Y	R	R	R	R	R	R	R		R	R	R	Y
⑤	R	R	R	R	R	R	G	Y	R		R	R	R	R
⑥ ⑦ ⑧	R	R	R	R	R	R	G	Y	R		R	R	R	R
⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯	DW	DW	DW	DW	DW	DW	DW	DW	DW		DW	DW	DW	OFF
FIXED		3	1		3	1		3	1					
MINIMUM	4			4			4							
PASSAGE	4			4			4							
MAXIMUM	**			**			**							
PEDESTRIAN *											10	7	1	
MEMORY	MoR			MoR			MoR							
* UPON PEDESTRIAN ACTUATION ONLY														
DIAL 1	35			15			25							
DIAL 2	45			20			30							
DIAL 3	30			10			25							
DIAL 4	25			10			20							

NOTES:

- ① ABSENCE OF PEDESTRIAN ACTUATION - PHASE 4 TIMING ADDED TO PHASE 1 GREEN (INTERVAL 1).
 ② MoR-MAXIMUM RECALL

PROGRAMS									
PROGRAM NUMBER	CYCLE LENGTH	OFF SET							
		LEONARD	MARKET	CENTER	IRON	EAST	FIFTH	SIXTH	PARK SEVENTH
1	105 SEC	57 SEC	0	0	3 SEC	0 SEC	62 SEC	75 SEC	80% 75 SEC
2	125 SEC	65 SEC	0	0	115 SEC	0 SEC	53 SEC	79 SEC	91% 75 SEC
3	95 SEC	11 SEC	70 SEC	0	0 SEC	0 SEC	37 SEC	41 SEC	56% 41 SEC
4	85 SEC	50 SEC	18 SEC	0	83 SEC	0 SEC	49 SEC	63 SEC	27% 63 SEC
5	FLASH								

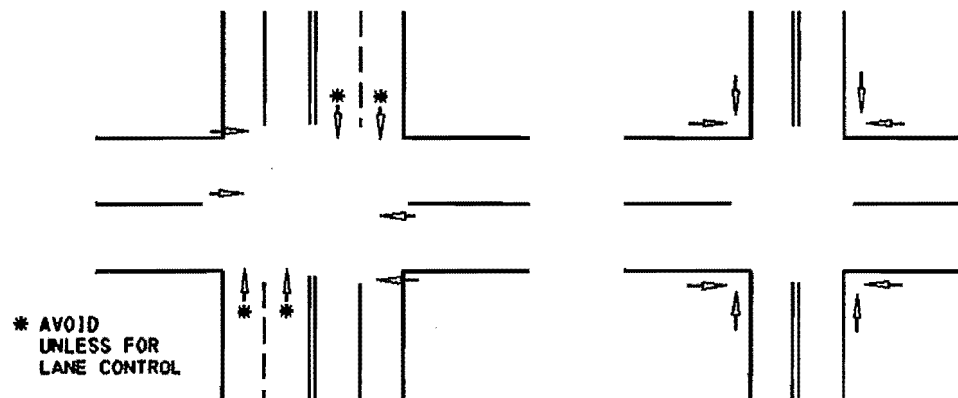
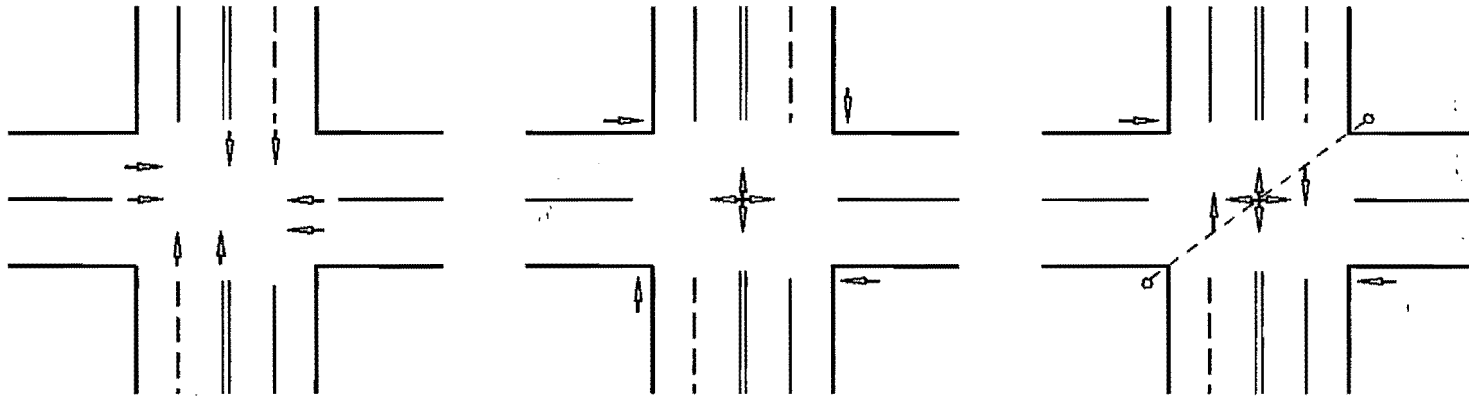


WEEKLY PROGRAM CHART							
EVENT	WEEK	DAY *	HOUR	MINUTE	SECOND	PROG. NO.	REMARKS
1	1 TO 52	1 TO	00	00	00	5	FLASH
2		5	06	00	00	4	85 SEC
3			07	00	00	1	105 SEC
4			09	00	00	3	95 SEC
5			14	00	00	2	125 SEC
6			17	00	00	3	95 SEC
7			19	00	00	1	105 SEC
8			22	00	00	4	85 SEC
9		6	00	00	00	5	FLASH
10			07	00	00	3	95 SEC
11			17	00	00	4	85 SEC
12		7	00	00	00	5	FLASH
13			08	00	00	3	95 SEC
14			16	00	00	4	85 SEC

* DAY 1 IS MONDAY

FIGURE A-5

ACCEPTABLE SIGNAL PLACEMENT
PEDESTRIAN MOVEMENTS MAY REQUIRE ADDITIONAL SIGNALS

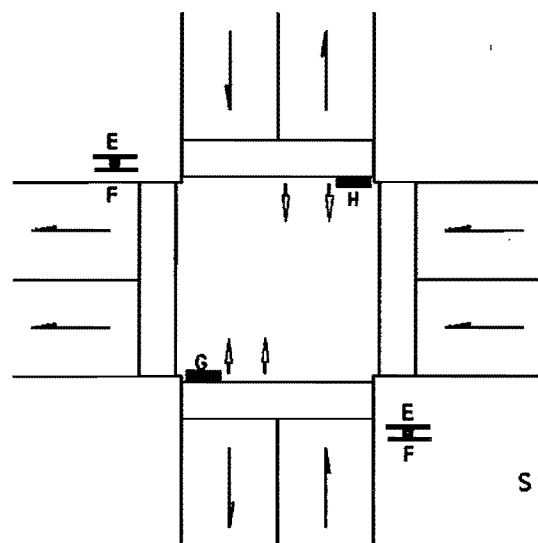


* AVOID
UNLESS FOR
LANE CONTROL

EXCLUSIVE SIDE MOUNTS TO BE USED
ON LOW SPEED (<25MPH) URBAN STREETS

FIGURE A-6

ONE-WAY; END ONE-WAY; 'T' INTERSECTION
MINIMUM SIGNALS AND SIGNING



ALL
SIGNALS



SIGNS

— OVERHEAD ○ GROUND MOUNTS

- A R 3-1 NO RIGHT TURN
- B R 3-2 NO LEFT TURN
- C R 3-7L LEFT LANE MUST TURN LEFT
- D R 5-1 DO NOT ENTER
- E R 6-1R OR R6-2R ONE WAY
- F R 6-1L OR R6-2L ONE WAY
- G R 6-2R ONE WAY
- H R 6-2L ONE WAY
- I R 6-10 TWO WAY TRAFFIC AHEAD
- K R 6-11 END ONE WAY
- L W 6-3 TWO WAY TRAFFIC
- W W 1-7 DOUBLE ARROW

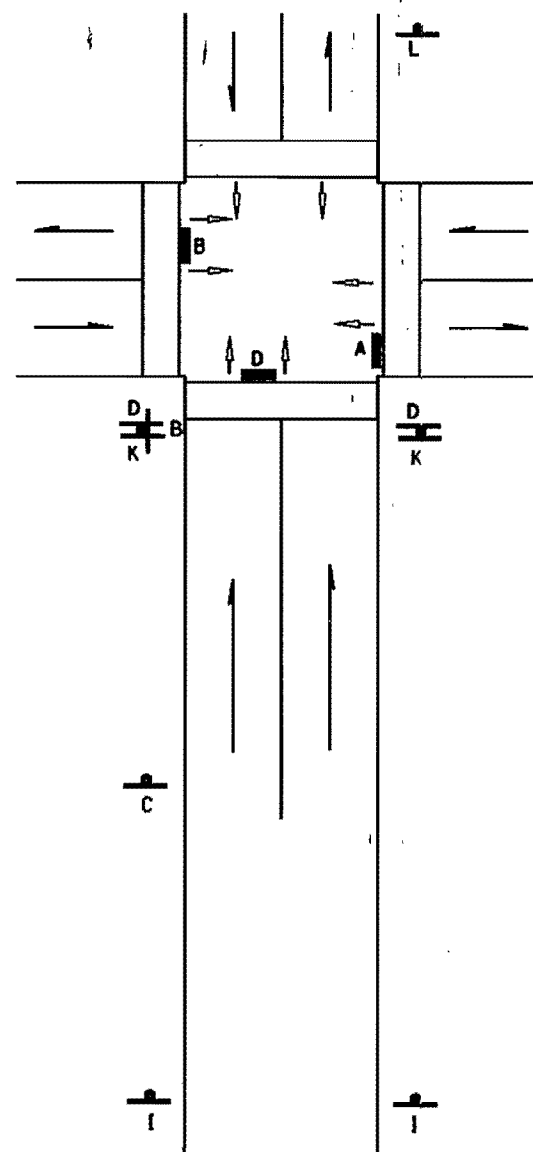
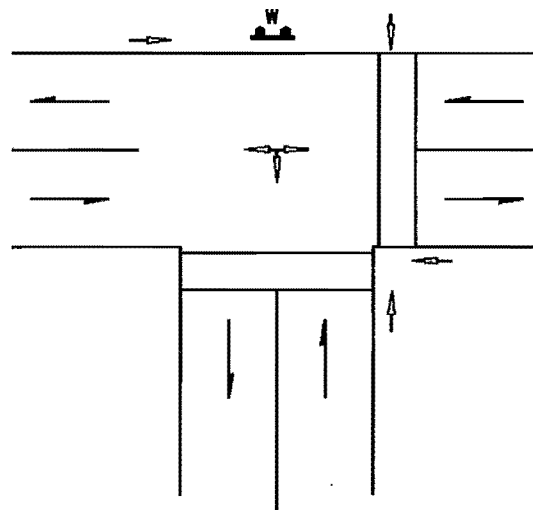
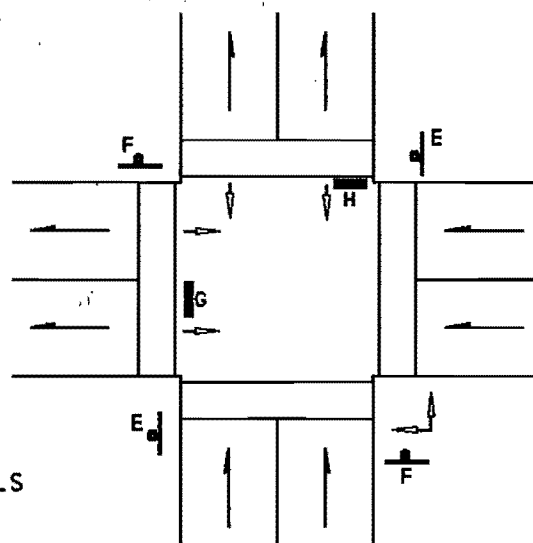
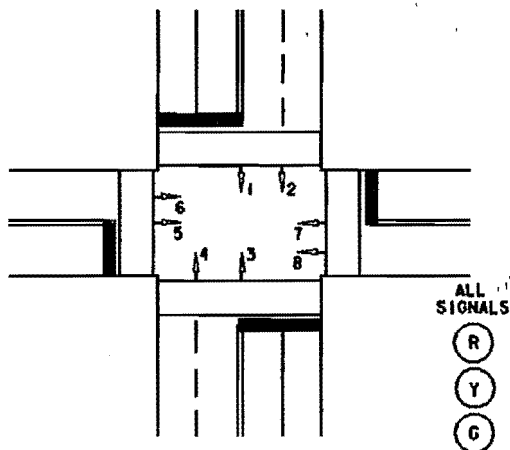


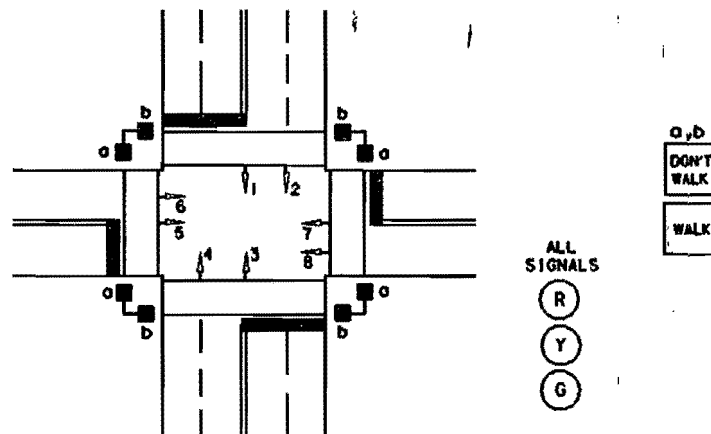
FIGURE A-7

TWO PHASE PRETIMED OR ACTUATED

VEHICULAR SIGNALS
FOR PEDESTRIAN TRAFFIC



PEDESTRIAN SIGNALS
FOR PEDESTRIAN TRAFFIC



PHASE	1				2				FLASHING
	1	2	3		1	2	3		
1-2	G	Y	R						Y
3-4	G	Y	R						Y
5-6					G	Y	R		R
7-8					G	Y	R		R

PRETIMED OR ACTUATED
SEE TIMING EXAMPLES FIG. 3.

PHASE	1				2				FLASHING
	1	2	3	4	1	2	3	4	
1-2	G	G	Y	R					Y
3-4	G	G	Y	R					Y
5-6					G	G	Y	R	R
7-8					G	G	Y	R	R
* a	W	FD	DW	DW	DW	DW	DW	DW	OFF
* b	DW	DW	DW	DW	W	FD	DW	DW	OFF

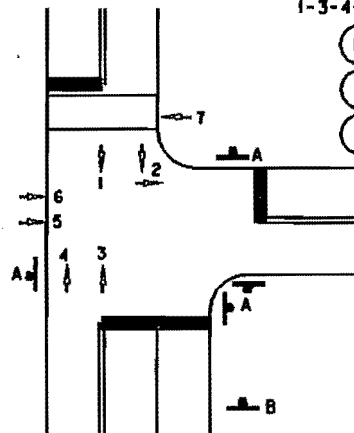
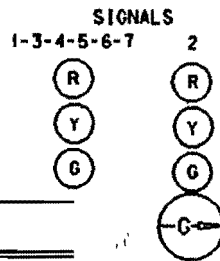
* IF PRETIMED, AS INDICATED.

IF ACTUATED, AS INDICATED UPON
PEDESTRIAN ACTUATION, OTHERWISE
DON'T WALK AT ALL TIMES.

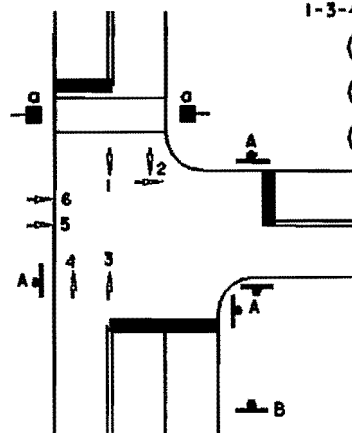
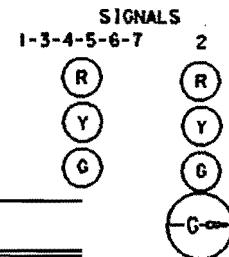
PRETIMED OR ACTUATED
SEE TIMING EXAMPLES FIG. 3.

WHERE NO DISPLAY IS INDICATED, VEHICULAR SIGNAL SHALL BE CIRCULAR RED.

TWO PHASE PRETIMED WITH CONTINUING RIGHT TURN



A R9-3
B R3-7R

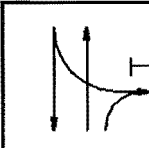
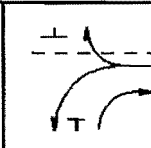


A R9-3
B R3-7R



PHASE	1				2					FLASHING
INTERVAL SIGNAL	I	2	3		I	2	3			
1	G	Y	R							Y
2	G	$\overline{G}$ $\overline{Y}$ $\overline{R}$	$\overline{G}$ $\overline{Y}$ $\overline{R}$		$\overline{G}$ $\overline{Y}$ $\overline{R}$	$\overline{G}$ $\overline{Y}$ $\overline{R}$	$\overline{G}$ $\overline{Y}$ $\overline{R}$			Y
3-4	G	Y	R							Y
5-6					G	Y	R			R
7					G	Y	R			R
TIME	G	Y	R		G	Y	R			

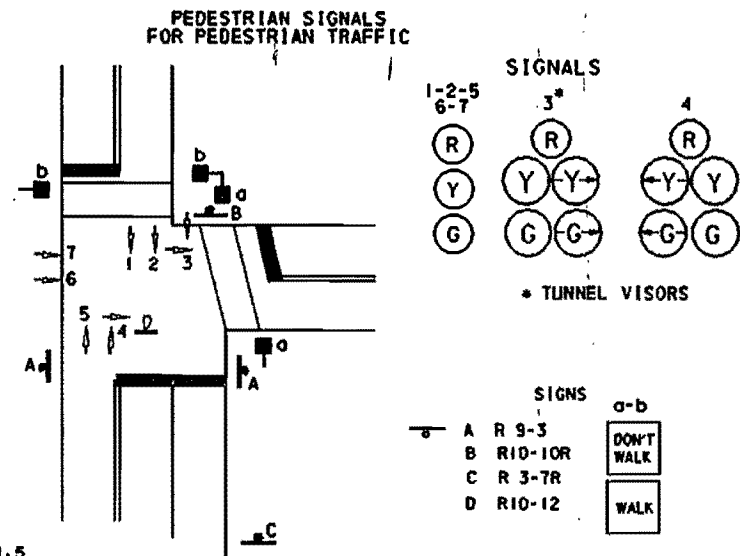
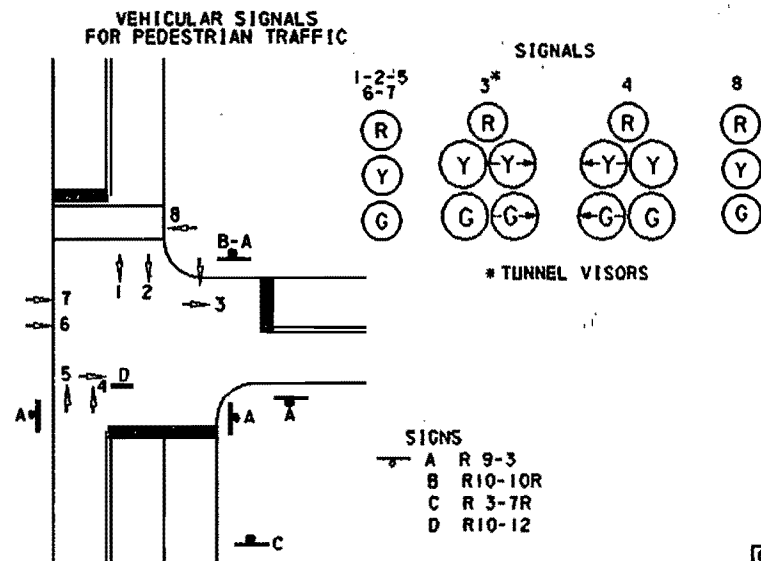
Y R - SEE SEC. 11.3

										
PHASE	1				2					
INTERVAL SIGNAL	1	2	3		1	2	3			
1	0	Y	R							
2	0	$\overline{Y}$	$\overline{R}$		$\overline{G}$	$\overline{R}$	$\overline{G}$	$\overline{R}$	$\overline{G}$	
3-4	0	Y	R							
5-6					G	G	Y	R		
0	DW	DW	DW		W	FD	DW	DW		
TIME	G	Y	R		G	P	Y	R		

WHERE NO DISPLAY IS INDICATED, VEHICULAR SIGNAL SHALL BE CIRCULAR RED.

FIGURE A-9

THREE PHASE PRETIMED PROTECTED/PERMITTED LEFT TURN AND CONTINUING RIGHT TURN



G - SEE SEC. 11.5
Y R - SEE SEC. 11.3
W F - SEE SEC. 11.4

PHASE	1	2	3	FLASHING
INTERVAL SIGNAL	1 2	1 2 3	1 2 3	
1-2		G Y R		Y
3		G Y R	R Y R	OFF
4	G G	G Y R		Y
5	G G	G Y R		Y
6-7			G Y R	R
8			G Y R	R
FIXED	G Y	G Y R	G Y R	

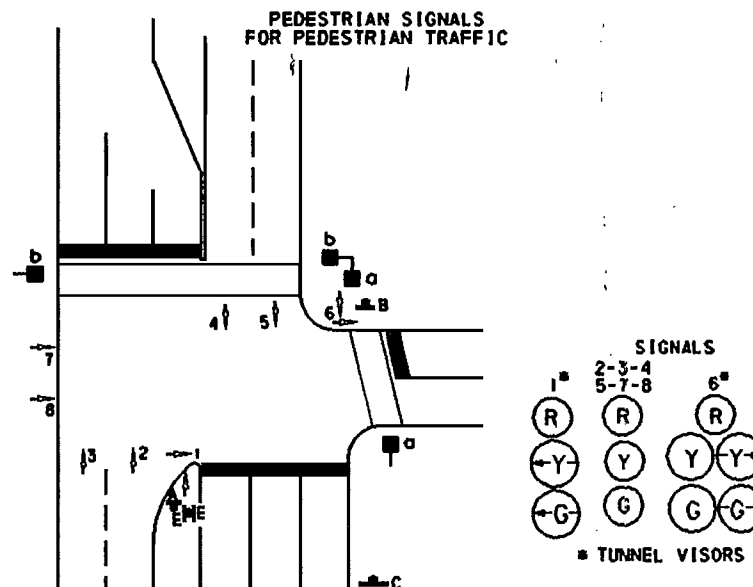
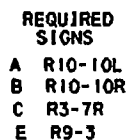
♦ 7 SEC. MIN.

PHASE	1	2	3	FLASHING
INTERVAL SIGNAL	1 2	1 2 3 4	1 2 3 4	
1-2		G G Y R		Y
3		G G Y R	R R Y R	OFF
4	G G	G G Y R		Y
5	G G	G G Y R		Y
6-7	R R	R R R R	G G Y R	R
α	D W D W	W F D W D W	D W D W D W	OFF
b	D W D W	D W D W D W	W F D W D W	OFF
FIXED	G Y	G F Y R	G F Y R	

♦ 7 SEC. MIN.

WHERE NO DISPLAY IS INDICATED, VEHICULAR SIGNAL SHALL BE CIRCULAR RED.

THREE PHASE ACTUATED
PROTECTED/PERMITTED LEFT TURN



											FLASHING	
PHASE	1			2			3					
INTERVAL SIGNAL	1	2	3	1	2	3		1	2	3		
1	G	Y	R									OFF
2-3	G	G	G	G	Y ⁽¹⁾	R ⁽¹⁾						Y
4-5				G	Y	R						Y
6				G	Y ⁽²⁾	R ⁽²⁾		R	Y ⁽⁴⁾	R ⁽⁴⁾		OFF
7-8								G	Y	R		R
9								G	Y	R		R
FIXED		Y	R		Y	R			Y	R		
MINIMUM	G			G				G				
PASSAGE	G			G				G				
MAXIMUM	G			G				G				
P								W	F			

- ① G IF FOLLOWED BY PHASE 1.
- ② Y IF FOLLOWED BY PHASE 1.
- ③ R IF FOLLOWED BY PHASE 1.
- ④ R/G- IF FOLLOWED BY PHASE 2.

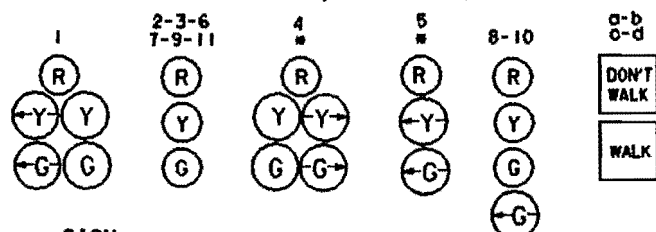
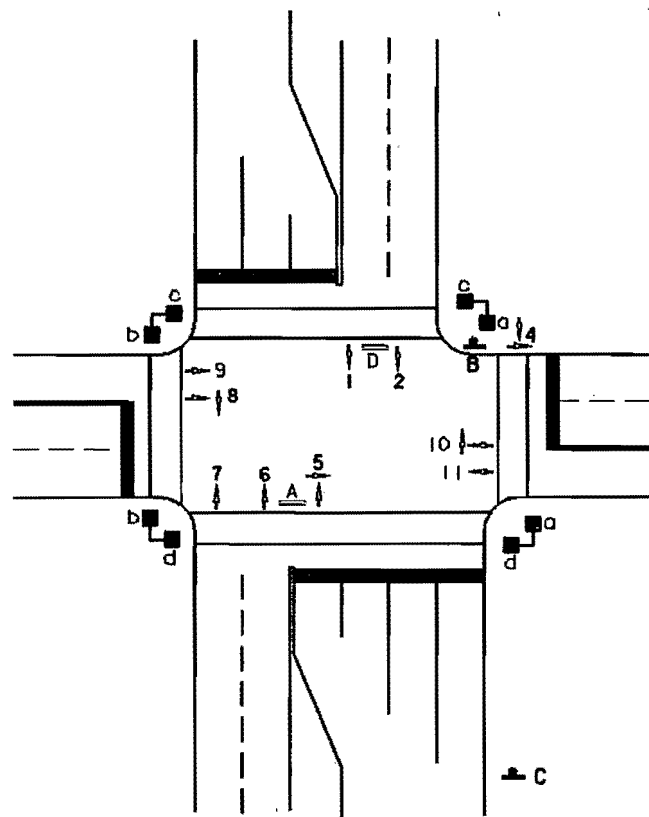
G - SEE SEC. 11.5
Y R - SEE SEC. 11.3
W F - SEE SEC. 11.4

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

																																							FLASHING																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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INTERVAL SIGNAL													I	2	3		I	2	3	4							I	2	3	4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									

FIGURE A-11

SIX PHASE ACTUATED
OVERLAPPING RIGHT TURN
PROTECTED/PROHIBITED & PROTECTED/PERMITTED LEFT TURNS
PEDESTRIAN SIGNALS FOR PEDESTRIAN TRAFFIC



SIGN
A R10-10L
B R10-10R
C R3-7R
D R10-12

* TUNNEL VISORS

G - SEE SEC. 11.5
Y R - SEE SEC. 11.3
W F - SEE SEC. 11.4

PHASE	1+5				2+5				1+6				2+6				3				4				FLASHING
INTERVAL SIGNAL	1	2	3		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	R	R	R	(1)	G	G	Y	(12)					G	G	Y	(4)									Y
2					G	G	Y	(3)					G	G	Y	(4)									Y
4					G	G	Y	(3)					G	G	Y	(3)	R	R	(8)	(8)					OFF
5									G	G	Y	(3)													OFF
6-7									G	G	Y	(3)	G	G	Y	(7)									Y
8																	G	G	Y	R					R
9																	G	G	Y	R					R
10																					G	G	Y	R	R
11																					G	G	Y	R	R
* a					W	FD	DW	DW					W	FD	DW	DW									OFF
* b									W	FD	DW	DW	W	FD	DW	DW									OFF
* c																	W	FD	DW	DW					OFF
* d																					W	FD	DW	DW	OFF
FIXED		Y	R			Y	R			Y	R			Y	R			Y	R			Y	R		
MINIMUM	G				G				G				G				G				G				
PASSAGE	G				G				G				G				G				G				
MAXIMUM	G				G				G				G				G				G				
PEDES- * TRIAN																									

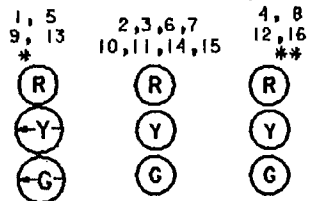
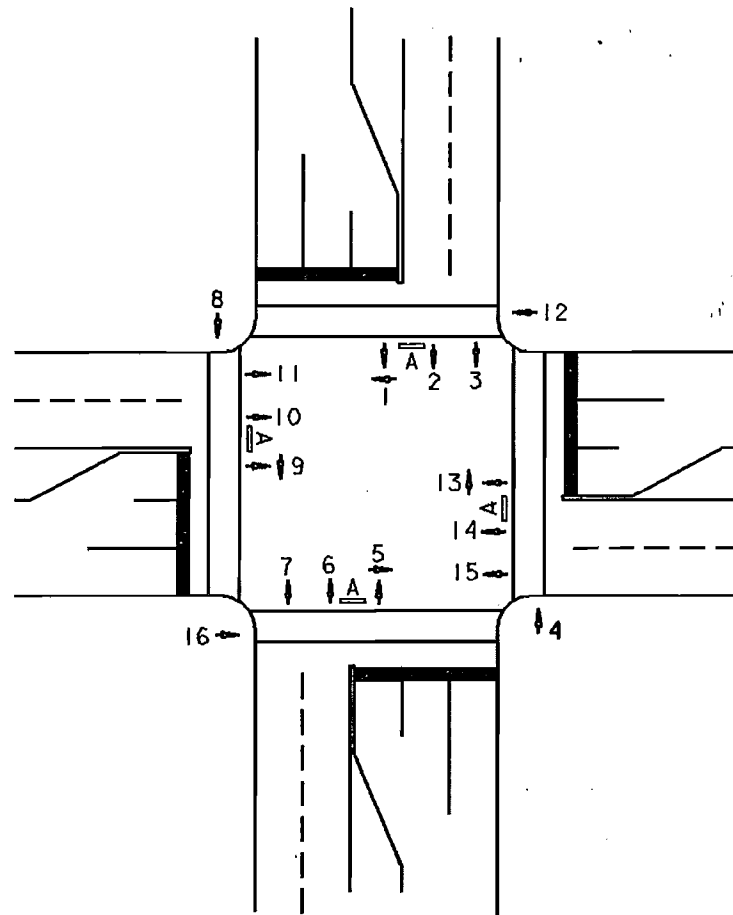
* UPON PEDESTRIAN ACTUATION, OTHERWISE DON'T WALK AT ALL TIMES.

- (1) R/-G IF FOLLOWED BY 2+5
- (2) R/-G IF FOLLOWED BY 1+6
- (3) G IF FOLLOWED BY 2+6
- (4) G IF FOLLOWED BY 2+5
- (5) Y/-G IF FOLLOWED BY 3
- (6) R/-G IF FOLLOWED BY 3
- (7) G IF FOLLOWED BY 1+6
- (8) R/-G IF FOLLOWED BY 2+6 OR 2+5
- (9) -G IF FOLLOWED BY 1+5
- (10) R/-G IF FOLLOWED BY 1+5
- (11) G/-Y IF FOLLOWED BY 2+6
- (12) G IF FOLLOWED BY 2+6
- (13) TIMING WILL BE AS SHOWN IN PHASE 2+6. INTERVALS 1 & 2 MAY TIME OUT IN THIS PHASE OR MAY BE COMPLETED IN PHASE 2+6

WHERE NO DISPLAY IS INDICATED, VEHICULAR SIGNAL SHALL BE CIRCULAR RED.

FIGURE A-12

EIGHT PHASE ACTUATED QUAD LEFT TURN VEHICULAR SIGNALS FOR PEDESTRIAN TRAFFIC



* TUNNEL VISORS
** LOUVER ALL LENSES

REQUIRED
SIGN
A R10-10L

[G] - SEE SEC. 11.5
[Y] [R] - SEE SEC. 11.3
[W] - SEE SEC. 11.4

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	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1	←G	Y	R				←G	Y	R																OFF
2-3-4							G	Y	R	G	Y	R													Y
5	←G	Y	R	←G	Y	R																			OFF
6-7-8				G	Y	R				G	Y	R													Y
9													←G	Y	R	←G	Y	R							OFF
10-11-12													G	Y	R				G	Y	R				R
13													←G	Y	R				←G	Y	R				OFF
14-15-16																G	Y	R	G	Y	R				R
FIXED		[Y]	[R]		[Y]	[R]		[Y]	[R]		[Y]	[R]		[Y]	[R]		[Y]	[R]		[Y]	[R]		[Y]	[R]	
MINIMUM	[G]			[G]			[G]			[G]			[G]			[G]			[G]			[G]			
PASSAGE	[G]			[G]			[G]			[G]			[G]			[G]			[G]			[G]			
MAXIMUM	[G]			[G]			[G]			[G]			[G]			[G]			[G]			[G]			
PEDES- TRIAN																									

* UPON PEDESTRIAN ACTUATION ONLY

WHERE NO DISPLAY IS INDICATED, VEHICULAR SIGNAL SHALL BE CIRCULAR RED.

- 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 LT. G ARROW IF FOLLOWED BY 3+8
- ⑦ LT. G ARROW 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 LT. G ARROW IF FOLLOWED BY 1+5
- ⑫ LT. G ARROW IF FOLLOWED BY 3+7
- ⑬ TIMING WILL BE AS SHOWN IN PHASE 2+6. IT MAY TIME OUT IN THIS PHASE OR BE COMPLETED IN PHASE 2+6
- ⑭ TIMING WILL BE AS SHOWN IN PHASE 4+8. IT MAY TIME OUT IN THIS PHASE OR BE COMPLETED IN PHASE 4+8

FIGURE A-13

INTERSECTION CONTROL BEACON

1,2,3,4

(Y)

5,6,7,8

(R)

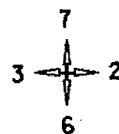
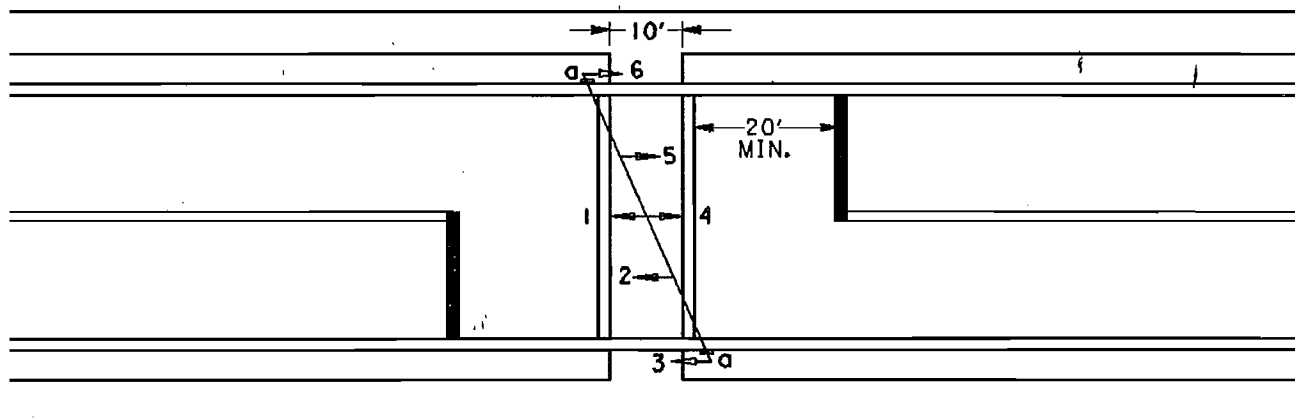


FIGURE A-14

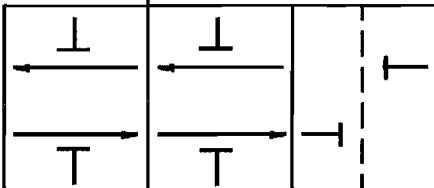
MID BLOCK SIGNAL



1-2-3
4-5-6



WHEN ACTUATED BY
PEDESTRIAN PUSH BUTTON

INTERVAL SIGNAL	NORMAL						
		1	2	3	4	5	6
1-2-3	FL. Y	G	Y	R			
4-5-6	FL. Y	G	Y	R			
a	OFF	D _W	D _W	D _W	W	FD	D _W
TIME	40 MIN.	10	3	2	10	10	2

WHEN ACTUATED BY
PEDESTRIAN PUSH BUTTON

INTERVAL SIGNAL	1	2	3	4	5	6
1-2-3	G	Y	R			
4-5-6	G	Y	R			
a	D _W	D _W	D _W	W	FD	D _W
TIME	40 MIN.	3	2	10	10	2

WHERE NO DISPLAY IS INDICATED, VEHICULAR SIGNAL SHALL BE CIRCULAR RED.

APPENDIX B

**CRITERIA FOR THE DESIGN OF
TRAFFIC-RELATED STRUCTURES**

Pennsylvania Department of Transportation

Criteria for the Design

of Traffic-Related Structures

The criteria as stated herein shall be utilized in the design of galvanized steel structures used for the support of overhead traffic signals and/or traffic signs.

Part A. Design Criteria for all Support Structures
(See 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 1975 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals," with interim specifications through 1981, hereafter referred to as "AASHTO specifications," with the following modifications and additions:

Section 1 - General Features of Design

The following additions and modifications apply to this section of the AASHTO specifications.

1.1.3

Supports shall not be designed as breakaway or yielding type supports.

Telescoping (slip-fit) splices for mast arms which rely solely on friction between the members for their connection will not be permitted.

1.1.5

Materials for supports shall be as listed in the Pennsylvania Department of Transportation specifications, Publication 408.

Section 2 - Loads

The following modifications apply to this section of the AASHTO specifications:

1.2.1

Dead loads for signs, traffic signals, back plates, brackets and all appurtenances shall be as given in this criteria.

1.2.2

Support members shall not be designed for the single live load of 500 lbs. as described in the AASHTO specifications since walkways or service platforms will not be required.

1.2.4

Design wind loads and pressures shall be computed based on a wind speed (V) of 80 mph, Annual Extreme-Mile, 30 feet above ground.

Section 3 - Method of Analysis

1.3.1

The following is added to Table 1.3.1B(3) of the AASHTO specifications:

Maximum shear stresses due to torsion (v_t) for round stepped tubes (hot-swaged shrink fit) shall be computed using the following formula:

$$v_t = \frac{M_z k_t}{6.28 R^2 t}$$

where M_z = total torsional moment (in-lbs)

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 4 - Steel Design

The following additions and modifications apply to this section of the AASHTO specifications:

1.4.1

The following is added to Table 1.4.1B(1) of the AASHTO specifications:

Octagonal and Dodecagonal steel tubes shall be considered compact if

$$\frac{b}{t} \leq \sqrt{\frac{6000}{F_y}}$$

where b = width of section between outside corners (in)

t = wall thickness (in)

F_y = specified minimum yield stress (psi)

When vertical steel support poles are fabricated of round stepped sections, the allowable compressive stress shall be computed based on the following formula:

$$F_a = 0.52 \left[\frac{\pi^2 E}{\left(\frac{KL}{r} \right)^2} \right]$$

$$\text{when } \frac{KL}{r} \geq \sqrt{\frac{2\pi^2 E}{F_y}}$$

where F_y = specified yield stress (psi)

K = 2.0 (cantilever column)

E = 29×10^6 psi

L = total length of pole (in)

r = radius of gyration based on an average radius (in)

1.4.2

Welding design and fabrication shall be in accordance with "AWS Structural Welding Code, Steel" D1.1-80, Sections 1 through 8 and the "Standard Specifications for Welding of Structural Steel Highway Bridges" - third edition, 1981 AASHTO. Transverse welds shall not be used to join pole sections.

1.4.3

All vertical steel poles and mast arms, including those manufactured of high strength and corrosive resistant steels, shall be galvanized according to ASTM A123 (AASHTO M111). Accessories and hardware shall be galvanized according to ASTM A153.

Section 9 - Details of Design

The following additions apply to this section of the AASHTO specifications:

1.9.1

The maximum allowable vertical deflection for mast arms under dead load shall be 5% of the arm length. Changes in deflection of multi-section arms will not be acceptable.

The maximum allowable horizontal deflection for vertical poles under dead load shall be 5% of the pole length.

Mast arms shall be designed with a maximum rise of 5%. A mast arm which deflects below a horizontal plane through its highest point is unacceptable.

1.9.2

The bottom six (6) feet of strain poles shall have a minimum wall thickness of 3/16 inch (0.1875 inch).

1.9.6(B)

All supports shall also be checked for fatigue stresses due to wind gusting. Wind pressure (psf) for determining fatigue stresses shall be computed using the following formula:

$$P = 10.82 C_d$$

where C_d is the drag coefficient from table 1.2.5C in the AASHTO specifications. Design should be based on 2 million cycles.

Part B. Design Criteria for Strain Poles (See 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 1.4.1 - Allowable Unit Stresses, in the 1975 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals" with interim specifications through 1981, hereafter referred to as "AASHTO Specifications."

2. Span and Tether Wires:

Span and tether wire shall conform to ASTM A475, Siemens-Martin Grade or ASTM B416.

Strain poles shall be designed for a sag of 5% of the span distance between poles under dead load. In computing dead load, the weight of the span and tether wires shall be based on a value of 1 lb. per linear foot.

3. Strain Pole Deflection:

The maximum horizontal deflection of strain poles, at the span wire connection, due to dead loads only, shall be 2.67% at 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* shall be used:

- a. Determine the effective weight of each item loaded on the span wire (traffic signal, traffic sign, signal wire and/or other attachment) by adding to the weight of each item, the weight 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 weight of each load 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 weights of the load items.
- 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 weight of each load item in moving across to, and ending with the vertical reaction of, the other strain pole structure. The low point in the span wire is the point at which the sign of the vertical shear changes (which indicates that the slope of the span wire has changed). If the vertical shear happens to be zero at any point between the strain pole structures, this indicates that two load items are at the same elevation and share the low point of the span wire. As a check, the vertical shear must begin and end at zero at the constituent strain pole structures.
- d. Determine the stringing tension by evaluating the summation of moments about the low point in the span wire. Since the span wire cannot resist bending moment, set the sum of the moments about the low point of all forces acting on the span wire between the low point and either of the strain pole structures equal to zero, where the horizontal pull acting on that strain pole structure is an unknown force acting at a distance equal to the maximum allowable sag (5 percent 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

*Based on the General Cable Theorem

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 in beginning with the connection at the first strain pole structure and successively add the respective elevation increments in moving across the span wire.

6. Application of Wind Load: (see Figure 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 paragraph 1.2.5(D)(4) 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 5 equal concentrated loads to be used. The tension forces throughout the wire now become a series of vectors with the vector component in the direction of the span equal in magnitude for each vector. Since the ratio of the vector length to the vector force is proportional to the ratio of the vector component length to the vector component force, the length of each vector may be expressed by the following equation:

$$\text{Vector Length} = \sqrt{F_x^2 + F_y^2 + F_z^2} \frac{dx}{F_x}$$

Where

$\sqrt{F_x^2 + F_y^2 + F_z^2}$	= 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
dx^*	= 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 determined 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 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 2

$$F_{z1} = R_z(L)$$

$$F_{z2} = R_z(L) - W_A$$

$$F_{z3} = R_z(L) - W_A - W_B$$

$$F_{z4} = R_z(R) - W_E - W_D$$

$$F_{z5} = R_z(R) - W_E$$

$$F_{z6} = R_z(R)$$

$$\begin{aligned} \text{The total length} \\ \text{of span wire} \end{aligned} = \sqrt{F_x^2 + F_{y1}^2 + F_{z1}^2} \frac{dx_1}{F_x} + \sqrt{F_x^2 + F_{y2}^2 + F_{z3}^2} \frac{dx_2}{F_x} + \dots$$

The reactions $R_z(L)$ and $R_z(R)$ may be determined by summing moments about a vertical line at 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 at 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.

8. Design Stresses:

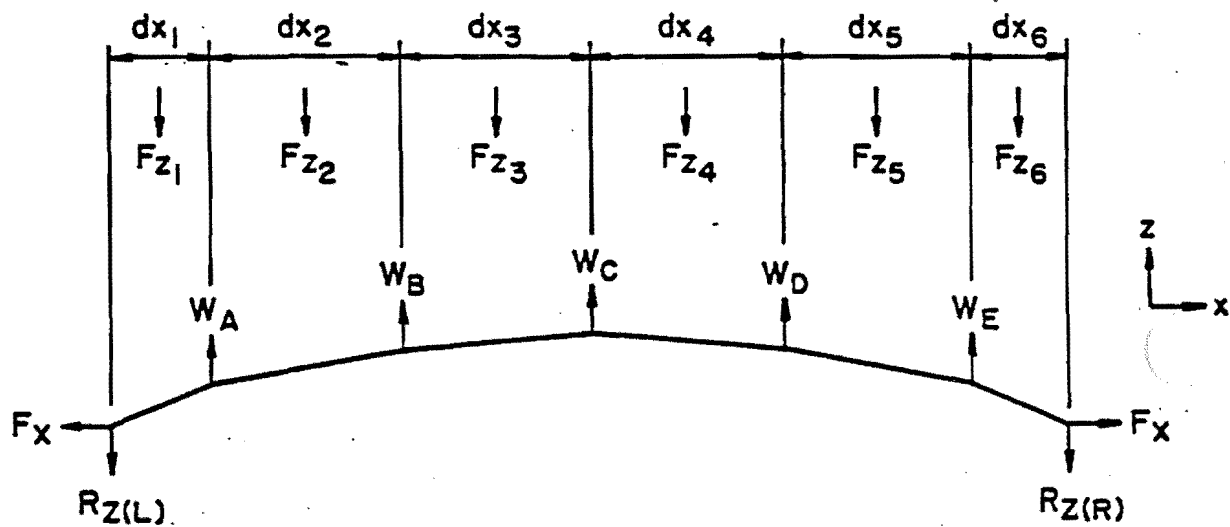
Strain Pole structures shall be designed and constructed to withstand maximum stresses based on Group I, Group II and Group III loadings (whichever controls, as defined in the AASHTO specification. In the case of strain poles which support more than one span, the resultant of the respective tensions for each span shall be used in combination with the wind applied in the direction which produces maximum stress.

Part C. Acceptance of Structural Designs

The manufacturer shall submit design calculations and detailed structural drawings for those signal supports that he proposes to supply in Pennsylvania. In addition, the manufacturer must provide the Department with certification, from a professional engineer, registered in Pennsylvania, indicating that the designs comply with the Department's criteria and are adequate to support the loads specified therein.

After acceptance by the Department, 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 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.

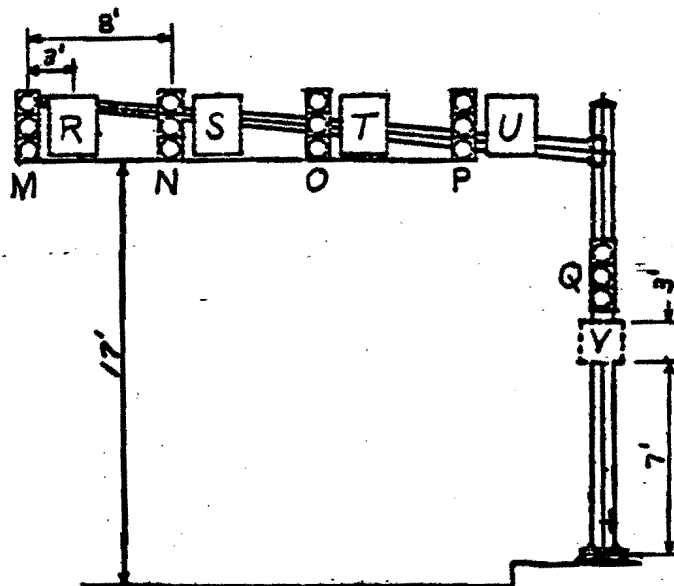
Shop drawings will be required for all signal supports on each project.



FORCE DIAGRAM

FIGURE 2

STANDARD STRUCTURE LOADINGS



12' Signals with backplates.
(Overhead)

W - Weight

A - Area

ARM LENGTH		SIGNALS					SIGNS				
		M	N	O	P	Q	R	S	T	U	V
15	W	90				110	12				12
	A	10.8				7.0	7.5				7.5
16 - 20	W	90	74			45	12				12
	A	10.8	8.5			2.7	7.5				7.5
21 - 25	W	90	74			45	12				12
	A	10.8	8.5			2.7	7.5				7.5
26 - 30	W	90	74			45	12				12
	A	10.8	8.5			2.7	7.5				7.5
31 - 35	W	90	74			75	12	12			12
	A	10.8	8.5			4.8	7.5	7.5			7.5
36 - 40	W	90	74	74		75	12	12			12
	A	10.8	8.5	8.5		4.8	7.5	7.5			7.5
41 - 45	W	90	74	74		75	12	12			12
	A	10.8	8.5	8.5		4.8	7.5	7.5			7.5
46 - 50	W	90	74	74	106	75	12	12		12	12
	A	10.8	8.5	8.5	13.1	4.8	7.5	7.5		7.5	7.5
51 - 60	W	90	74	74	106	75	12	12		12	12
	A	10.8	8.5	8.5	13.1	4.8	7.5	7.5		7.5	7.5

**WEIGHTS AND PROJECTED WIND AREAS
FOR TRAFFIC SIGNAL HEADS**

LENS SIZE - INCHES ALL SECTIONS	SIGNAL CONFIGURATION #1	SIGNAL SECTIONS EACH DIRECTION	DIRECTIONS	WEIGHT - POUNDS WITHOUT BACKPLATE *2	WIND AREA - SQUARE FEET WITHOUT BACKPLATE *3	WEIGHT - POUNDS WITH BACKPLATE *2, 4	WIND AREA - SQUARE FEET WITH BACKPLATE 5 IN. BORDER *3	WIND AREA - SQUARE FEET WITH BACKPLATE 8 IN. BORDER *3
8	A	3	1	40	2.1	46	5.6	8.3
8	A	4	1	50	2.8	57	6.9	10.1
8	B	3	2	75	2.1	87	5.6	8.3
8	C	3	2	75	4.8	87	8.3	11.0
8	B	4	2	95	2.8	109	6.9	10.1
8	C	4	2	95	6.4	109	10.5	13.7
8	D	3	3	110	4.8	128	8.3	11.0
8	E	3	3	110	7.5	128	11.0	13.7
8	D	4	3	135	6.4	156	10.5	13.7
8	E	4	3	135	10.0	156	14.1	17.3
8	F	3	4	140	7.5	164	11.0	13.7
8	F	4	4	175	10.0	203	14.1	17.3
12	A	3	1	65	4.1	74	8.5	11.8
12	A	4	1	80	5.4	90	10.8	14.6
12	B	3	2	140	4.1	158	8.5	11.8
12	C	3	2	140	8.9	158	13.3	16.6
12	B	4	2	155	5.4	175	10.8	14.6
12	C	4	2	155	11.9	175	17.3	21.1
12	D	3	3	175	8.9	202	13.3	16.6
12	E	3	3	175	13.7	202	18.1	18.4
12	D	4	3	225	11.9	255	17.3	21.1
12	E	4	3	225	18.3	255	23.7	27.5
12	F	3	4	230	13.7	266	18.1	21.4
12	F	4	4	295	18.3	335	23.7	27.5

***NOTES:**

- 1 - Refer to the attached figure of traffic signal configurations.
- 2 - A one-way 12" lens section weighs 15 pounds w/o back plate.
- 3 - Add appropriate incremental signal area and/or back plate area for over four section heads.
- 4 - Add 1 pound for back plate where applicable per one-way section for over four section heads.

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 in all configurations

APPENDIX C

STANDARD FORMS
AND POLICIES



**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 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)

CHECK LIST FOR CONDITION DIAGRAM

1. Plan of intersection extending 150 ft. on each approach. Scale 1" = 20 ft. or 1" = 25 ft. Show street names, legislative route numbers, if any. Maximum size of plan shall be 22" by 36" (additional sheets may be used if necessary).
2. Show north arrow.
3. Show pavement, lane and shoulder widths, all pavement markings, right-of-way and property lines, approximate grades, drainage pipes and inlets, curbing radii (curbed or uncurbed, driveways and barriers).
4. Show utility poles, street lighting, traffic islands, traffic signal poles, vehicular detectors, signal heads and controller, if any.
5. Locate no parking and restricted parking zones, hours etc., bus stops, and direction of one-way streets, if any. Show all traffic control signs and the speed limits on each approach.
6. Show existing buildings and locate any obstruction to sight distance for the driver approaching the intersection. This will include trees, shrubbery, fences, billboards, walls, etc.
7. Show location of any railroad or rail transit grade crossings within 300 feet of the intersection. Give name of the railroad or transit company, indicate existing protection and whether siding, mainline, etc.
8. Indicate distance to nearest existing traffic signal on each approach, if one mile or less. Show municipal boundaries, if within the area of the plan and identify the municipality.
9. A reproducible tracing or transparency of the Condition Diagram is to be submitted with the application for a traffic signal permit. Tracings on transparencies shall never be folded, they shall be rolled and mailed in mailing tube.

The following information shall be placed on the condition diagram by the District Traffic Engineering Unit conducting the Traffic Signal Investigation.

1. Legislative route number, if not shown, and station number for centerlines of each approach.
2. All proposed pavement markings, including cross walks, stop lines, words, symbols center and lanelines.
3. All proposed traffic signals and detectors.

4. All necessary signs for proper operation and control of the proposed signalized intersection. Decals should be used for sign and signal illustrations whenever possible.
5. The numerical designation of any signals having the same color sequence should be combined on one line of the Color Sequence and Movement Chart.
6. If traffic signals are not present within a mile, on any approach, so indicate on the condition diagram.
7. Hourly movement charts (see figure 22) for phasing and timing of Traffic Signals shall be placed on, or attached to, the condition diagram.

INDICATIONS FOR PEDESTRIANS AT SIGNALIZED INTERSECTION

All traffic signal installations, which are likely to be utilized by pedestrians, shall provide a visible indication to any pedestrian desiring to cross the street. In urban districts, it should be assumed that an occasional pedestrian will be present at most intersections. Pedestrian use shall be based on pedestrian count covering those periods of the day when pedestrian activity would normally occur. This pedestrian count should be obtained in conjunction with the vehicle count taken to warrant the signal installation or improvement.

1. Type of indication

The type of indication visible to a pedestrian shall consist of one of the following:

- 1.1 A red, yellow and green traffic signal which is one of the primary signal indications for vehicles and is visible to pedestrians.
- 1.2 A red, yellow and green traffic signal which supplements the primary vehicle signals and is provided specifically for pedestrian guidance because the visibility of the primary signals is inadequate for pedestrian use.
- 1.3 A WALK/DON'T WALK signal provided specifically for pedestrian guidance.
- 1.4 A R9-3 (NO PEDESTRIAN CROSSING) sign when pedestrian crossings at an intersection or specific legs of an intersection are prohibited because of safety considerations.

2. Use of Vehicular Signals

A red, yellow and green traffic signal will be considered the primary indication used for pedestrian guidance. Normally, the indications for vehicular traffic will provide an adequate indication for both vehicles and pedestrians but there will be occasions when an additional vehicular signal will be required to provide an indication for pedestrians. This signal shall be installed as provided in the Department's Regulations.

3. Use of WALK/DON'T WALK Signals

WALK/DON'T WALK signals shall be used in conjunction with vehicular traffic signals under any of the following conditions:

- 3.1 When a traffic signal is installed under the pedestrian volume or school crossing warrant.

- 3.2 When an exclusive interval or phase is provided for pedestrian movement in one or more crosswalks with all conflicting vehicular movements required to stop before proceeding with any legal movement.
- 3.3 When the proper vehicular indications are confusing to pedestrians due to conflicting messages.
- 3.4 At established school crossings. An official school crossing exists if any one of the following exists:
 - 3.4.1 The intersection is adjacent to school property.
 - 3.4.2 The school crossing is an official school crossing designated by school and/or traffic officials responsible for school safety.
- 3.5 When the normal vehicle clearance time does not provide sufficient time to minimize vehicle-pedestrian conflicts.
- 3.6 When multi-phase or split phase timing would tend to confuse pedestrians guided only by vehicle signal indications for a specific approach.
- 3.7 When pedestrians cross part of the street, to or from an island, during a particular interval and where they should not be permitted to cross another part of that street during any part of the same interval.

When WALK/DON'T WALK signals are installed for one or more crosswalks at an intersection, WALK/DON'T WALK signals should be installed at all crosswalks within the intersection. However, the designer must be certain that all crossings within an intersection have some type of indication visible to the pedestrian.

4. Exclusive WALK Phase

- 4.1 If it is determined that there would be significant conflicts between turning vehicles and pedestrians during the WALK mode of operation, an actuated exclusive WALK phase may be considered as follows:
 - 4.1.1 A capacity analysis is performed assuming the exclusive WALK phase occurs every cycle. The results of this analysis must be used to optimize the signal timing such that a level of service consistent with the Design Manual is obtained.

4.1.2 If a satisfactory level of service cannot be obtained in accordance with 4.1.1, another capacity analysis will be made based on the usage of the exclusive WALK phase. This amount of usage will be based upon the actual numbers and arrival rates of pedestrians at the intersection (based on at least a 30 minute count taken during the peak hours). Then the percent of cycles utilized will be determined and an adjustment in the G/C ratio made. The revised analysis will be used to determine the optimum signal timing consistent with the level of service requirements of the Design Manual.

4.1.3 If an acceptable level of service cannot be obtained under method 4.1.1 or 4.1.2 above and the need for an exclusive WALK phase is still apparent, the District Traffic Engineer shall submit all available documentation on the need for the exclusive WALK phase along with his recommendations to the Traffic Engineering and Operations Division for review and comment.

5. Use of the R9-3 (No Pedestrian Crossing) Sign

The R9-3 sign should be used to prohibit pedestrians from crossing the roadway at a point where geometrics and/or traffic conditions create an unsafe condition. Unless this condition can be adequately documented, provisions shall be made to give the pedestrian an opportunity to legally cross a roadway, even though the movement occurs only occasionally. If actuated equipment is being used, this means that pedestrian pushbuttons shall be installed at each end of any crosswalk controlled by an actuated phase. Prohibition of pedestrian movements across an approach at an intersection because of the lack of pushbuttons is not permitted.

6. Additional Considerations

The following items shall be considered during the design of the traffic signals for an intersection involving pedestrian movements:

- 6.1 Crosswalks shall be marked at those crossings where WALK/DON'T WALK signals are utilized or at those intersections where pedestrian movements are restricted to certain crossings because of the use of R9-3 signs.
- 6.2 When actuated signals are installed, pedestrian pushbuttons shall also be installed in accordance with Department Regulations.
- 6.3 When the signalized intersection is within an interconnected progressive system, the pedestrian phase shall be incorporated into the background cycle to maintain a desirable progression and band width.
- 6.4 At signalized intersections where a right turn "yield" movement is allowed, the following shall be considered:
 - 6.4.1 If the approach is to have crosswalks installed, crosswalks may be used across the right turn "yield" movement.
 - 6.4.2 Crosswalks across the "yield" should be located to provide the optimum sight distance for both the pedestrian and the motorist involved.
 - 6.4.3 WALK/DON'T WALK signals shall not be used across "yield" movements.

TRAFFIC SIGNAL REPORT

County - Township, Borough or City
Intersection
Traffic Signals

A summary of our traffic signal investigation for the subject intersection is as follows:

1. Vehicular traffic entering the intersection from all approaches on the major street and the minor street during the peak hour is _____ vehicles per hour.
2. Vehicular traffic entering the intersection from both approaches on the major street during the eighth matching hours is _____ vehicles per hour. (Manual _____). There is (are) _____ lane(s) on each approach.
3. Vehicular traffic entering the intersection from one approach on the minor street during the eighth matching hour is _____ vehicles per hour. (Manual _____). There is (are) _____ lane(s) on each approach.
4. An accident report is (not) attached. There are _____ reported accidents for the last three (3) years. _____ of these would have been susceptible to correction by traffic signals. (Required if accidents are used to justify signals).
5. At the present time there are (not) traffic signals operating here.
6. () Street is (not) posted for a _____ speed limit. The 85th percentile speed is _____ miles per hour.
() Street is (not) posted for a _____ speed limit. The 85th percentile speed is _____ miles per hour.
7. Left turns on the _____ approach satisfy the conflict factor of _____ for at least two hours. (See attachment.)
8. General Information:
 - (a) This is a (business) (residential) district in a (rural) (urban) area.
 - (b) The sight distance at this intersection does (not) exceed the minimum acceptable criteria.
 - (c) The volume of turning vehicles does (not) present difficulty for the pedestrian crossing here.
 - (d) Elderly or handicapped pedestrians do (not) cross this intersection. (If "do" explain in remarks).
 - (e) This is (not) a school crossing which is (not) controlled by a school patrol or crossing guard.
 - (f) If railroad grade crossing is nearby, give details pertaining to same. (See Figure J.)
 - (g) The level of service provided for each approach is:
NB _____ SB _____ EB _____ WB _____

9. We discussed the matter of placing signals here with the proper local officials on (Date). The officials contacted were (Names). The following is a report of that meeting.*
10. We (do not) recommend the issuance of the requested permit for (Type) signals. This recommendation is based on the attached data which satisfies Warrant _____. (Include any other pertinent comments which support your recommendation.)

District Traffic Engineer

Approved:

District Engineer _____

Date _____

If a signal is not recommended, an alternate solution for the problem should be given which may be included in the letter of rejection.

The above is the general information that should be included in all reports. Additional comments should be included when needed to clarify the recommended action.

*A meeting with local officials should be held regardless of the results of the study and a report of the discussion should be included in this section.

RAILROAD GRADE CROSSING INFORMATION

When there are railroad or transit crossings at grade within 300 feet of the intersection, in any direction, the following information shall be submitted for any traffic signal request.

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 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. Example, fast train v.s. slow train, transit vehicle with a stop before reaching the crossing v.s. no stop).
7. The Speed Limit of the train over the crossing.
8. The Number and Position of the tracks should be shown on the condition diagram.



24 HOUR RECORDER COUNT SUMMARY

COUNTY _____

DATE TABULATED _____

MUNICIPALITY _____

DATES COUNTED _____

		MAJOR STREET			MINOR STREET			MAJOR STREET TOTAL	MINOR HIGHEST ONE-WAY	NOTES
		BOUND	BOUND	STREET TOTAL	BOUND	BOUND	STREET TOTAL			
A. M.	12-1									
	1-2									
	2-3									
	3-4									
	4-5									
	5-6									
	6-7									
	7-8									
	8-9									
	9-10									
	10-11									
	11-12									
P. M.	12-1									
	1-2									
	2-3									
	3-4									
	4-5									
	5-6									
	6-7									
	7-8									
	8-9									
	9-10									
	10-11									
	11-12									
TOTAL										

MAJOR STREET: _____ HOURS OF 8 HOURS MEETS _____ VPH
MINOR STREET: _____ HOURS OF 8 HOURS MEETS _____ VPH

AREA:
☐ RURAL
☐ URBAN

County _____

Municipality _____

[illegible]

C-11

Location _____

County _____

Date _____ Day of Week _____ Weather _____ Computer _____

[illegible]

Time _____ Maximum Hour Crossing _____ All Cross Walks _____

PS-1B (10-72)
CC-0830-6300-0020

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
PLANNING AND TRAFFIC DIVISION

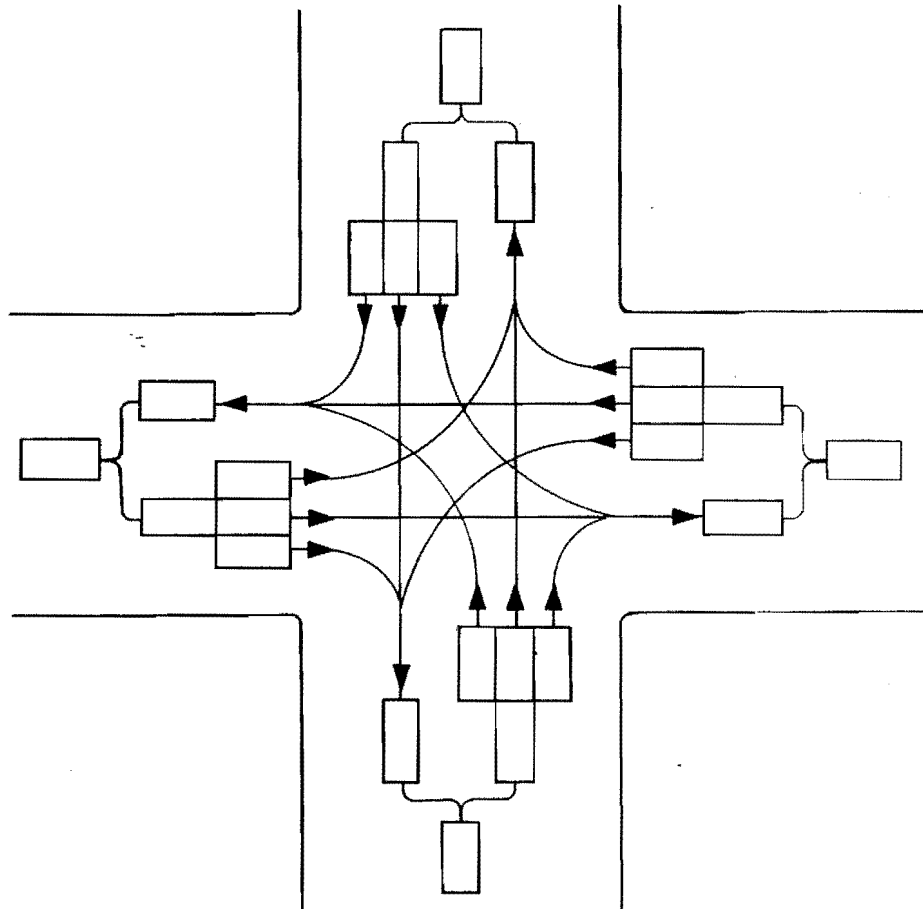
DIRECTIONAL TRAFFIC FLOW DIAGRAM
(4 WAY)

DATE _____

County _____ Township _____ Municipality _____

Intersection _____

Remarks _____



CRITERIA FOR SIGNALIZATION OF LEFT TURNING 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 by 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 geometrics and the type of signal operation in the area or along the street. Therefore, the following criteria has 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 turning movement. This study shall discuss each of the following criteria and include a capacity analysis for both the existing and proposed signal operation.

1. Volume:

Based upon the Department's experience and the data in the Highway Capacity Manual, an approach volume of two left turns for each existing cycle or two 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. In addition a conflict factor (CF), which is the product of the left turning volume and the opposing through traffic volume for two one hour periods of a normal weekday, should satisfy the following guidelines. Meeting these values only indicates the need for a left turn phase, the type of operation should be the one which provides the most efficient operation.

1.1 Protected/Permitted Left Turn Phase

A. Without separate turning lanes

- 1 opposing lane; CF = 35,000
- 2 opposing lanes; CF = 45,000

B. With separate turning lane

- 1 opposing lane; CF = 50,000
- 2 opposing lanes; CF = 65,000

1.2 Protected/Prohibited Left Turn Phase (must have a separate turning lane)

- 1 opposing lane; CF = 67,500
- 2 opposing lanes; CF = 90,000

2. Geometric and Operational Characteristics:

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

2.1 Accident Records

A review of the accident records should be made to determine the number of reported accidents which may be corrected by a left turn phase that have occurred within a 12 month period. A minimum of five correctable accidents within this period would justify consideration of a left turn phase.

2.2 Geometrics

A field review of the intersection and approach geometrics 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.

2.3 Vehicle Characteristics

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

2.4 Adjacent Traffic Signals

Consideration must 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 must be considered.

After tabulating the results of the above items and completing the capacity analysis, a written report must be retained as part of the District's file before they issue a new or revised permit or deny the request.

LEFT TURN SIGNALIZATION

COUNTY _____ MUNICIPALITY _____

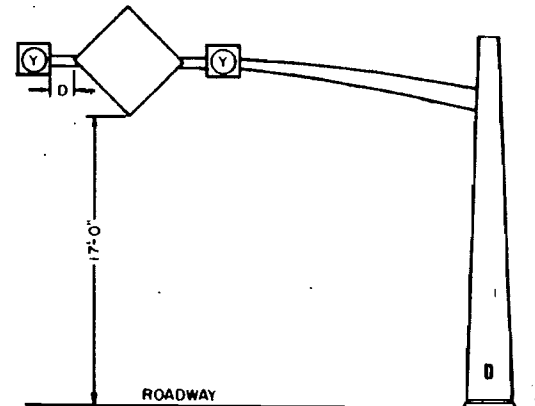
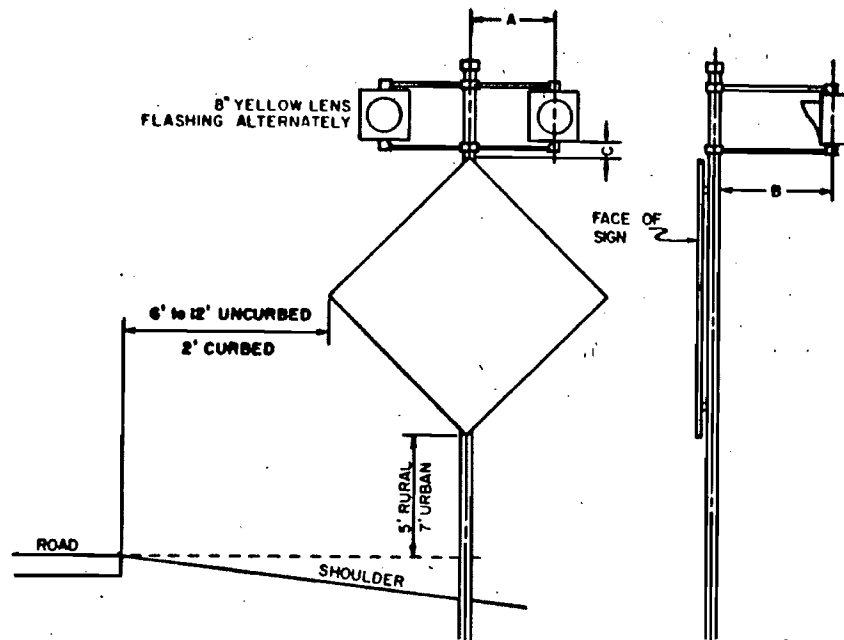
INTERSECTION _____

TIME	LEFT TURN				OPPOSING		CALCULATED CONFLICT FACTOR
	DIRECTION	EXCLUSIVE LANE	VOLUME	PER CYCLE	THROUGH VOLUME	NUMBER OF LANES	

COMMENTS:

COMPLIED BY _____

DATE _____



SIGN SIZE	A	B	C	D
30 x 30	16"	15"	6"	12"
36 x 36	*20"	15"	6"	12"
48 x 48	28"	15"	6"	12"
60 x 60	37"	15"	6"	12"

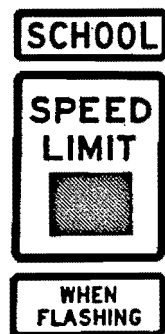
* Dimension A for S1-1 and S2-1 signs is 16" and the 36" x 36" is the minimum size sign used.

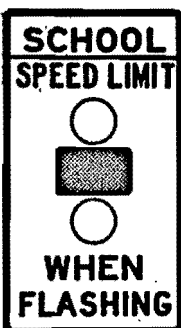
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF TRAFFIC ENGINEERING

FLASHING WARNING
DEVICE DETAIL
(TYP.)

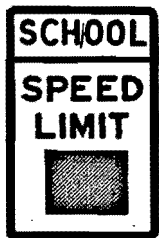
APPROVED GR Doughty
Director Bureau of Traffic Engr.

NO SCALE | DATE 7/17/78

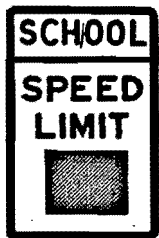

 SCHOOL S4-3

 SPEED
LIMIT

 R2-1 ()
24"x30"

 WHEN
FLASHING S4-4


 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 8" diameter signals mounted externally.
3. Type II must have a PennDOT Certificate of Approval. The sign shall have minimum dimensions of 30"x54" with 6" or 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 24"x38" and 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 12" from the edge of the sign.

 COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF TRAFFIC ENGINEERING

 VARIABLE SCHOOL SPEED
LIMIT SIGNS

 APPROVED 9/13/78 Doughty
Director Bureau of Traffic Engr.

NO SCALE

DATE 9/14/78

CONDUIT SIZE

FROM TO

CABLE # 14 AWG				CABLE # 12 AWG				GROUND WIRE			DET. LEAD-IN			CONDUIT SIZE	
Conduct.	Cable Area	Quan.	Area	Conduct.	Cable Area	Quan.	Area	Quan.	Area Each	Area	Quan.	Area Each	Area		
3	.107			3	.145				.013			.100*			
5	.152			5	.212										
7	.180			7	.273										
Totals				+				+			+			=	

3	.107			3	.145				.013			.100*			
5	.152			5	.212										
7	.180			7	.273										
Totals					+			+			+			=	1

3	.107			3	.145				.013			.100*				
5	.152			5	.212											
7	.180			7	.273											
Totals				+				+				+			=	

3	.107			3	.145				.013			.100*			
5	.152			5	.212										
7	.180			7	.273										
Totals					+			+			+			=	

3	.107			3	.145				.013			.100*			
5	.152			5	.212										
7	.180			7	.273										
Totals					+			+			+			=	

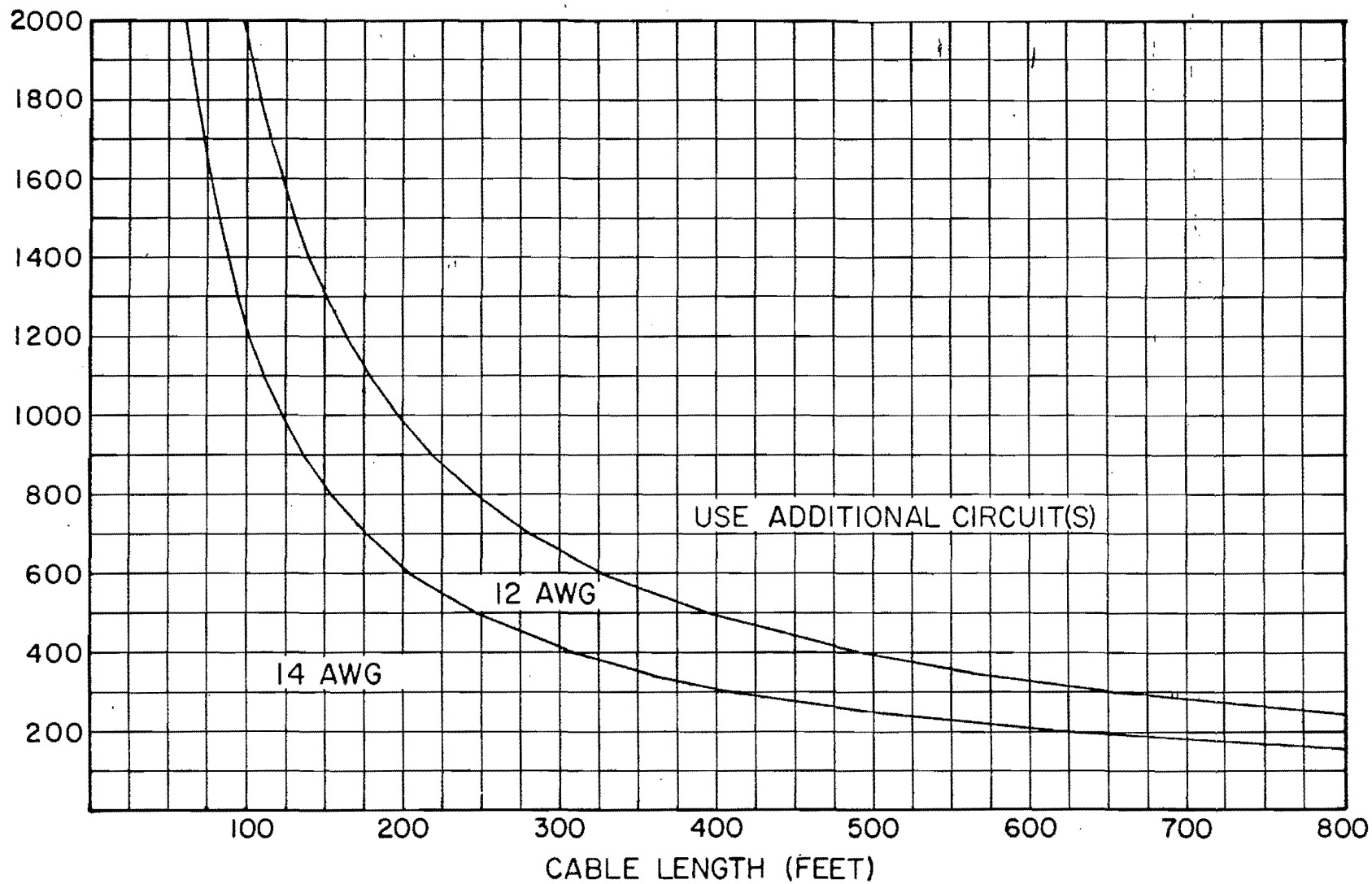
3	.107			3	.145				.013			.100*					
5	.152			5	.212												
7	.180			7	.273												
Totals				+				+				+				=	

CONDUCTOR SIZE

CONTROLLER CABINET		- Signal Head		- Signal Support	8 in. Signal - 100 Watt
		- Detector		- Junction Box	12 in. Signal - 150 Watt
					All Ped. Signals - 100 Watt

NOTE: When calculating cable length include all vertical dimensions
e.g. inside support shafts and signal heads, drip loops,
slack in junction boxes and controller cabinet.

C-21
LOAD
(WATTS)



CONDUCTOR SIZE - TRAFFIC SIGNAL CABLE



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; or 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

C-22

BY _____
☐ CHIEF, TRAFFIC ENGINEERING & OPERATIONS DIVISION
BUREAU OF HIGHWAY SERVICES
☐ DISTRICT ENGINEER



TRAFFIC SIGNAL DESCRIPTION

Municipality _____ County _____

Intersection _____

Permit No. _____

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

No. of Signal Faces _____ 8" Lenses _____ 12" Lenses _____ Arrows: Vert. _____ Right _____ Left _____

W/DW - 3" Letters _____ W/DW - 4½" Letters _____

Type of Controller: Pretimed _____ Semi-Act. _____ Full Act. _____ Vol. Den. _____

Other _____

Make of Controller and Model No. _____ P.D.T. 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. _____ P.D.T. Approval No. _____

Type and number of Detector/s _____
Loop _____ Sonic _____ Radar _____ Magnetic _____ Ped. _____ Other _____

Make of Detector and Model No. _____ P.D.T. Approval No. _____

Make of Detector and Model No. _____ P.D.T. Approval No. _____

Make of Detector and Model No. _____ P.D.T. 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 _____



TRAFFIC SIGNAL DESCRIPTION

Municipality (1) County (2)Intersection (3)Permit No. (4)(5)
Type of Mounting: Post Mounted Overhead Post Mounted & Overhead (8)No. of Signal Faces (6) 8" Lenses (7) 12" Lenses Arrows: Vert. Right Left (9)
W/DW - 3" Letters W/DW - 4½" Letters (10)
Type of Controller: Pretimed Semi-Act. Full Act. Vol. Den. Other Make of Controller and Model No. (11) P.D.T. Approval No. (12)
Make of Conflict Monitor and Model No. (13)
Is Installation: Isolated In a system Location of master controller

(14)

Flashing Operation: Emergency Time Clock Manual (15)
Yellow On Red On (16)
Make of Flashing Unit and Model No. P.D.T. Approval No. (17)
Type and number of Detector/s (18)
Loop Sonic Radar Magnetic Ped. Other Make of Detector and Model No. P.D.T. Approval No. Make of Detector and Model No. P.D.T. Approval No. Make of Detector and Model No. P.D.T. Approval No.

(19) (20)

Does installation & operation conform with permit? Does installation & operation conform to present standards? (21) (22)
Have Stop Signs been removed? Date signal placed in operation (25)
REMARKS AND RECOMMENDATIONS (include any additional facts necessary for full description. Use back of form if necessary.)(23)
Signed (24)
Date

GUIDE FOR COMPLETION OF FORM T.E. 699

<u>Item No.</u>	<u>Procedure</u>
1.	List municipality(ies) where signal is located.
2.	List county(ies) where signal is located.
3.	<u>Include</u> all LR's, TR's, street names, and twp. road numbers, if known.
4.	Permit number as listed on permit.
5.	Check type of mounting.
6.	Total number of signal faces including W/DW. List manufacturer's name, model number and 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 W/DW lenses of each type.
10.	Check type of controller <u>not</u> <u>type</u> of operation.
11.	Give manufacturer's name, model number and approval number for controller. When applicable, list modules 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. If controller is not equipped with a flashing unit, indicate "None" on line 16.
15.	List streets that have flashing yellow and flashing red, respectively.
16.	List manufacturer's name, model number and 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 approval number for each type detector unit or amplifier.

Item No.Procedure

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, coordinating equipment, electrically operated signs, etc., should be identified on the back of the form by showing manufacturer's name, model number and 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. Submit a copy of this form and the condition diagram with a copy of the final letter to the Bureau of Highway Services, Traffic Engineering and Operations Division.