CHAPTER 4D. TRAFFIC CONTROL SIGNAL FEATURES

Section 4D.02 Responsibility For Operation and Maintenance

The following is added to this section:

Support:

The Department of Transportation is responsible for the operation of all State highway traffic signals, regardless of whether the signal is maintained by the State or by others.

Standard:

State highway traffic signals shall include, but are not necessarily limited to, all signals on a State highway and at ramp connections to local streets.

Maintenance and operation of highway traffic signals involving State Highways by an agency other than the Department of Transportation shall require a jointly approved written agreement.

Section 4D.04 Meaning of Vehicular Signal Indications

In the second paragraph, item C.2, delete the second sub-paragraph that begins with "When an R10-17a sign…" The R10-17a sign shall not be used in California. Turning on a steady red arrow is not permitted in California.

Section 4D.05 Application of Steady Signal Indications

Delete subparagraph s B.4 (c) and B.4 (d) in the Standard that begins with "An engineering…" Signs W25-1 and W25-2 shall not be used in California.

Delete and replace the last paragraph under Option that begins "If U-turns are permitted…" with:

Standard:

When a RIGHT TURN ARROW controls the Right Turn movement, a conflicting U-turn approach shall be prohibited.

Section 4D.06 Application of Steady Signal Indications for Left Turns

Delete subparagraphs A.4 in the Standard that begins "If the left-turn signal face…"

The following is added to this section:

Guidance:

Since separate signal phases for protected left turns will reduce the green time available for other phases, alternate means of handling left turn conflicts should be considered first.

Support:

The most likely possibilities are:

1. Prohibition of left turns. This can be done only if there are convenient alternate means of making the movement. Typical alternate means are:
   a. A series of right and/or left turns around a block to permit getting to the desired destination; or
   b. Making the left turn at an adjacent unsignalized intersection during gaps in the opposing through traffic.
2. Geometric changes to eliminate the left turn. An effective change would be a complete separation or a complete or partial "clover leaf" at grade. Any of these, while eliminating left turns, requires additional cost and right of way.
3. Provide protected-permissive or permissive-protected left turn operation. The protected left turn interval may be prohibited during certain periods of the day to allow only permissive intervals for left turn movement in order to increase the green time available for other phases. Refer to Section 4D.112 for the requirements of protected-permissive or permissive-protected left turn operation.

Guidance:

Protected left turn phases should be considered where such alternatives couldn't be utilized, and one or more of the following conditions exist:

1. Accidents - Five or more left turn accidents for a particular left turn movement during a recent 12-month period.
2. Delay - Left-turn delay of one or more vehicles, which were waiting at the beginning of the green interval and are still remaining in the left turn lane after at least 80% of the total number of cycles for one hour.
3. Volume - At new intersections where only estimated volumes are available, the following criteria may be used. For pretimed signal or a background-cycle-controlled actuated signal, a left turn volume of more than two vehicles per approach per cycle for a peak hour; or for a traffic-actuated signal, 50 or more left turning vehicles per hour in one direction with the product of the turning and conflicting through traffic during the peak hour of 100,00 or more.
4. Miscellaneous. Other factors that might be considered include but are not limited to: impaired sight distance due to horizontal or vertical curvature, or where there are a large percentage of buses and trucks.

Section 4D.07 Application of Steady Signal Indications for Right Turns

The following is added to this section:

Guidance:

A right-turn green arrow should be considered for use only when there is an exclusive right-turn lane or it is the only movement that traffic is permitted to make or when the right-turn volume exceeds 200 vehicles per hour.

Section 4D.09 Unexpected Conflicts During Green or Yellow Intervals

In the Standard, subparagraph A, first sentence, place a period (.) after "…signal indication." Delete "…except for the situation regarding U-turns described in Section 4D.05."

Section 4D.10 Yellow Change and Red Clearance Intervals

The following is added to this section:

Support:

The purpose of the yellow signal indication is to warn traffic approaching the signal that the related green movement is ending or that a red indication will be exhibited immediately thereafter and traffic will be required to stop when the red signal is exhibited.

Guidance:

The length of the yellow change interval is dependent upon the speed of approaching traffic. See Table 4D-102 for suggested minimum yellow interval timing.

Option:

Red clearance intervals which follow yellow change intervals are not required, but may be considered where any of the following conditions exist:

1. Intersections that are wide, offset or contain unusual geometry; intersections where the visibility of conflicting traffic is blocked or limited;
2. Movements where the approach speeds are 90 km/h (55 mph) or more; or
3. Where it is desirable to help clear vehicles that recurrently become queued in the intersection where there are permissive left turns.

Guidance:

Red clearance intervals range from 0.01 to 2.0 seconds and should not exceed 6 seconds.

Section 4D.13 Preemption and Priority Control of Traffic Control Signals

In Options subparagraph C, delete the word "turning" to change the sentence to read:

A. A special sequence of signal phases to display a red indication to prohibit all movements toward the track during the approach or passage of a train or transit vehicle.

The following is added to this Section:
Guidance:

Traffic control signals within 60 m (200 ft) of a highway-rail crossing should be operated during railroad pre-emption in a manner that minimizes delay and potential conflicts. These alternatives include steady all-red, all-red flash, limited service or special sequential signal phasing.
Option:

Extinguishable or changeable message regulatory signs and/or appropriate red traffic control signal indications that are visible only during railroad or light rail transit pre-emption may be used to prohibit movements from a signalized location toward a highway-rail crossing. Examples of applicable regulatory signs that may be used in a extinguishable format include the R3-1, R3-2 and R5-1 signs.
Support:

Left turns from a nearby signalized intersection toward a highway-rail crossing can be prohibited during railroad or light rail transit pre-emption by use of a red-left arrow display or a extinguishable R3-2 sign. Likewise, right turns from a nearby signalized intersection toward such a crossing can be prohibited by use of a red right arrow display or a extinguishable R3-1 sign. Through movements from a nearby signalized intersection toward a highway-rail crossing can be prohibited by a circular red display or a extinguishable R5-1 sign.

Where the highway-rail crossing impacts two streets near a signalized intersection, then steady all red operation may be appropriate during railroad or light rail transit pre-emption.
Where the typical pre-emption period tends to be short, such as for light rail transit or commuter trains, a single pre-emption signal phase that serves some vehicular movements and prohibits others may be appropriate. So-called “limited-service” operation, which provides a steady circular green to traffic parallel to the rail line, is one such example.

Where the pre-emption period tends to be long, such as for some freight train movements, all-red flash or special sequential phases that alternate among movements that do not approach the highway-rail crossing, possibly in combination with extinguishable signs, may be appropriate to provide alternating right-of-way.

Where there are exclusive turn lanes that accommodate turns toward the highway-rail crossing, then it becomes practical to prohibit those moves during railroad pre-emption.

Where exclusive turn lanes or special sequential phases are not feasible, then all-red flash may be desirable to allow movements to be made after motorists stop to assess the railroad or light rail transit pre-emption operation.

The desirability of prohibiting movements toward the highway-rail crossing during railroad or light rail transit pre-emption increases as:

1) the distance between the signalized intersection and the highway-rail crossing decreases; and,
2) the volume that likely would enter increases.

Section 4D.15 <u>Size, Number, and Location of Signal Faces by Approach</u>
The following is added to the first standard, second paragraph of this section:
Standard:

F. For mast-arm mounted, span-wire mounted and signal bridge mounted indications
The following is added to this section:
Standard:

There shall be at least two signal faces for each controlled approach of an intersection including signalized left turn lanes.
Guidance:

Supplemental signal faces should be considered if any of the following conditions exist:

1. The area is rural.
2. The area is urban and the signal is the first one on a particular highway.
3. The roadway is striped for two or more approach lanes.

4. Where visibility of the signal is affected by alignment or obstructions.

Support:

On an undivided roadway, the signal faces for each through approach of an intersection are usually placed at the far right and far left corners.

Option:

The signal faces for two or more approaches may be combined on a single standard.

Support:

However, it is generally desirable to locate the signal faces on separate standards at curb returns. This practice will tend to maximize the visibility of the signal faces for the controlled approach while minimizing the visibility of the signal faces intended for the cross-street approach.

Guidance:

Separate standards should be considered whenever the curb return radius is greater than 3 m (10 ft).

The preferred locations for new installations of signal faces for fully-protected left turn movements at a typical intersection are on a mast arm of sufficient length to place one signal face as nearly as practical in line with the left turn lane and to place the second face on a standard at the far left corner.

Option:

Unusual roadway geometrics, wide medians, wide roadways, more than one left turn lane in the same direction or other factors may require the left turn signal face(s) to be mounted on standard(s) located in a median to satisfy visibility requirements.

A signal face, containing a circular green indication, may be located in a far median only when:

1. The signal phasing provides a protected left turn movement; or
2. The signal face is provided with some type of visibility control so that the indications are not visible to traffic in the left turn storage lane; or
3. It is not facing a left turn storage lane.

A signal face containing a circular green indication may be located in the near median where there is a left turn storage lane and there is no associated left turn phase.

Supplemental signal faces may be placed at a near side location or suspended from a mast arm.

Section 4D.19 <u>Lateral Placement of Signal Supports and Cabinets</u>

The following is added to this section:

Guidance:

Normally, controller cabinets should be located in accordance with the following:

1. It should not be vulnerable to traffic.
2. Traffic movements at the intersection should be visible from the controller timing position.
3. The doors of the cabinet should open away from the curb or traveled way.
4. It should be possible to park a maintenance truck close to the cabinet.
5. It should not be located in a drainage ditch, in an area which could be under water or where subjected to water from sprinklers.
6. It should not obstruct sidewalks, wheelchair ramps, or store entrances.
7. It should be placed so as not to obstruct pedestrian or driver visibility.

Support:

Refer to Figures 4D-102 through 4D-108 for typical signal layouts for various intersections.

Standard:

Upon requests, keys for the police panel on traffic signal controller cabinets shall be furnished to the California Highway Patrol offices or local enforcement agencies.

Section 4D.20 Temporary Traffic Control Signals

The following is added to this section:

Option:

Temporary signals for traffic control at the intersection of a State highway and a haul road, or to provide one-way traffic control through a construction zone, may be either the fixed or portable type. Such signals are normally installed by a contractor and may require an Encroachment Permit.

Standard:

1. **Requirements.**
   Each plan for temporary signals shall include the equipment details as well as the following operating requirements:
   a. **Shall meet all requirements of section 4D.20 of the MUTCD**
   b. **Signal faces, detectors and control equipment is to be kept in good operating condition at all times.**
   c. **When not in use, portable signals are to be removed from the vicinity of the highway and fixed signals are to be placed in flashing operation with yellow indications for the highway and red indications for the haul road.**
   d. **Timing of the signals will be determined by the Agency having jurisdiction.**
   e. **A Signal Ahead (W3-3) sign (and flashing beacon, if required) is to be placed on each approach of the highway in advance of the signal.**
   f. **Haul road signals shall be operated using manual control or vehicle detectors. The operation shall provide a green indication to the haul road only if the contractor's equipment is approaching the crossing. The haul road green interval shall not exceed 10 seconds and the highway green interval shall not be less than 20 seconds, unless specific permission is given in writing. A 3-second, minimum, yellow change interval, and any required red clearance interval shall follow each green interval.**
   g. **One-way traffic control signals may utilize pretimed or traffic-actuated controller units, or may be manually controlled.**
   h. **A 3-second, minimum, yellow change interval shall follow each green interval. An all-red clearance interval shall follow each yellow change interval. The all-red clearance interval shall permit a vehicle to travel the length of the one-way lane before a green indication is shown to opposing traffic.**
   i. **Failure to comply with any of the above or other specified conditions will be justification for revoking the permit.**
2. **Equipment Details.**
   Fixed temporary traffic signals shall be designed for 120-volt operation, while portable temporary signals may be battery operated. The vehicle signal faces shall be the standard 3-section type with no less than two separate signal faces for each approach, including the haul road approaches. The signal faces shall be mounted a minimum of 3 m (10 ft) above the roadway and directed so that the indications are readily seen by traffic. The signal faces for highway traffic shall be equipped with backplates.

   For one-way lane control or where conditions require sets of signals to be coordinated, the sets may be interconnected by cable or radio so that they are operated from a single manual or automatic control. The control system shall be designed to prevent conflicting green indications.

Section 4D.101 Traffic Signal Design Introduction

Support:

The design of traffic signals by the Department of Transportation is based upon the following publications:

1. Manual on Uniform Traffic Control Devices (MUTCD)
2. California Supplement to the MUTCD.
3. Standard Specifications.
4. Standard Plans.
5. Signal and Lighting Design Guide.
6. Ramp Meter Design Manual.
7. Highway Design Manual.

Additional references that can be used include:

1. Traffic Engineering Handbook.
2. Manual of Traffic Signal Design.
3. Traffic Control Systems Standards.
4. Traffic Control Devices Handbook.

See Section 1A.11 for information regarding these publications.

Section 4D.102 Signal Plan Schedules

Guidance:

The traffic signal plans for the installation of a new signal or the major modification of an existing signal should include the following schedules:

1. Pole and Equipment Schedule.
   A pole and equipment schedule shows the types of standards, mast arm lengths, types and mounting for vehicle and pedestrian signal faces, and other equipment. See Table 4D-106 and the Standard Plans.
2. Conductors and Conduit Schedule.
   A conductor and conduit schedule shows the size of each conduit run, and the size, type and number of conductors or cables in each conduit run. See Table 4D-107.

Support:

Dimensions of conductors and conduit and data for determining conduit size are shown in Tables 4D-108 and 4D-109.

Section 4D.103 Vehicle Detectors

Support:

The proper operation of a traffic-actuated signal is dependent upon the appropriate type and proper placement of detectors. The types and applications of vehicle detectors currently used include the following:

1) Inductive Loop - The inductive loop detector, because of its presence feature, detects a standing vehicle as well as a moving one. The detection area is roughly that enclosed by the loop.
2) Magnetometer- The magnetometer detector detects a standing vehicle, as well as a moving one, and has a detection area up to 1 m (3.3 ft) in diameter over each sensing element.
3) Magnetic- The magnetic detector detects only vehicles moving in excess of 8 km/h (5 mph). One sensing element covers one or two traffic lanes.
4) Video Detection- Detects vehicles passing through the field of view of a CCTV camera or image sensor. They are useful during construction or other temporary situations when lanes change frequently in width and location as well as where the installation of conduit and detector loops is expensive or difficult. Care is necessary to avoid locations and conditions, which could obscure the detector's visibility such as extreme weather, sun glare and moving shadows.

5) Pressure Sensitive.

Standard:

No new pressure sensitive installations shall be made. Existing units shall be replaced with other types of detectors loop when:

a. They require relocation;
b. The traffic signal is to be modified; or
c. The roadway is to be resurfaced.

Support:

The normal installation of inductive loop and magnetometer detectors requires sound pavement if the detector is to operate reliably.

Guidance:

If the pavement on an approach in which these detectors are to be installed is cracked, the project should include resurfacing of the areas where the detectors and lead-in cables are to be placed.

Support:

Typical installation details for inductive loop and magnetometer detectors are shown on the Standard Plans. The longitudinal location (setback) of detectors relative to the limit line depends on the speed of traffic and the type of detector operation desired. See Table 4D-101 for suggested setback from Limit lines.

Section 4D.104 Bicycle Signals

Support:

A bicycle signal is an electrically powered traffic control device that may only be used in combination with an existing traffic signal. Bicycle signals shall direct bicyclists to take specific actions and may be used to improve an identified safety or operational problem involving bicycles.

Standard:

When bicycle traffic is controlled, only green, yellow and red lighted bicycle symbols, shall be used to implement bicycle movement at a signalized intersection. The application of bicycle signals shall be implemented only at locations that meet Department of Transportation Bicycle Signal Warrants. This will remain in effect until January 1, 2005.

A separate signal phase for bicycle movement shall be used.

Guidance:

Alternative means of handling conflicts between bicycles and motor vehicles should be considered first. Two alternatives that should be considered are:

1. Striping to direct a bicyclist to a lane adjacent to a traffic lane such as a bike lane to left of a right-turn-only lane.
2. Redesigning the intersection to direct a bicyclist from an off-street path to a bicycle lane at a point removed from the signalized intersection.

A bicycle signal phase should be considered only after these and other less restrictive remedies have had an adequate trial with enforcement and with the result that the collision frequency has not been reduced.

Section 4D.105 Bicycle Detectors

Option:

Bicycle detectors may be required at traffic-actuated signal installations.

Standard:

A Type D loop configuration shown on Department of Transportation's Standard Plan ES5B is effective for detecting bicycles and small motorcycles and shall be installed at the bicycle loop detector locations. Loop detectors shall not be placed within a pedestrian crosswalk or where it could conflict with pedestrian traffic.

Option:

The loop detector logo shown on Department of Transportation's Standard Plan A24C may be used to show a bicyclist where to stop in a bike lane or traffic lane to be detected.

Guidance:

The logo should be applied to the pavement in the center of the Type D loop.

Support:

See Figure 4D-111 for suggested locations of bicycle detectors and Department of Transportation's Standard Plans for typical bike lane pavement markings.

Section 4D.106 Selection of Traffic Signal Operation

Guidance:

A prime factor to be considered in selection of the type of traffic signal operation is adequacy. While it may be true that a sophisticated signal control will operate satisfactorily at any intersection, the intersection should not be provided with a type of control that is unnecessarily complex and expensive.

Support:

The type of traffic signal operation to be used is dependent upon the variations in traffic demand. The two general types of signal operation are pretimed and traffic-actuated. Traffic-actuated operation can be further classified as full-traffic-actuated or semi-traffic-actuated. With full-traffic-actuated operation, all traffic movements or phases are provided with detectors. In semi-traffic-actuated operation, certain phases (usually the coordinated phases) do not have detectors.

Guidance:

Pretimed and semi-traffic-actuated operation should be used in coordinated systems only. They should not be installed at isolated intersections (more than 1.6 km (1 mile) from the closest signalized intersection).

Where the distance between signalized intersections is 0.8 km (0.5 mile) or less, coordination of signals should be considered, including the preparation of a time-space diagram and an evaluation of the cost-effectiveness of coordination.

Discretion should be used with phasing at offset intersections as it may introduce operational problems, which should be recognized and avoided. The most critical of these problems is where one approach right-of-way is terminated while the opposing approach continues with a green indication.

Section 4D.107 Selection of Left-Turn Phasing

Support:

There are various methods to signalize left turn movements. See Figure 4D-101.

Guidance:

If the left turn volume is 300 or more vehicles per hour, or if delays to traffic at the intersection can be significantly reduced, consideration should be given to a two-lane left turn.

Section 4D.108 Dual Left

Support:

This method is most effective during free or isolated operation and is traffic-actuated. It is the most efficient means of providing protected left turn movements since the various phases and combinations of phases appear only on demand. A through movement is allowed to go with its associated left turn movement when there is no opposing left turn traffic.

Section 4D.109 Lead-Lag

Guidance:

This operation can be either pretimed or traffic-actuated. Normally, "Lead-Lag" phasing should be considered for coordinated signals when the offset timing determined by the system time-space diagram

results in the arrival of the two directions of traffic at different times during a cycle. This will provide the most efficient progressive band.

Section 4D.110 Opposite or Opposing

Guidance:

Opposing operation should be used where the left turn volume per lane is very high in either direction and is about equal to or greater than the companion through movement.

Support:

This method is especially useful when one of the through lanes must be used as an optional turning lane or where a separate left turn lane cannot be provided.

Section 4D.111 Permissive Left-Turn Phasing

Guidance:

When a protected-permissive or permissive-protected left-turn phasing operation is used for a signal system, no information sign is necessary.

Standard:

If a sign is used, it shall be a LEFT TURN YIELD ON GREEN (Green Ball symbol) (R10-12) sign.

Option:

Public agencies having jurisdiction may use an extinguishable message sign on local roads in place of the R10-12 sign on their local roads that are not part of an intersection with a State highway.

Standard:

The extinguishable message shall say LEFT TURN YIELD in at least 150 mm (6 in) high letters. The light source shall be designed and constructed so that when illuminated, the message shall be white and remain dark when not in use. The message shall be illuminated only when the green permissive ball is lighted.

The following apply to permissive left-turn phasing:

1. **This operation shall not be initiated where the left turn accident warrant is satisfied.**
2. **Both directions of through traffic shall be terminated simultaneously except where opposing left turns or opposing U-turns are prohibited.**

Guidance:

3. Signal faces should not be placed in a median facing a left turn lane.

Support:

4. Signs are not required for this operation unless U-turns are to be prohibited.

Section 4D.112 Signals at Interchanges

Support:

Signals at freeway interchanges require special consideration as to phasing and timing to minimize backup of traffic onto the freeway lanes.

In addition, signals at diamond-type interchanges require phasing and timing to provide the necessary turning movements from the cross street to and from the ramps, without a backup of traffic between the ramps.

Guidance:

Figures 4D-109 and C4D-110 are guides and should be used to determine the timing of traffic signals at diamond interchanges. These figures should be used in conjunction with Table 4D-103 to determine the timing of the splits and offsets for diamond interchange signals.

Support:

The decision whether to use pretimed or traffic-actuated operation is dependent not only upon traffic conditions in the interchange area, but also upon traffic conditions along the cross street. For example, a

coordinated traffic signal system along the cross street may require that the signals at the interchange be coordinated with the cross street progression

Section 4D.113 Timing of Green Intervals

Guidance:

The proportion of green time, or split, allotted to each phase or combination of phases during a signal cycle, should be as close as practicable to the proportion of critical lane traffic volumes on the respective approaches. In traffic-actuated operation, this proportioning is done automatically and continuously as a result of vehicle detector inputs to the controller unit.

Option:

Factors that may modify this proportioning are the time required for pedestrian intervals and the requirements of a coordinated system.

Support:

In the usual signal operation, predetermined splits can be selected by time-of-day or traffic-responsive equipment. In coordinated signal systems, the cycle length and the split can be varied by command from the system master controller.

Section 4D.114 Review of Traffic Signal Operations

Guidance:

All traffic signals should be periodically reviewed for proper operation. The traffic signal operation should be observed during morning and evening peak traffic periods and during off-peak periods. If an operating deficiency is observed, the reason for the deficiency should be determined. If there is a malfunction, Maintenance unit should be notified, and after corrective work is done, further surveillance should be conducted to be sure no deficiency remains. If a need for a design change is observed, an analysis should be made to determine what improvement might be necessary to improve the design.

Improvements to consider are:

1. Timing of:
   a. Maximums or Force Offs
   b. Gap Interval
   c. Offsets
   d. Cycle Length
2. Time-of-Day or Traffic Responsive Settings
3. Signal Phasing or Phase Sequence
4. Type of Operation
5. Coordination of Signals
6. Signs, Striping and/or Pavement Markings
7. Roadway Improvements

Standard:

Timing and phasing of traffic signals and any subsequent changes in timing shall be approved by the public agency having jurisdiction. Timing records shall be kept by the agency responsible for the maintenance and/or operation and be readily available to the maintenance and traffic operations staffs and other agencies, where appropriate.

Support:

Aids for timing are shown in Tables 4D-104 and 4D-105.

Section 4D.115 Railroad Preemption

Support:

Railroad preemption results in a special traffic signal operation depending on the relation of the railroad tracks to the intersection, the number of phases in the traffic signal and other traffic conditions. Railroad preemption is normally controlled by the railroad grade crossing warning equipment.

Guidance:

Typical circumstances where railroad preemption is required and the following type of signal operation should be provided during preemption:

1. Where a railroad grade crossing, provided with grade crossing warning equipment, is within 60 m (200 ft) of a signalized intersection, preemption of the traffic signal should provide the following sequence of operation:
   a. A yellow change interval and any required red clearance interval for any signal phase that is green or yellow when preemption is initiated and which will be red during the track clearance interval. The length of yellow change and red clearance intervals shall not be altered by preemption. Phases, which are in the green interval when preemption is initiated, and which will be green during the track clearance interval, shall remain green. Any pedestrian walk or clearance interval, in effect when preemption is initiated, shall immediately be terminated and all pedestrian signal faces shall display steady upraised HAND.
   b. A track clearance interval for the signal phase or phases controlling the approach that crosses the railroad tracks. The signal indication for the clearance interval may be either green or flashing red.
   c. A yellow change interval if green signal indications were provided during the track clearance interval.
   d. Depending on traffic requirements and phasing of the traffic signal controller, the traffic signal may then do one of the following:
      (1) Go into flashing operation, with flashing red or flashing yellow indications for the approaches parallel to the railroad tracks and flashing red indications for all other approaches. Pedestrian signals shall be extinguished. If flashing red is used for all approaches, an all-red or other clearance interval shall be provided prior to returning to normal operation.
      (2) Revert to limited operation with those signal indications controlling through and left turn approaches towards the railroad tracks displaying steady red. Permitted pedestrian signal phases shall operate normally. This operation shall be used only if the grade crossing warning equipment includes gates.
   e. The traffic signal shall return to normal operation following release of preemption control.
2. Where the railroad tracks run within a roadway and train speeds exceed 16 km/h (10 mph), preemption of the traffic signal should provide the following sequence of operation.
   a. A yellow change interval and any required red clearance interval for all signal phases that are green or yellow when preemption is initiated and which will be red during the preemption period. The length of yellow change and red clearance intervals shall not be altered by preemption. Phases, which are in the green interval when preemption is initiated, and which will be green during the preemption period, shall remain green. Any walk or pedestrian clearance intervals in effect when preemption is initiated shall be immediately terminated and all pedestrian signal faces shall display upraised HAND.
   b. All signal faces controlling traffic movements parallel to the railroad tracks will display green or flashing yellow indications. All other vehicle signal faces will display red indications; pedestrian signal faces will display upraised HAND.
3. Where the railroad tracks run along a roadway of a signalized intersection and train speeds do not exceed 16 km/h (10 mph), trains may be controlled by the vehicle signal indications. This type of

train control requires approval from the railroad, the Public Utilities Commission and the Director of Transportation.

4. Unusual or unique track or roadway configurations may require other solutions than those described above.

Section 4D.116 Emergency Vehicle Preemption

Option:

Authorized emergency vehicles may preempt traffic signals. The purpose of such preemption is to provide the right of way to the emergency vehicle as soon as practical. The preemption may be controlled by one of the following means:

1. By direct wire, modulated light or radio from a remote location such as a fire house; and
2. By modulated light or radio from an emergency vehicle.

Guidance:

Emergency vehicle preemption should provide the following sequence of operation:

1. A yellow change interval and any required red clearance interval for any signal phase that is green or yellow when preemption is initiated and which will be red during the preemption interval. The length of the yellow change and red clearance intervals shall not be altered by preemption. Phases, which are in the green interval when preemption is initiated, and which will be green during the preemption period shall remain green. Any pedestrian walk interval in effect when preemption is initiated shall be immediately terminated. The normal pedestrian clearance interval may be abbreviated.

Standard:

2. An all-red intersection preemption display shall not be used.

3. The traffic signal shall return to normal operation upon termination of the demand for preemption or the termination of the assured green interval.

At a traffic signal provided with both emergency vehicle preemption and railroad preemption, the railroad preemption shall have priority. In the event of a demand for an emergency vehicle preemption during the time that the intersection is operating on railroad preemption, the railroad preemption sequence shall continue unaffected until completion. In the event of a demand for railroad preemption during emergency vehicle preemption operation, railroad preemption shall immediately assume control of the intersection.

When control of emergency vehicle preemption is by means of a radio or modulated light source, the following shall apply:

1. **The transmitter shall be permanently mounted on the emergency vehicle or building and shall operate at a range sufficient to permit a normal yellow change interval and any required clearance intervals to take place prior to the arrival of the emergency vehicle. The normal pedestrian clearance interval may be abbreviated.**
2. **The preemption system may provide an indication (such as a special signal) to the driver of an emergency vehicle that preemption of the traffic signal has been effected. If a special signal light is used, the color shall not be red, yellow, or green.**
3. **The system shall be designed to prevent simultaneous preemption by two or more emergency vehicles on separate approaches to the intersection.**

When performed by a local agency, the installation of emergency vehicle preemption equipment shall be covered by an Encroachment Permit issued by the Department of Transportation's District Director.

The permit shall state the applicable requirements from those listed above and the following:

1. **It should be understood that the permit for the installation might be revoked or changed as deemed advisable or necessary by the Department of Transportation.**

2. **The timing of the preemption equipment shall be as approved in advance by the Department of Transportation and shall not be changed without written permission. The Permittee shall make any changes in timing, requested by the Department of Transportation.**
3. **The Permittee shall assume all liability for the claims, which arise due to or because of the permit.**

Support:

Normally emergency vehicle preemption equipment is installed, operated, and maintained at no cost to the State. An exception is where the equipment is installed for use by vehicles of another State agency.

Standard:

The State shall maintain the preemption equipment at the traffic signal when the signal is maintained by the State. The costs of such maintenance shall be at 100% local agency expense.

Section 4D.117 Bus/Transit Vehicle Priority

Standard:

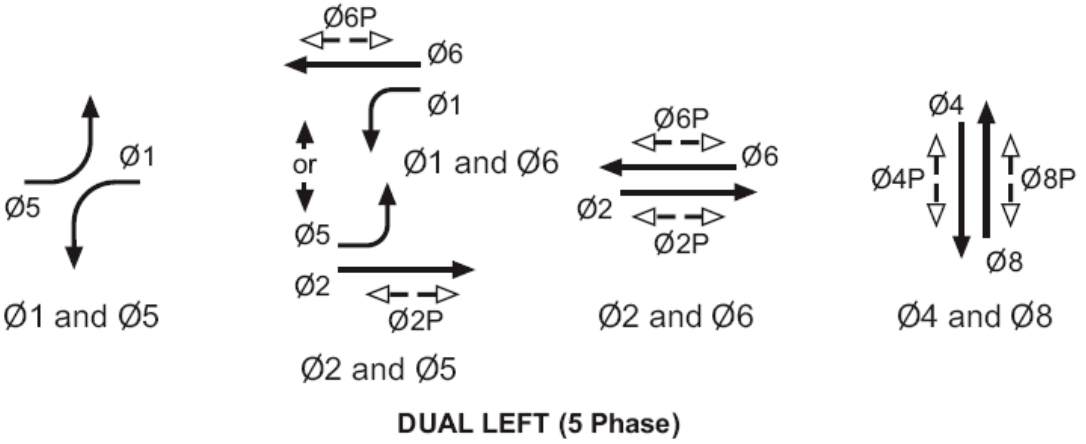
The requirements for bus/transit vehicle priority insofar as installation, encroachment permit, maintenance and funding are the same as stated above for emergency vehicle preemption. The equipment and operation requirements for bus/transit vehicle priority shall be similar to those above for emergency vehicle priority. Some exceptions to these requirements are:

1. **Equipment requirements for the transmitter are set forth in CVC Section 25352.**
2. **Any pedestrian interval in effect when priority is initiated shall not have its timing affected.**

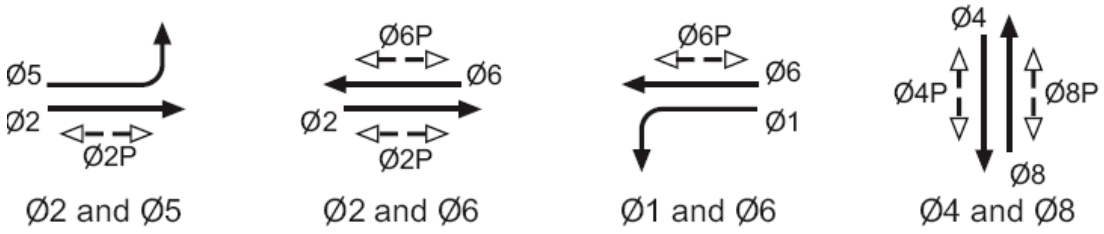
Guidance:

3. Normally, bus/transit priority should not occur more than once every other signal cycle.

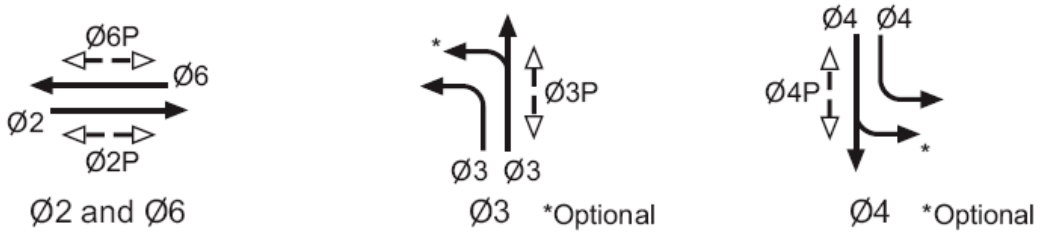
Figure 4D-101. Left-Turn Phasing Methods (Phase Diagrams)



DUAL LEFT (5 Phase)

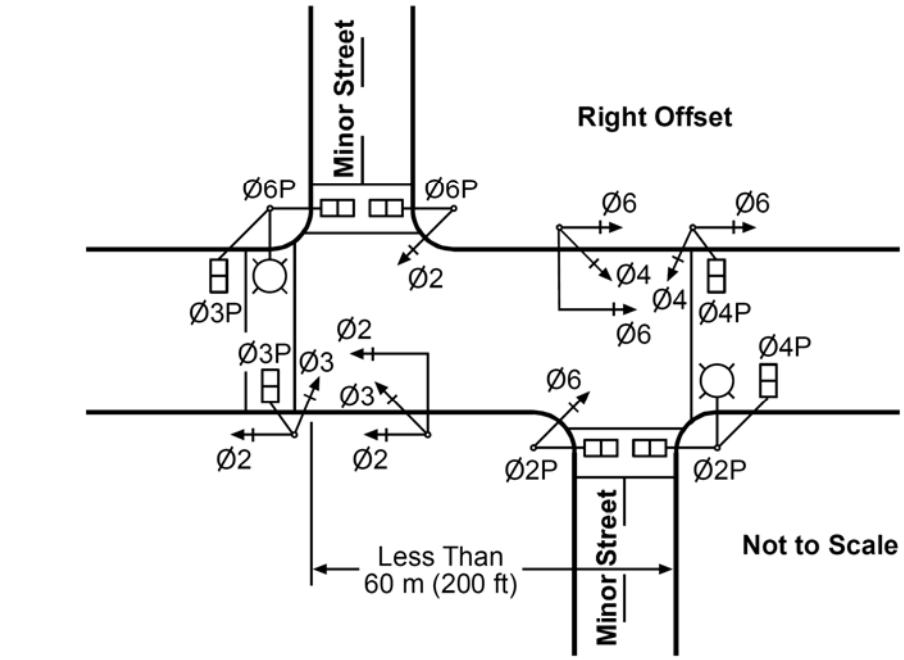


LEAD - LAG

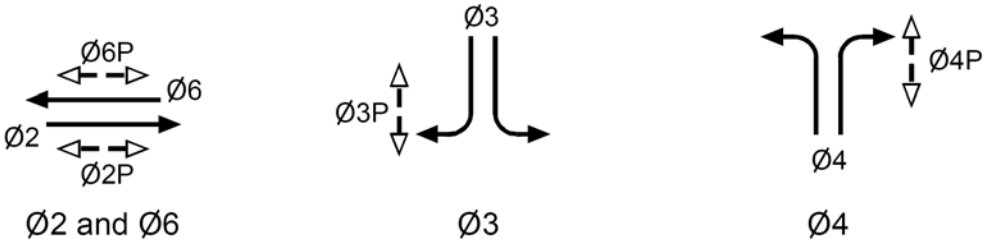


OPPOSITE (Opposing)

Figure 4D-102. Typical Signal Layout at Offset Intersections, Signalized and Marked as a Single Intersection (Sheet 1 of 4)

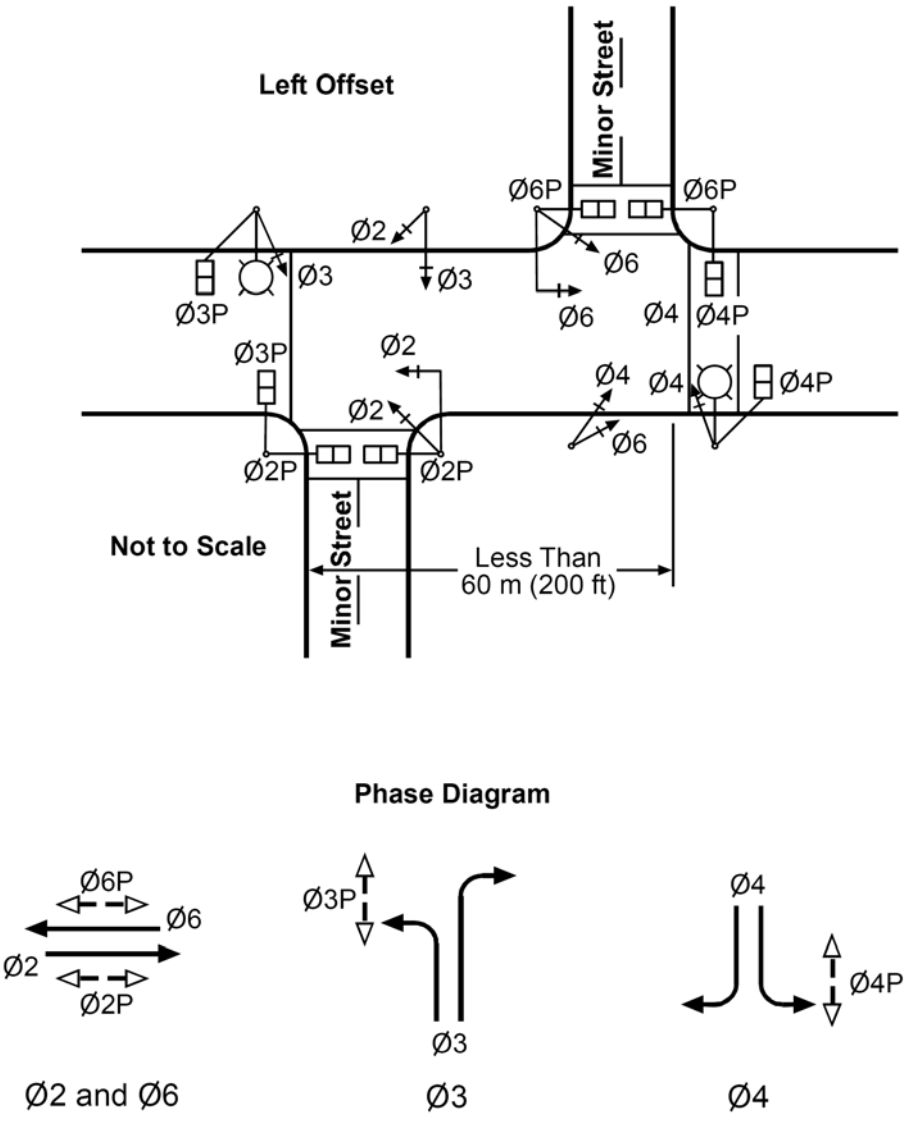


Phase Diagram



NOTE: Safety Lighting Design shall satisfy the requirements of Traffic Manual, Section 9-10.3.

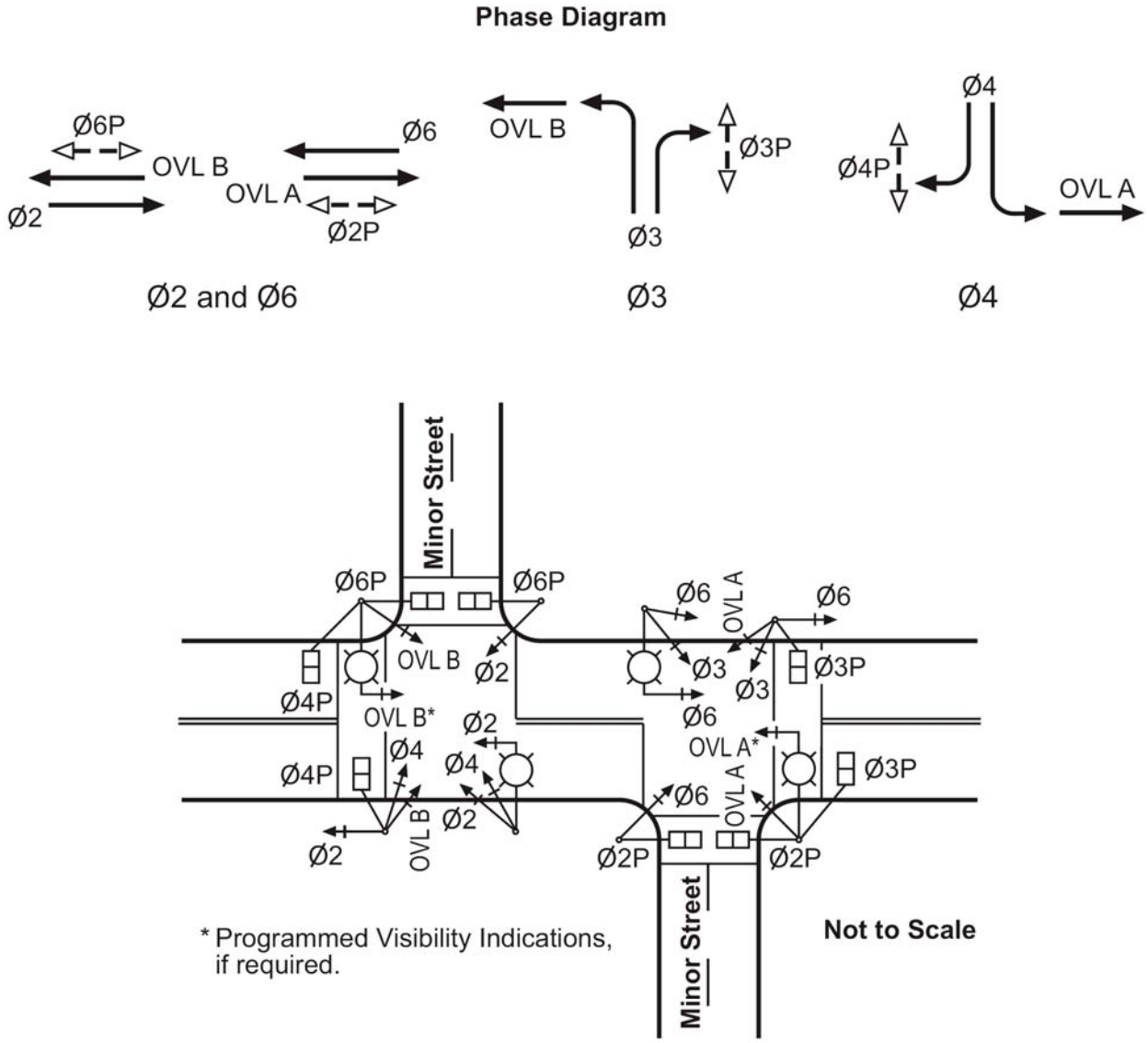
Figure 4D-102. Typical Signal Layout at Offset Intersections, Signalized and Marked as a Single Intersection (Sheet 2 of 4)



Phase Diagram

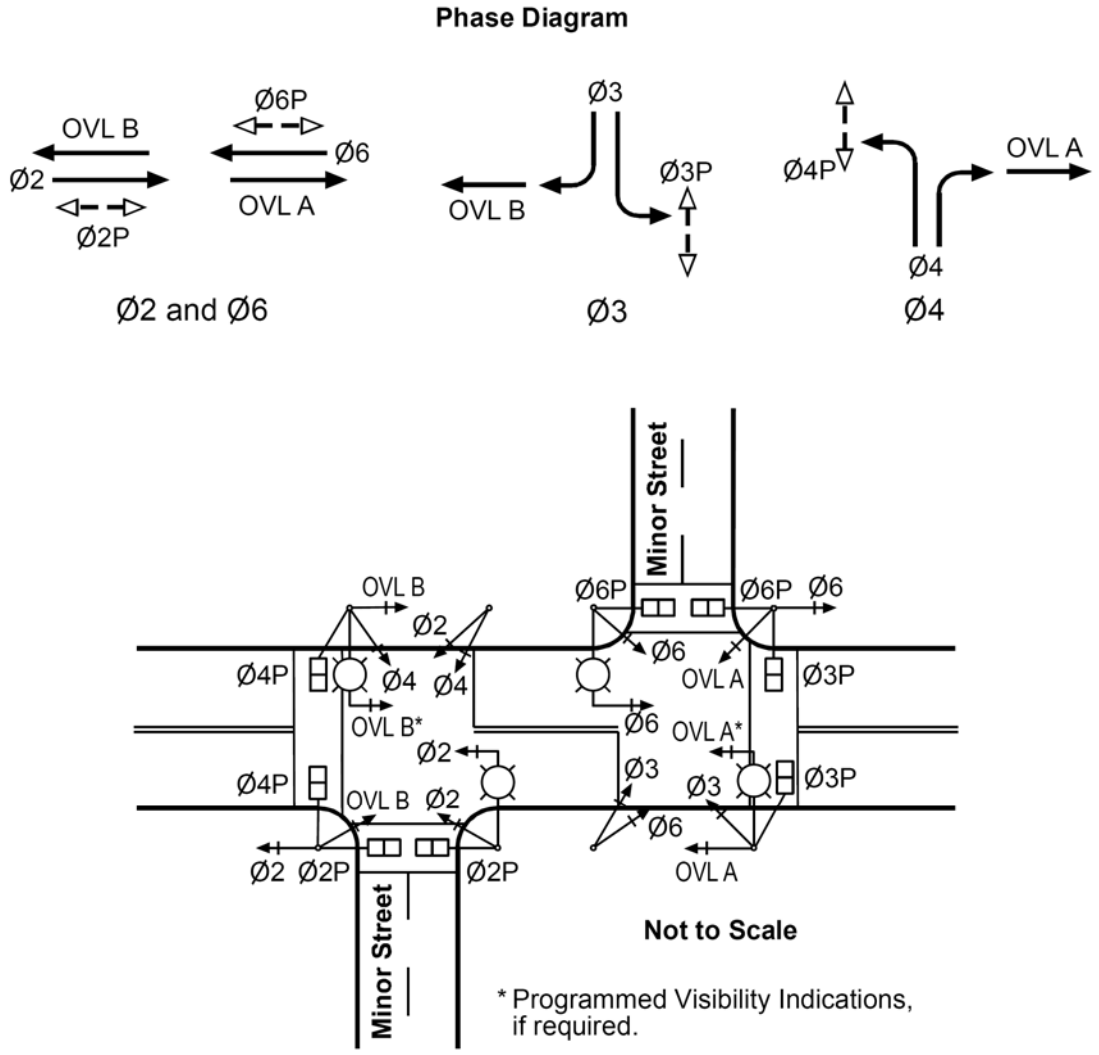
NOTE: Safety Lighting Design shall satisfy the requirements of Traffic Manual, Section 9-10.3.

Figure 4D-102. Typical Signal Layout at Offset Intersections, Signalized and Marked as a Single Intersection (Sheet 3 of 4)



NOTE: Safety Lighting Design shall satisfy the requirements of Traffic Manual, Section 9-10.3.

Figure 4D-102. Typical Signal Layout at Offset Intersections, Signalized and Marked as a Single Intersection (Sheet 4 of 4)



NOTE: Safety Lighting Design shall satisfy the requirements of Traffic Manual, Section 9-10.3.

Figure 4D-103. Typical Signal Layout (Two Phase Operation)

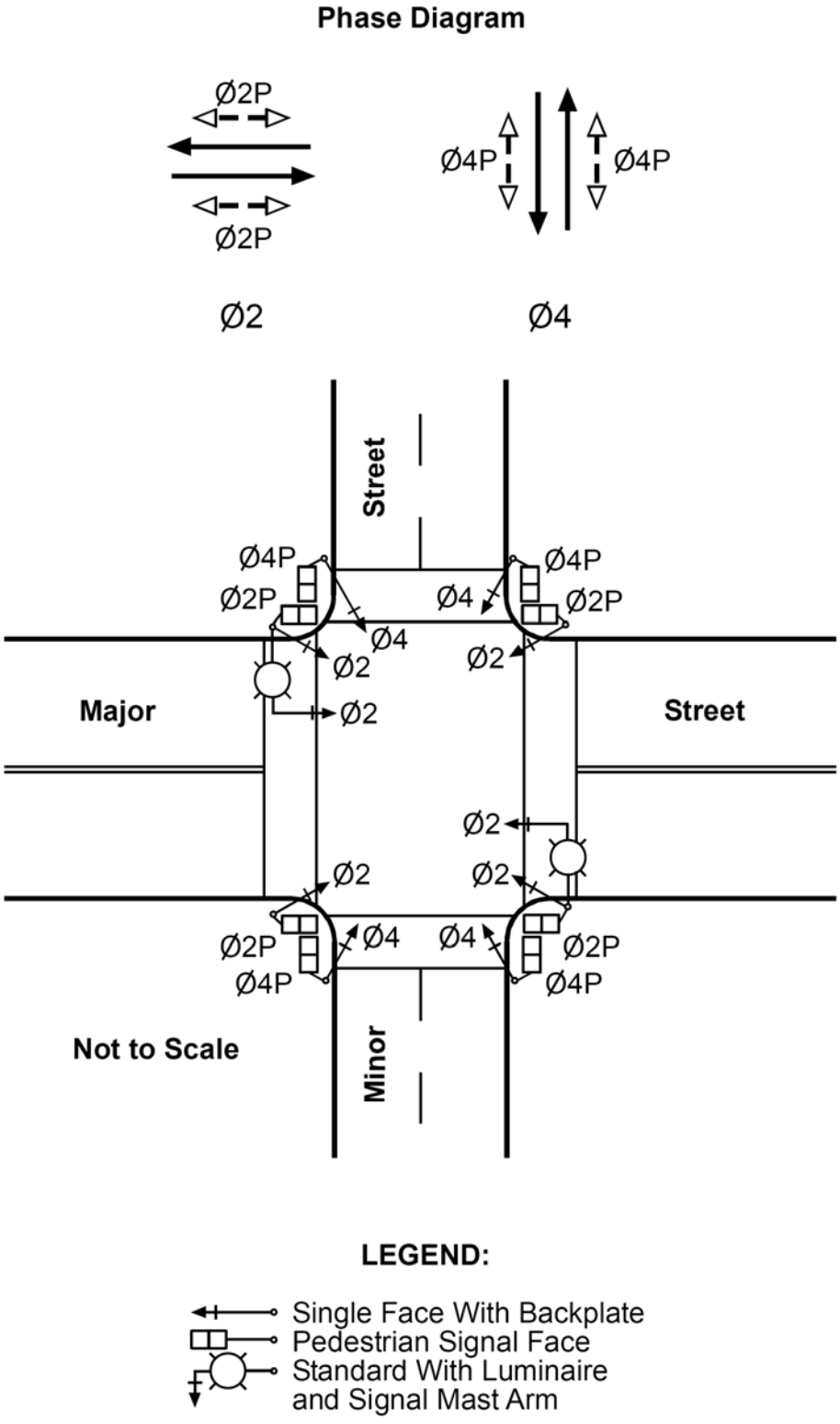


Figure 4D-105. Typical Signal Layout
(Five Phase "Dual Left" Operation)

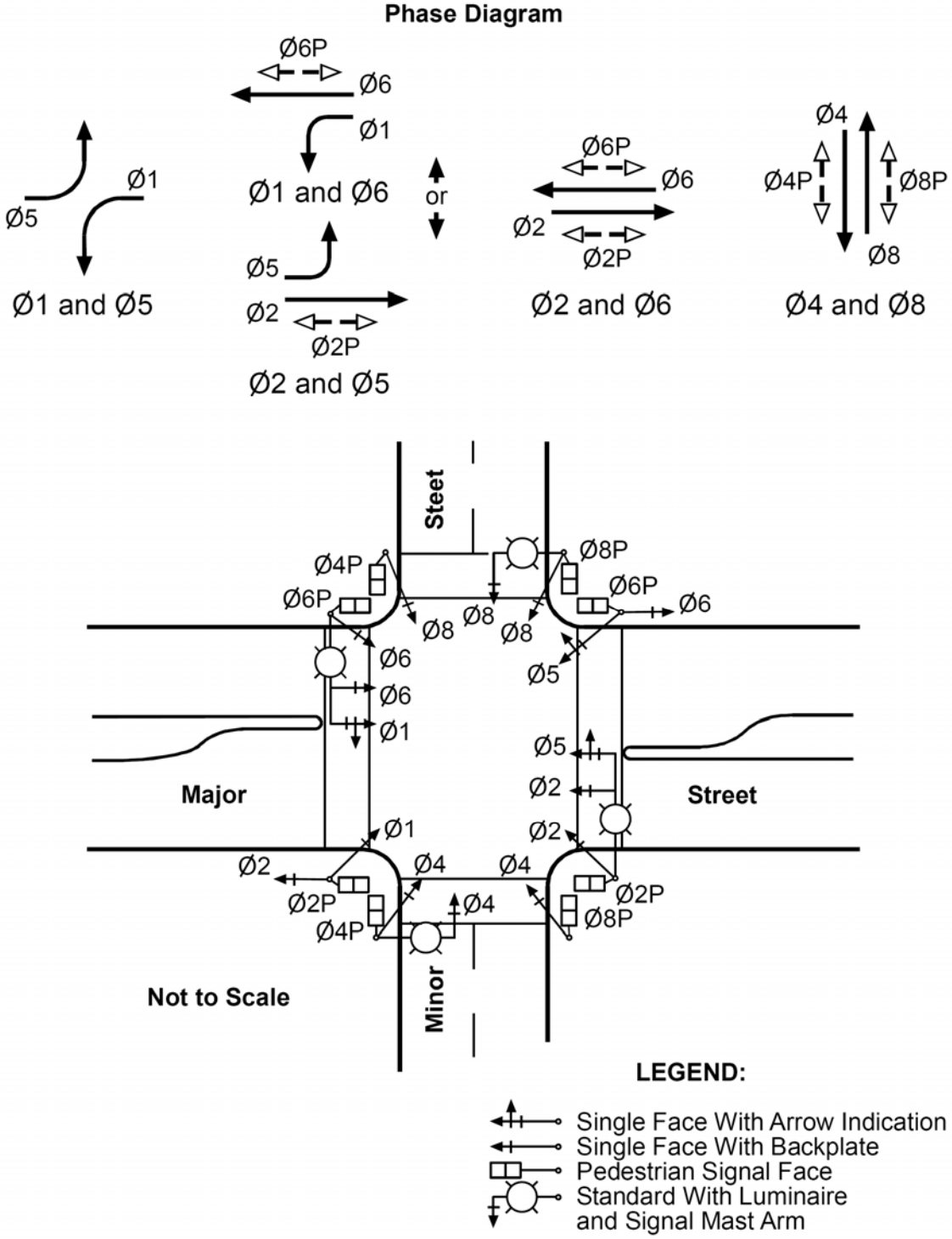


Figure 4D-106. Typical Signal Layout
(Six Phase "Opposing" Operation)

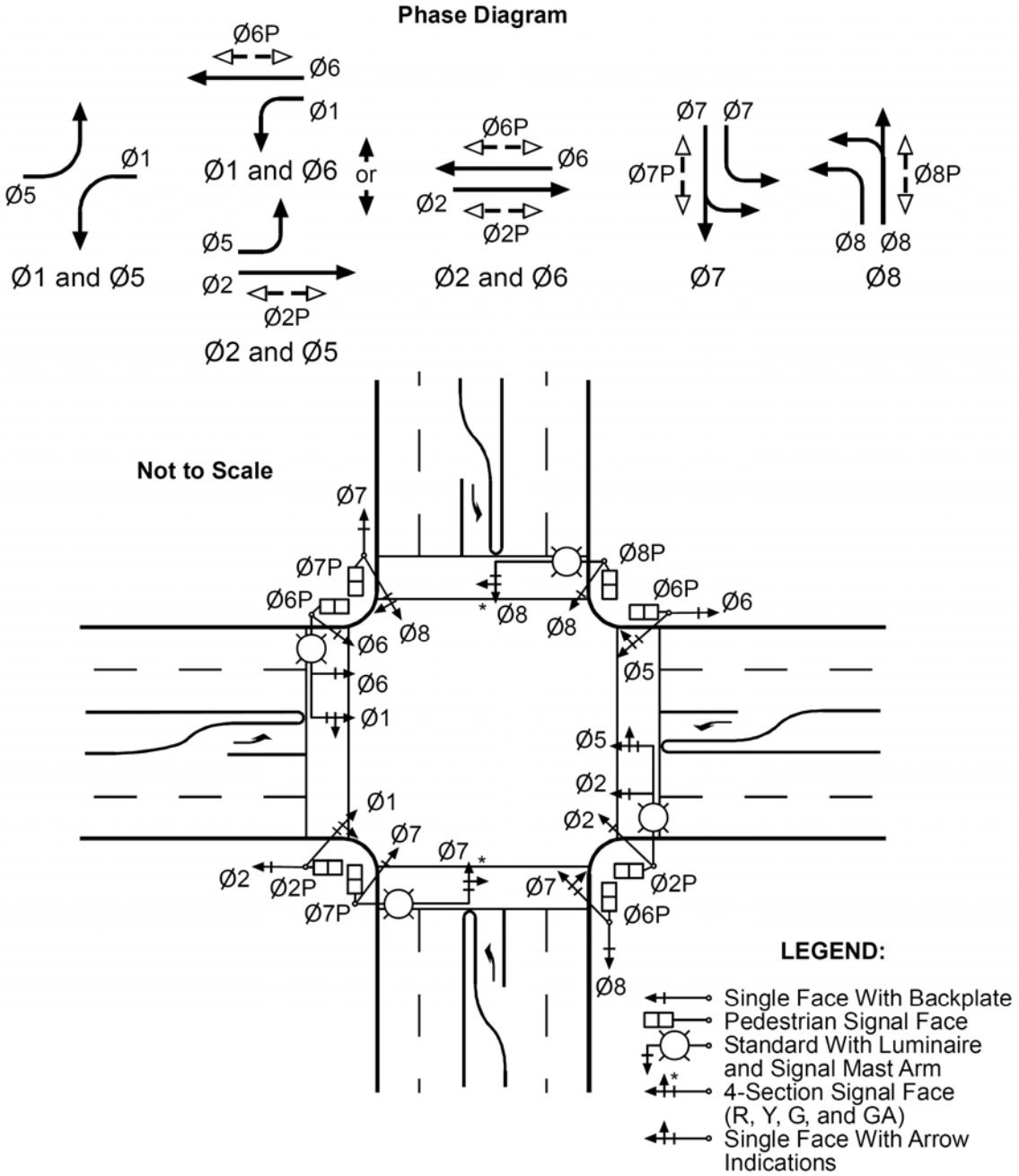


Figure 4D-107. Typical Signal Layout
(Eight Phase "Quad Left" Operation)

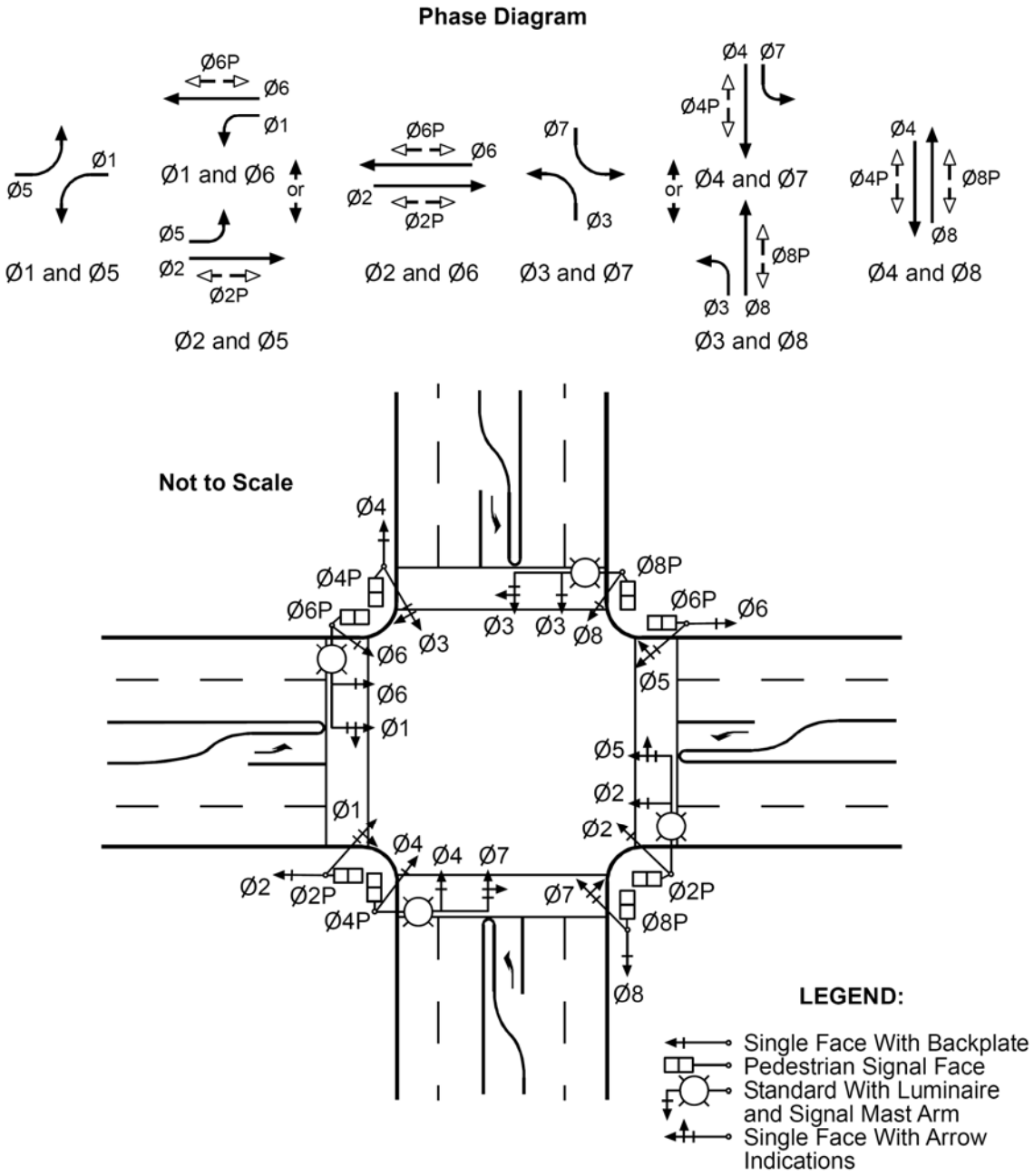
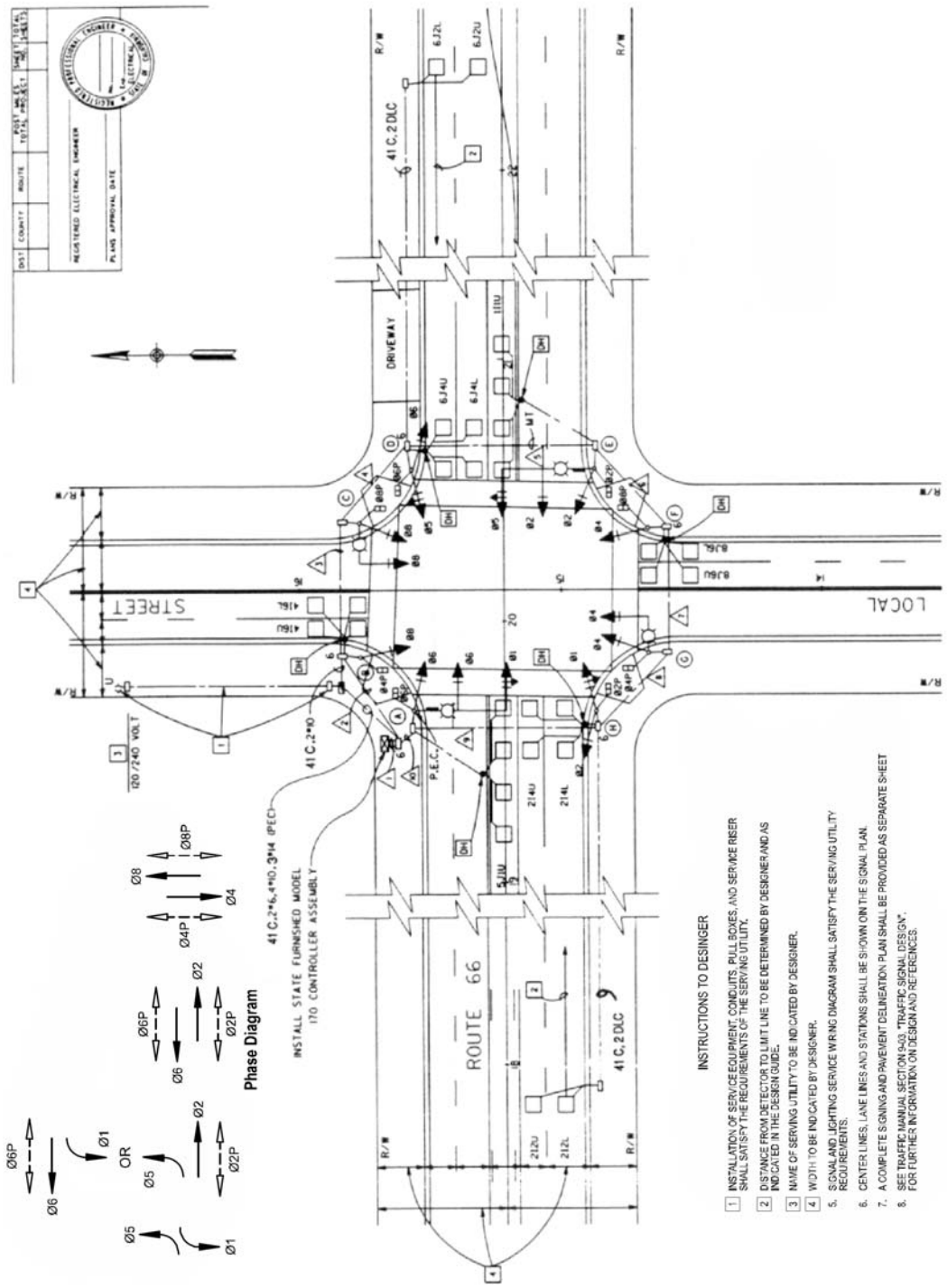
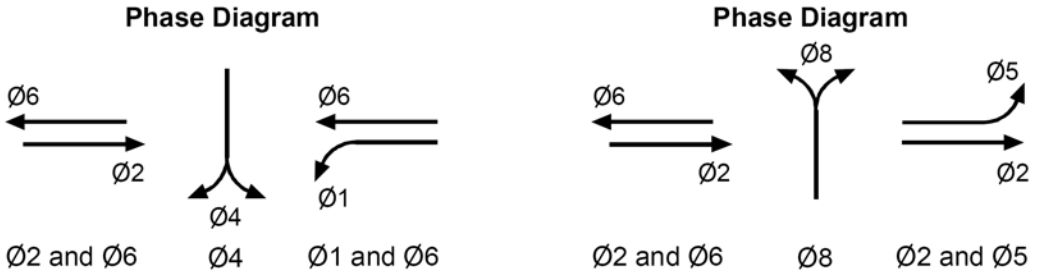


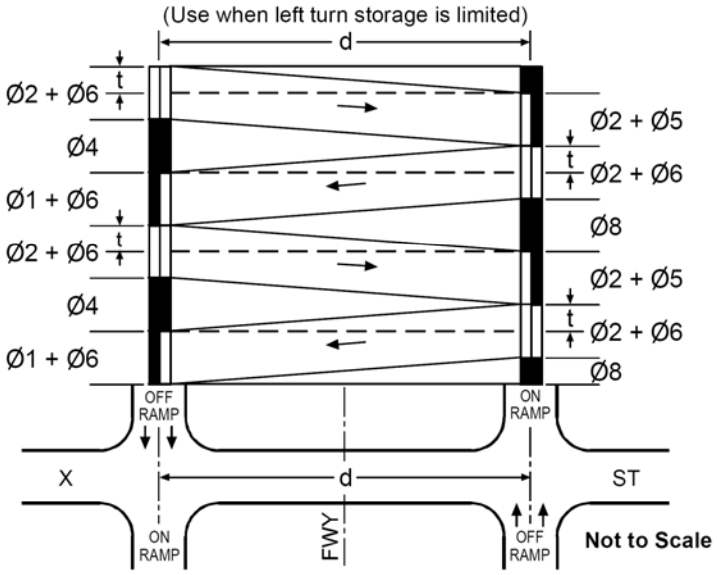
Figure 4D-108. Typical Traffic Signal Installation



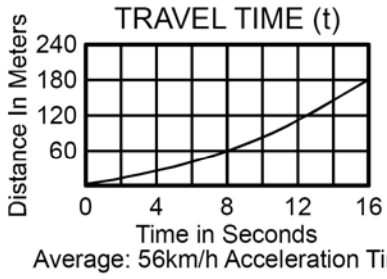
NOTE: This plan accurate for electrical work only.

Figure 4D-109. Diamond Interchange Timing Chart (Heavy Left-Turn - 200 vphpl or More - Using Two Controllers)



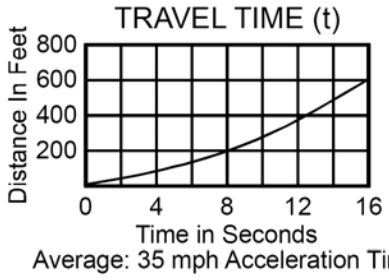


Ø2 + Ø6 should be = <Ø5
Ø2 + Ø6 should be = <Ø1
Ø4 should be = <Ø2 + Ø6
Ø8 should be = <Ø2 + Ø6
Phase Times are Green-Yellow



Average: 56km/h Acceleration Time

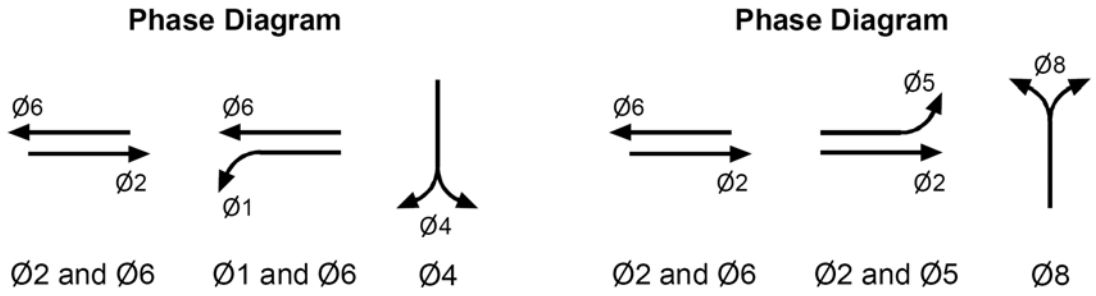
2t + Ø6 + Ø5 = Cycle Length
Ø2 + Ø6 + Ø4 = 2t + Ø5
Ø2 + Ø6 + Ø8 = 2t + Ø1
"t" = Time to go distance "d"

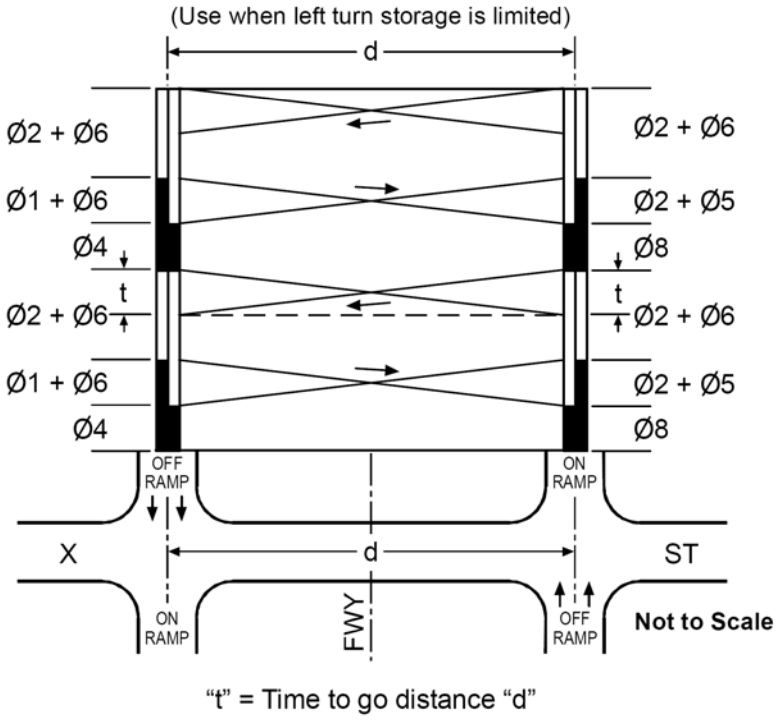


Average: 35 mph Acceleration Time

NOTE: These timing guidelines are ideal. Variations in timing may be necessary to provide proper splits to meet volume demands (See Table 4D-101).

Figure 4D-110. Diamond Interchange Timing Chart (Light Left-Turn - 200 vphpl or Less - Using Two Controllers)

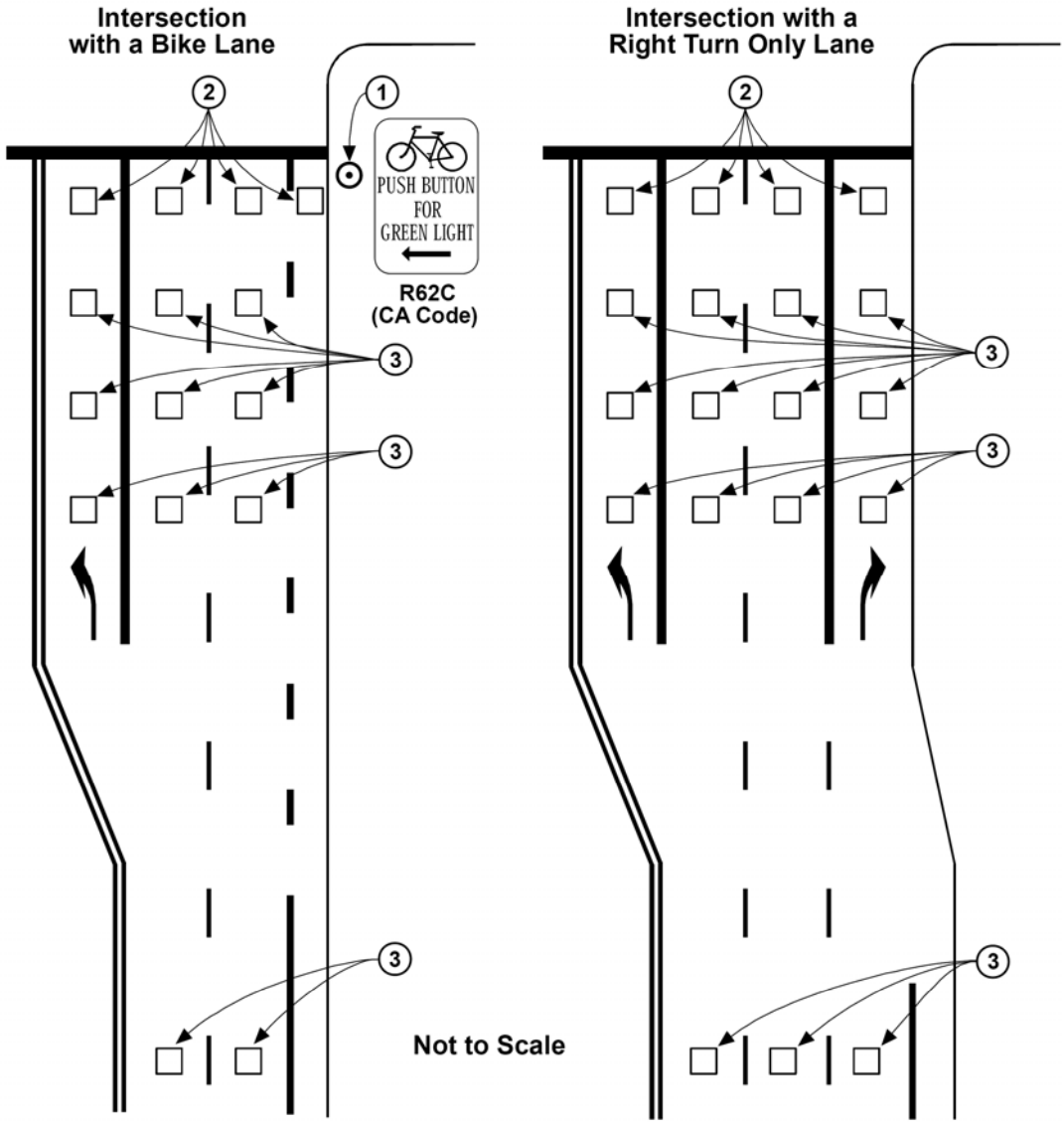




"t" = Time to go distance "d"

NOTES: 1. These timing guidelines are ideal. Variations in timing may be necessary to provide proper splits to meet volume demands (See Table 4D-101).
2. The Green-Yellow interval for phases 1, 4, 5 or 8 should equal time "t".

Figure 4D-111. Bicycle Detection Systems



NOTES:

1. **Bike/Push Button for Green Light (CA Code R62C) Sign or a Type D Loop Detector may be used to activate a traffic signal. A push button should be located so it is convenient to use by bicyclists.**
2. **Typical Type D Loop Detector locations.**
3. **Typical Loop Detector locations. See Section 4D.105.**
4. **See Standard Plan A24C for Bicycle Loop Detector pavement marking details.**

Table 4D-101. Suggested Detector Setbacks From Limitline

Deceleration Rate d = 3.05 m per second^2

Reaction Time r = 1.00 second

Deceleration Distance = $^1/_2dt^2$ or $^1/_2Vt$ or $\frac{V^2}{2d}$

Deceleration Time = $\frac{V}{d}$

Detector Setback = Deceleration Distance + Reaction Time = $\frac{V^2}{2d} + Vr$

V = Speed (meter per second)

d = Deceleration Rate (meter per second^2)

t = Deceleration Time (seconds)

Note: When English units are used, replace "d" (Deceleration Rate) with 10 ft per second^2. Speed must be expressed in feet per second and the Deceleration Setback will be measured in feet.

SPEED				DEC. TIME	DECELERATION DISTANCE		TOTAL TIME	DETECTOR SETBACK			
								ACTUAL		SUGGESTED	
mph	km/h	m/s	feet/s	Seconds	Meters	Feet	Seconds	Meters	Feet	Meters	Feet
25	40	11.18	36.68	3.67	20.49	66.93	4.67	31.67	103.90	30	105
30	48	13.42	44.00	4.40	29.51	96.82	5.40	42.93	140.80	45	140
35	56	15.65	51.35	5.13	40.17	131.80	6.13	55.82	183.10	55	185
40	64	17.89	58.69	5.87	52.46	204.90	6.87	70.35	230.80	70	230
45	72	20.13	66.04	6.60	66.40	217.80	7.60	86.52	283.90	85	285
50	80	22.36	73.36	7.33	81.97	268.90	8.33	104.33	342.30	105	345
55	89	24.60	80.71	8.06	99.18	325.40	9.06	123.78	406.10	125	405
60	97	26.83	88.00	8.80	118.04	387.30	9.80	144.87	475.30	145	475
65	105	29.07	95.37	9.53	138.53	454.50	10.53	167.60	549.90	170	550
70	113	31.29	102.7	10.27	160.50	526.60	11.27	191.79	649.30	190	650

Table 4D-102. Suggested Minimum Yellow Interval Timing

APPROACH SPEED		YELLOW INTERVAL
mph	km/h	Seconds
25 or less	40 or less	3.0
30	48	3.2
35	56	3.6
40	64	3.9
45	72	4.3
50	80	4.7
55	89	5.0
60	97	5.4
65	105	5.8

Table 4D-103. Traffic Signal Timing Analysis Chart

Number of Cars	Min. Time in Seconds Req. for Cars	Length of Stopped Queue		Length of Moving Queue		Moving Queue Time (Bond Width in Seconds)	NUMBER OF VEHICLES PER HOUR LANE AT INDICATED CYCLE LENGTH									
		Meters	Feet	Meters (48 km/h)	Feet (30 mph)		50 Sec.	60 Sec.	70 Sec.	80 Sec.	90 Sec.	100 Sec.	120 Sec.	150 Sec.	180 Sec.	240 Sec.
1	4	8	25	0	0	2	70	60	50	45	40	35	30	25	20	15
2	7	16	50	27	88	4	145	120	100	90	80	70	60	50	40	30
3	9	24	75	54	176	6	215	180	150	135	120	110	90	70	60	45
4	11	32	100	81	264	8	290	240	205	180	160	145	120	95	80	60
5	13	40	125	108	352	10	360	360	255	225	200	180	150	120	100	75
6	15	48	150	135	440	12	430	420	310	270	240	215	180	145	120	90
7	17	54	175	162	528	14	505	480	360	315	280	250	210	170	140	105
8	19	62	200	189	616	16	575	540	410	360	320	290	240	190	160	120
9	21	70	225	216	704	18	650	600	460	405	360	320	270	215	180	135
10	23	78	250	243	792	20	720	660	510	450	400	360	300	240	200	150
11	25	84	275	270	880	22	790	720	560	495	440	400	330	265	220	165
12	27	92	300	297	968	24	865	780	610	540	480	430	360	290	240	180
13	29	100	325	324	1056	26	935	840	665	585	520	470	390	315	260	195
14	31	108	350	351	1144	28	1020	900	715	630	560	500	420	340	280	210
15	33	114	375	378	1232	30	1080	960	765	675	600	540	450	365	300	225
16	35	122	400	405	1320	32	1150	1020	815	720	640	580	480	385	320	240
17	37	130	425	432	1408	34	1225	1080	865	765	680	610	510	410	340	255
18	39	138	450	459	1496	36	1295	1140	920	810	720	650	540	430	360	270
19	41	146	475	486	1584	38		1200	970	855	760	680	570	455	380	285
20	43	154	500	513	1672	40		1260	1020	900	800	720	600	480	400	300
21	45	162	525	540	1760	42		1320	1070	945	840	760	630	505	420	315
22	47	170	550	567	1848	44		1380	1120	990	880	790	660	530	440	330
23	49	178	575	594	1936	46		1440	1175	1035	920	830	690	550	460	345
24	51	186	600	621	2024	48			1225	1080	960	860	720	575	480	360
25	53	194	625	648	2112	50			1275	1125	1000	900	750	600	500	375
26	55	202	650	675	2200	52			1325	1170	1040	930	780	625	520	390
27	57	210	675	702	2288	54			1375	1215	1080	960	810	650	540	405
28	59	218	700	729	2376	56			1430	1260	1120	990	840	670	560	420
29	61	226	725	756	2464	58				1305	1160	1020	870	700	580	435

Table 4D-104. Signal Operations - Vehicular Speed (Metric Units)

SECONDS		10	15	20	25	30	35	40	45	50	55	60
km/h	m/s	DISTANCE TRAVELED IN METERS										
1	0.28	2.80	4.20	5.60	7.00	8.40	9.80	11.20	12.60	14.00	15.40	16.80
2	0.56	5.60	8.40	11.20	14.00	16.80	19.60	22.40	25.20	28.00	30.80	33.60
3	0.83	8.30	12.45	16.60	20.75	24.90	29.05	33.20	37.35	41.50	45.65	49.80
4	1.10	11.00	16.50	22.00	27.50	33.00	38.50	44.00	49.50	55.00	60.50	66.00
5	1.39	13.90	20.85	27.80	34.75	41.70	48.65	55.60	62.55	69.50	76.45	83.40
10	2.80	28.00	42.00	56.00	70.00	84.00	98.00	112.00	126.00	140.00	154.00	168.00
15	4.17	41.70	62.60	83.40	104.30	125.00	146.00	167.00	188.00	209.00	229.00	250.00
20	5.56	55.60	84.00	111.00	139.00	167.00	195.00	222.00	250.00	278.00	306.00	334.00
25	6.94	69.40	104.00	139.00	174.00	208.00	243.00	278.00	312.00	347.00	382.00	416.00
30	8.33	83.30	125.00	167.00	208.00	250.00	292.00	333.00	375.00	417.00	458.00	500.00
35	9.72	97.20	146.00	194.00	243.00	292.00	340.00	389.00	437.00	486.00	535.00	583.00
40	11.10	111.00	167.00	222.00	278.00	333.00	389.00	444.00	500.00	555.00	611.00	666.00
45	12.50	125.00	188.00	250.00	313.00	375.00	438.00	500.00	563.00	625.00	688.00	750.00
50	13.89	138.90	208.00	278.00	347.00	417.00	486.00	556.00	625.00	695.00	764.00	834.00
55	15.28	152.80	229.00	306.00	382.00	458.00	535.00	611.00	688.00	764.00	840.00	917.00
60	16.67	166.70	250.00	333.00	416.00	500.00	583.00	667.00	750.00	833.00	917.00	1000.00
65	18.06	180.60	271.00	361.00	452.00	542.00	632.00	722.00	813.00	903.00	993.00	1084.00
70	19.44	194.40	292.00	389.00	486.00	583.00	680.00	778.00	875.00	972.00	1069.00	1166.00
75	20.83	208.30	312.00	417.00	521.00	625.00	729.00	833.00	937.00	1042.00	1146.00	1250.00
80	22.22	222.20	333.00	444.00	555.00	667.00	778.00	889.00	1000.00	1111.00	1222.00	1333.00
85	23.61	236.10	354.00	472.00	590.00	708.00	826.00	944.00	1062.00	1180.00	1298.00	1416.00
90	25.00	250.00	375.00	500.00	625.00	750.00	875.00	1000.00	1125.00	1250.00	1375.00	1500.00
95	26.39	263.90	396.00	528.00	660.00	792.00	924.00	1056.00	1188.00	1320.00	1452.00	1584.00
100	27.78	277.80	417.00	556.00	695.00	834.00	972.00	1112.00	1251.00	1390.00	1529.00	1668.00
105	29.17	291.70	437.00	583.00	729.00	875.00	1021.00	1167.00	1313.00	1458.00	1604.00	1750.00
110	30.56	305.60	458.00	611.00	764.00	917.00	1070.00	1222.00	1375.00	1528.00	1681.00	1834.00

Table 4D-104. Signal Operations - Vehicular Speed (English Units)

SECONDS		10	15	20	25	30	35	40	45	50	55	60
mph	ft/s	DISTANCE TRAVELED IN FEET										
1	1.46	14.6	21.9	29.3	36.6	44.0	51.3	58.6	66.0	73.3	80.6	88.0
2	2.93	29.3	44.0	58.6	73.3	88.0	102.6	117.3	132.0	146.6	161.3	176.0
3	4.40	44.0	66.0	88.0	110.0	132.0	154.0	176.0	198.0	220.0	242.0	264.0
4	5.86	58.6	88.0	117.3	146.6	176.0	205.3	234.6	264.0	293.3	322.6	352.0
5	7.30	73.0	110.0	147.0	183.0	220.0	257.0	293.0	330.0	367.0	403.0	440.0
10	14.60	146.0	220.0	293.0	366.0	440.0	513.0	587.0	660.0	733.0	807.0	880.0
15	22.00	220.0	330.0	440.0	550.0	660.0	770.0	880.0	990.0	1,100.0	1,210.0	1,320.0
20	29.30	293.0	440.0	587.0	733.0	880.0	1,027.0	1,173.0	1,320.0	1,467.0	1,613.0	1,760.0
25	36.70	367.0	550.0	733.0	917.0	1,100.0	1,283.0	1,467.0	1,650.0	1,833.0	2,017.0	2,200.0
30	44.00	440.0	660.0	880.0	1,100.0	1,320.0	1,540.0	1,760.0	1,980.0	2,200.0	2,420.0	2,640.0
35	51.30	513.0	770.0	1,027.0	1,283.0	1,540.0	1,797.0	2,053.0	2,310.0	2,567.0	2,823.0	3,080.0
40	58.70	587.0	880.0	1,173.0	1,467.0	1,760.0	2,053.0	2,347.0	2,640.0	2,933.0	3,227.0	3,520.0
45	66.00	660.0	990.0	1,320.0	1,650.0	1,980.0	2,310.0	2,640.0	2,970.0	3,300.0	3,630.0	3,960.0
50	73.30	733.0	1,100.0	1,467.0	1,833.0	2,200.0	2,567.0	2,933.0	3,300.0	3,667.0	4,033.0	4,400.0
55	80.70	807.0	1,210.0	1,613.0	2,017.0	2,420.0	2,823.0	3,227.0	3,630.0	4,033.0	4,437.0	4,840.0
60	88.00	880.0	1,320.0	1,760.0	2,200.0	2,640.0	3,080.0	3,520.0	3,960.0	4,400.0	4,840.0	5,280.0
65	95.30	953.0	1,430.0	1,907.0	2,383.0	2,860.0	3,337.0	3,813.0	4,290.0	4,767.0	5,243.0	5,720.0
70	102.70	1,027.0	1,540.0	2,053.0	2,567.0	3,080.0	3,593.0	4,107.0	4,620.0	5,133.0	5,647.0	6,160.0
75	110.00	1,100.0	1,650.0	2,200.0	2,750.0	3,300.0	3,850.0	4,400.0	4,950.0	5,500.0	6,050.0	6,600.0
80	117.30	1,173.0	1,760.0	2,347.0	2,933.0	3,520.0	4,107.0	4,693.0	5,280.0	5,867.0	6,453.0	7,040.0
85	124.70	1,247.0	1,870.0	2,493.0	3,117.0	3,740.0	4,363.0	4,987.0	5,610.0	6,233.0	6,858.0	7,480.0
90	132.00	1,320.0	1,980.0	2,640.0	3,300.0	3,960.0	4,620.0	5,280.0	5,940.0	6,600.0	7,260.0	7,920.0
95	139.30	1,393.0	2,090.0	2,787.0	3,483.0	4,180.0	4,877.0	5,573.0	6,270.0	6,967.0	7,663.0	8,360.0
100	146.70	1,467.0	2,200.0	2,933.0	3,667.0	4,400.0	5,133.0	5,867.0	6,600.0	7,333.0	8,067.0	8,800.0
105	154.00	1,540.0	2,310.0	3,080.0	3,850.0	4,620.0	5,390.0	6,160.0	6,930.0	7,700.0	8,470.0	9,240.0
110	161.30	1,613.0	2,420.0	3,227.0	4,033.0	4,840.0	5,647.0	6,453.0	7,260.0	8,067.0	8,873.0	9,680.0
115	168.60	1,686.0	2,530.0	3,373.0	4,217.0	5,060.0	5,903.0	6,747.0	7,590.0	8,434.0	9,277.0	10,120.0
120	176.00	1,760.0	2,640.0	3,520.0	4,400.0	5,280.0	6,160.0	7,040.0	7,920.0	8,800.0	9,680.0	10,560.0

Table 4D-105. Signal Operation - Cycle Percentage Conversion (Sheet 1 of 2)

PERCENT	50	60	70	80	90	100	110	120	150	180	240
1	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.5	1.8	2.4
2	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	3.0	3.6	4.8
3	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	4.5	5.4	7.2
4	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	6.0	7.2	9.6
5	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	7.5	9.0	12.0
6	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	9.0	10.8	14.4
7	3.5	4.2	4.9	5.6	6.3	7.0	7.7	8.4	10.5	12.6	16.8
8	4.0	4.8	5.6	6.4	7.2	8.0	8.8	9.6	12.0	14.4	19.2
9	4.5	5.4	6.3	7.2	8.1	9.0	9.9	10.8	13.5	16.2	21.6
10	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	15.0	18.0	24.0
11	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2	16.5	19.8	26.4
12	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	18.0	21.6	28.8
13	6.5	7.8	9.1	10.4	11.7	13.0	14.3	15.6	19.5	23.4	31.2
14	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	21.0	25.2	33.6
15	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	22.5	27.0	36.0
16	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2	24.0	28.8	38.4
17	8.5	10.2	11.9	13.6	15.3	17.0	18.7	20.4	25.5	30.6	40.8
18	9.0	10.8	12.6	14.4	16.2	18.0	19.8	21.6	27.0	32.4	43.2
19	9.5	11.4	13.3	15.2	17.1	19.0	20.9	22.8	28.5	34.2	45.6
20	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	30.0	36.0	48.0
21	10.5	12.6	14.7	16.8	18.9	21.0	23.1	25.2	31.5	37.8	50.4
22	11.0	13.2	15.4	17.6	19.8	22.0	24.2	26.4	33.0	39.6	52.8
23	11.5	13.8	16.1	18.4	20.7	23.0	25.3	27.6	34.5	41.4	55.2
24	12.0	14.4	16.8	19.2	21.6	24.0	26.4	28.8	36.0	43.2	57.6
25	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	37.5	45.0	60.0
26	13.0	15.6	18.2	20.8	23.4	26.0	28.6	31.2	39.0	46.8	62.4
27	13.5	16.2	18.9	21.6	24.3	27.0	29.7	32.4	40.5	48.6	64.8
28	14.0	16.8	19.6	22.4	25.2	28.0	30.8	33.6	42.0	50.4	67.2
29	14.5	17.4	20.3	23.2	26.1	29.0	31.9	34.8	43.5	52.2	69.6
30	15.0	18.0	21.0	24.0	27.0	30.0	33.0	36.0	45.0	54.0	72.0
31	15.5	18.6	21.7	24.8	27.9	31.0	34.1	37.2	46.5	55.8	74.4
32	16.0	19.2	22.4	25.6	28.8	32.0	35.2	38.4	48.0	57.6	76.8
33	16.5	19.8	23.1	26.4	29.7	33.0	36.3	39.6	49.5	59.4	79.2
34	17.0	20.4	23.8	27.2	30.6	34.0	37.4	40.8	51.0	61.2	81.6
35	17.5	21.0	24.5	28.0	31.5	35.0	38.5	42.0	52.5	63.0	84.0
36	18.0	21.6	25.2	28.8	32.4	36.0	39.6	43.2	54.0	64.8	86.4
37	18.5	22.2	25.9	29.6	33.3	37.0	40.7	44.4	55.5	66.6	88.8
38	19.0	22.8	26.6	30.4	34.2	38.0	41.8	45.6	57.0	68.4	91.2
39	19.5	23.4	27.3	31.2	35.1	39.0	42.9	46.8	58.5	70.2	93.6
40	20.0	24.0	28.0	32.0	36.0	40.0	44.0	48.0	60.0	72.0	96.0
41	20.5	24.6	28.7	32.8	36.9	41.0	45.1	49.2	61.5	73.8	96.4
42	21.0	25.2	29.4	33.6	37.8	42.0	46.2	50.4	63.0	75.6	100.8
43	21.5	25.8	30.1	34.4	38.7	43.0	47.3	51.6	64.5	77.4	103.2
44	22.0	26.4	30.8	35.2	39.6	44.0	48.4	52.8	66.0	79.2	105.6
45	22.5	27.0	31.5	36.0	40.5	45.0	49.5	54.0	67.5	81.0	108.0
46	23.0	27.6	32.2	36.8	41.4	46.0	50.6	55.2	69.0	82.8	110.4
47	23.5	28.2	32.9	37.6	42.3	47.0	51.7	56.4	70.5	84.6	112.8
48	24.0	28.8	33.6	38.4	43.2	48.0	52.8	57.6	72.0	86.4	115.2
49	24.5	29.4	34.3	39.2	44.1	49.0	53.9	58.8	73.5	88.2	117.6
50	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	75.0	90.0	120.0

Table 4D-105. Signal Operation - Cycle Percentage Conversion (Sheet 2 of 2)

PERCENT	50	60	70	80	90	100	110	120	150	180	240
51	25.5	30.6	35.7	40.8	45.9	51.0	56.1	61.2	76.5	91.8	122.4
52	26.0	31.2	36.4	41.6	46.8	52.0	57.2	62.4	78.0	93.6	124.8
53	26.5	31.8	37.1	42.4	47.7	53.0	58.3	63.6	79.5	95.4	127.2
54	27.0	32.4	37.8	43.2	48.6	54.0	59.4	64.8	81.0	97.2	129.6
55	27.5	33.0	38.5	44.0	49.5	55.0	60.5	66.0	82.5	99.0	132.0
56	28.0	33.6	39.2	44.8	50.4	56.0	61.6	67.2	84.0	100.8	134.4
57	28.5	34.2	39.9	45.6	51.3	57.0	62.7	68.4	85.5	102.6	136.8
58	29.0	34.8	40.6	46.4	52.2	58.0	63.8	69.6	87.0	104.4	139.2
59	29.5	35.4	41.3	47.2	53.1	59.0	64.9	70.8	88.5	106.2	141.6
60	30.0	36.0	42.0	48.0	54.0	60.0	66.0	72.0	90.0	108.0	144.0
61	30.5	36.6	42.7	48.8	54.9	61.0	67.1	73.2	91.5	109.8	146.4
62	31.0	37.2	43.4	49.6	55.8	62.0	68.2	74.4	93.0	111.6	148.8
63	31.5	37.8	44.1	50.4	56.7	63.0	69.3	75.6	94.5	113.4	151.2
64	32.0	38.4	44.8	51.2	57.6	64.0	70.4	76.8	96.0	115.2	153.6
65	32.5	39.0	45.5	52.0	58.5	65.0	71.5	78.0	97.5	117.0	156.0
66	33.0	39.6	46.2	52.8	59.4	66.0	72.6	79.2	99.0	118.8	158.4
67	33.5	40.2	46.9	53.6	60.3	67.0	73.7	80.4	100.5	120.6	160.8
68	34.0	40.8	47.6	54.4	61.2	68.0	74.8	81.6	102.0	122.4	163.2
69	34.5	41.4	48.3	55.2	62.1	69.0	75.9	82.8	103.5	124.2	165.6
70	35.0	42.0	49.0	56.0	63.0	70.0	77.0	84.0	105.0	126.0	168.0
71	35.5	42.6	49.7	56.8	63.9	71.0	78.1	85.2	106.5	127.8	170.4
72	36.0	43.2	50.4	57.6	64.8	72.0	79.2	86.4	108.0	129.6	172.8
73	36.5	43.8	51.1	58.4	65.7	73.0	80.3	87.6	109.5	131.4	175.2
74	37.0	44.4	51.8	59.2	66.6	74.0	81.4	88.8	111.0	133.2	177.6
75	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	112.5	135.0	180.0
76	38.0	45.6	53.2	60.8	68.4	76.0	83.6	91.2	114.0	136.8	182.4
77	38.5	46.2	53.9	61.6	69.3	77.0	84.7	92.4	115.5	138.6	184.8
78	39.0	46.8	54.6	62.4	70.2	78.0	85.8	93.6	117.0	140.4	187.2
79	39.5	47.4	55.3	63.2	71.1	79.0	86.9	94.8	118.5	142.2	189.6
80	40.0	48.0	56.0	64.0	72.0	80.0	88.0	96.0	120.0	144.0	192.0
81	40.5	48.6	56.7	64.8	72.9	81.0	89.1	97.2	121.5	145.8	194.4
82	41.0	49.2	57.4	65.6	73.8	82.0	90.2	98.4	123.0	147.6	196.8
83	41.5	49.8	58.1	66.4	74.7	83.0	91.3	99.6	124.5	149.4	199.2
84	42.0	50.4	58.8	67.2	75.6	84.0	92.4	100.8	126.0	151.2	201.6
85	42.5	51.0	59.5	68.0	76.5	85.0	93.5	102.0	127.5	153.0	204.0
86	43.0	51.6	60.2	68.8	77.4	86.0	94.6	103.2	129.0	154.8	206.4
87	43.5	52.2	60.9	69.6	78.3	87.0	95.7	104.4	130.5	156.6	208.8
88	44.0	52.8	61.6	70.4	79.2	88.0	96.8	105.6	132.0	158.4	211.2
89	44.5	53.4	62.3	71.2	80.1	89.0	97.9	106.8	133.5	160.2	213.6
90	45.0	54.0	63.0	72.0	81.0	90.0	99.0	108.0	135.0	162.0	216.0
91	45.5	54.6	63.7	72.8	81.9	91.0	100.1	109.2	136.5	163.8	218.4
92	46.0	55.2	64.4	73.6	82.8	92.0	101.2	110.4	138.0	165.6	220.8
93	46.5	55.8	65.1	74.4	83.7	93.0	102.3	111.6	139.5	167.4	223.2
94	47.0	56.4	65.8	75.2	84.6	94.0	103.4	112.8	141.0	169.2	225.6
95	47.5	57.0	66.5	76.0	85.5	95.0	104.5	114.0	142.5	171.0	228.0
96	48.0	57.6	67.2	76.8	86.4	96.0	105.6	115.2	144.0	172.8	230.4
97	48.5	58.2	67.9	77.6	87.3	97.0	106.7	116.4	145.5	174.6	232.8
98	49.0	58.8	68.6	78.4	88.2	98.0	107.8	117.6	147.0	176.4	235.2
99	49.5	59.4	69.3	79.2	89.1	99.0	108.9	118.8	148.5	178.2	237.6

Table 4D-106. Pole and Equipment Schedule

	STANDARD						VEHICLE SIGNAL MAST		PED. SIGNAL MTG.	PPB		HPS LUM.	SPECIAL REQUIREMENTS
	TYPE		SIGNAL MAST ARM		LUMINAIRE MAST ARM								
	Wind Velocity km/h	Wind Velocity mph	Meters	Feet	Meters	Feet	MAST	POLE		Ø	ARROW		
A	24-4-129	24-4-80	10.7	35	3.7	12	MAT MAS	SV-1-T	SP-1-T	4	←	200W	Interally Illuminated Street Name Sign "Local Streets"
B	1A							TV-1-T	SP-1-T	6	→		
C	19-1-129	19-1-80	4.6	15	3.7	12	MAS	SV-1-T	SP-1-T	6	←	200W	
D	1A							TV-2-T	SP-1-T	8	→		
E	24-4-129	24-4-80	10.7	35	3.7	12	MAT MAS	SV-1-T	SP-1-T	8	←	200W	Interally Illuminated Street Name Sign "Local Streets"
F	1A							TV-1-T	SP-1-T	2	→		
G	19-1-129	19-1-80	4.6	15	3.7	12	MAS	SV-1-T	SP-1-T	2	←	200W	
H	1A							TV-2-T	SP-1-T	4	→		

Note: Designer should verify structure requirements before adding side mounting vehicle signals.

Table 4D-107. Conductor and Conduit Schedule

AWG or CABLE	CONDUCTOR RUN	1	2	3	4	5	6	7	8	9	10
# 14	Ø1	3								3	3
	Ø2	3					3	3	3	3	3
	Ø4	3						3	3	3	3
	Ø5	6	3	3	3		3	3	3	3	3
	Ø6	6	3	3	3						3
	Ø8	3	3	3							
	Ø2P	2					2	2	2	2	2
	Ø4P	4	2						2	2	2
	Ø6P	4	2	2	2						2
	Ø8P	4	2	2				2	2	2	2
	Ø2PPB	1						1	1	1	1
	Ø4PPB	1								1	1
	Ø6PPB	1	1	1							
	Ø8PPB	2	1	1	1		1	1	1	1	1
	PPB Common	2	1	1	1		1	1	1	1	1
	P.E.C.										3
	Spares	6	3	3	3		3	3	3	3	
	Total # 14	51	21	19	13		13	19	21	25	35
# 10	Internally Illuminated Street Name Sign						2	2	2	2	2
	Luminaires			2			2	2	2	2	2
	Signal Common	2	1	1	1		1	1	1	1	1
	Total # 10	2	1	3	1		5	5	5	5	5
# 6	Signal Service	2									
Detector-Lead-In Cable	Ø 1 Detectors	1					1	1	1	1	1
	Ø 2 Detectors	4								4	4
	Ø 4 Detectors	2	2								
	Ø 5 Detectors	1									1
	Ø 6 Detectors	4	4	4	4						
	Ø 8 Detectors	2						2	2	2	2
	TOTAL DLC	14	6	4	4		1	3	3	7	8
CONDUIT SIZE		2-78C	78C	63C	53C	78C	53C	63C	63C	78C	78C

Table 4D-108. Available Conduit Area

SQUARE MILLIMETERS					
CONDUIT SIZE	PERCENT OF FILL				
	26%	35%	40%	50%	100%
35	145	194	220	277	555
41	340	460	526	658	1316
53	563	759	867	1084	2168
63	803	1081	1236	1545	3090
78	1237	1666	1904	2380	4761
91	1661	2235	2554	3193	6387
103	2134	2872	3282	4103	8206

As a practical limit, projects for new installations should be designed to the 26% fill limitation.

SQUARE INCHES					
CONDUIT SIZE	PERCENT OF FILL				
	26%	35%	40%	50%	100%
1”	0.23	0.30	0.35	0.43	0.86
1-1/2”	0.53	0.72	0.82	1.02	2.04
2”	0.87	1.18	1.34	1.68	3.36
2-1/2”	1.24	1.68	1.92	2.45	4.79
3”	1.92	2.58	2.96	3.69	7.38
3-1/2”	2.57	3.47	3.96	4.95	9.90
4”	3.31	4.45	5.09	6.36	12.72

As a practical limit, projects for new installations should be designed to the 26% fill limitation.

Table 4D-109. Conductor Size

METRIC UNITS			
CONDUCTOR SIZE (AWG)	TYPES TW,THW, USE, RHH & RHN		D.C. RESISTANCE Ohms/1000 m
	INSULATION THICKNESS (mm)	TOTAL AREA (Sq mm)	
#14	1.14	14	10.67
#12	1.14	16	6.33
#10	1.14	20	3.97
#8 Stranded	1.50	40	2.56
#6 Stranded	1.50	53	1.61
#4 Stranded	1.50	70	1.02
#2 Stranded	1.50	95	0.62
Type B Loop DetectorLead-in Cable (DLC)		47	
Type C Loop Detector Lead-in Cable (MLC)		42	
Magnetometer Detector Lead-in Cable (MLC)		32	
Signal Interconnect Cable (3-Pair)		60	
Signal Interconnect Cable (6-Pair)		117	

ENGLISH UNITS			
CONDUCTOR SIZE (AWG)	TYPES TW,THW, USE, RHH & RHN		D.C. RESISTANCE Ohms/1000 ft
	INSULATION THICKNESS (Inches)	TOTAL AREA (Sq Inches)	
#14	0.045	0.021	3.07
#12	0.045	0.025	1.93
#10	0.045	0.031	1.21
#8 Stranded	0.060	0.060	0.78
#6 Stranded	0.060	0.082	0.49
#4 Stranded	0.060	0.109	0.31
#2 Stranded	0.060	0.147	0.19
Type B Loop DetectorLead-in Cable (DLC)		0.073	
Type C Loop Detector Lead-in Cable (MLC)		0.064	
Magnetometer Detector Lead-in Cable (MLC)		0.049	
Signal Interconnect Cable (3-Pair)		0.091	
Signal Interconnect Cable (6-Pair)		0.181	