PART 4
HIGHWAY TRAFFIC SIGNALS

CHAPTER 4A. GENERAL

Section 4A.01 Types

Support:

01 The following types and uses of highway traffic signals are discussed in Part 4: traffic control signals; pedestrian signals; hybrid beacons; emergency-vehicle signals; traffic control signals for one-lane, two-way facilities; traffic control signals for freeway entrance ramps; traffic control signals for movable bridges; toll plaza traffic signals; flashing beacons; lane-use control signals; and in-roadway lights.

Section 4A.02 Definitions Relating to Highway Traffic Signals

Support:

01 Definitions and acronyms pertaining to Part 4 are provided in Sections 1A.13 and 1A.14.

CHAPTER 4B. TRAFFIC CONTROL SIGNALS—GENERAL

Section 4B.01 General

Support:

01 Words such as pedestrians and bicyclists are used redundantly in selected Sections of Part 4 to encourage sensitivity to these elements of "traffic."

02 Standards for traffic control signals are important because traffic control signals need to attract the attention of a variety of road users, including those who are older, those with impaired vision, as well as those who are fatigued or distracted, or who are not expecting to encounter a signal at a particular location.

Section 4B.02 Basis of Installation or Removal of Traffic Control Signals

Guidance:

01 *The selection and use of traffic control signals should be based on an engineering study of roadway, traffic, and other conditions.*

Support:

02 A careful analysis of traffic operations, pedestrian and bicyclist needs, and other factors at a large number of signalized and unsignalized locations, coupled with engineering judgment, has provided a series of signal warrants, described in Chapter 4C, that define the minimum conditions under which installing traffic control signals might be justified.

Guidance:

03 *Engineering judgment should be applied in the review of operating traffic control signals to determine whether the type of installation and the timing program meet the current requirements of all forms of traffic.*

04 *If changes in traffic patterns eliminate the need for a traffic control signal, consideration should be given to removing it and replacing it with appropriate alternative traffic control devices, if any are needed.*

05 *If the engineering study indicates that the traffic control signal is no longer justified, and a decision is made to remove the signal, removal should be accomplished using the following steps:*

A Determine the appropriate traffic control to be used after removal of the signal.
B. Remove any sight-distance restrictions as necessary.
C. Inform the public of the removal study.
D. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.
E. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed.

Option:

06 Because Items C, D, and E in Paragraph 5 are not relevant when a temporary traffic control signal (see Section 4D.32) is removed, a temporary traffic control signal may be removed immediately after Items A and B are completed.

07 Instead of total removal of a traffic control signal, the poles, controller cabinet, and cables may remain in place after removal of the signal heads for continued analysis.

Standard:

08 **Once a traffic signal at an intersection or pedestrian crossing has been energized, it shall not be turned off unless arrangements have been made for temporary control by traffic officers, temporary stop signs or an approved temporary signal.**

Section 4B.03 Advantages and Disadvantages of Traffic Control Signals

Support:

01 When properly used, traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow.

02 Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

A. They provide for the orderly movement of traffic.
B. They increase the traffic-handling capacity of the intersection if:
1. Proper physical layouts and control measures are used, and
2. The signal operational parameters are reviewed and updated (if needed) on a regular basis (as engineering judgment determines that significant traffic flow and/or land use changes have occurred) to maximize the ability of the traffic control signal to satisfy current traffic demands.
C. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions.
D. They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
E. They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

03 Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to traffic control signals being installed at many locations where they are not needed, adversely affecting the safety and efficiency of vehicular, bicycle, and pedestrian traffic.

04 Traffic control signals, even when justified by traffic and roadway conditions, can be ill-designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages:
A. Excessive delay,
B. Excessive disobedience of the signal indications,
C. Increased use of less adequate routes as road users attempt to avoid the traffic control signals, and
D. Significant increases in the frequency of collisions (especially rear-end collisions).

Section 4B.04 Alternatives to Traffic Control Signals

Guidance:

01 *Since vehicular delay and the frequency of some types of crashes are sometimes greater under traffic signal control than under STOP sign control, consideration should be given to providing alternatives to traffic control signals even if one or more of the signal warrants has been satisfied.*

Option:

02 These alternatives may include, but are not limited to, the following:
A. Installing signs along the major street to warn road users approaching the intersection;
B. Relocating the stop line(s) and making other changes to improve the sight distance at the intersection;
C. Installing measures designed to reduce speeds on the approaches;
D. Installing a flashing beacon at the intersection to supplement STOP sign control;
E. Installing flashing beacons on warning signs in advance of a STOP sign controlled intersection on major and/ or minor-street approaches;
F. Adding one or more lanes on a minor-street approach to reduce the number of vehicles per lane on the approach;
G. Revising the geometrics at the intersection to channelize vehicular movements and reduce the time required for a vehicle to complete a movement, which could also assist pedestrians;
H. Revising the geometrics at the intersection to add pedestrian median refuge islands and/or curb extensions;
I. Installing roadway lighting if a disproportionate number of crashes occur at night;
J. Restricting one or more turning movements, perhaps on a time-of-day basis, if alternate routes are available;
K. If the warrant is satisfied, installing multi-way STOP sign control;
L. Installing a pedestrian hybrid beacon (see Chapter 4F) or In-Roadway Warning Lights (see Chapter 4N) if pedestrian safety is the major concern;
M. Installing a roundabout; and
N. Employing other alternatives, depending on conditions at the intersection.

Section 4B.05 Adequate Roadway Capacity

Support:

01 The delays inherent in the alternating assignment of right-of-way at intersections controlled by traffic control signals can frequently be reduced by widening the major roadway, the minor roadway, or both roadways. Widening the minor roadway often benefits the operations on the major roadway, because it reduces the green

time that must be assigned to minor-roadway traffic. In urban areas, the effect of widening can be achieved by eliminating parking on intersection approaches. It is desirable to have at least two lanes for moving traffic on each approach to a signalized location. Additional width on the departure side of the intersection, as well as on the approach side, will sometimes be needed to clear traffic through the intersection effectively.

Guidance:

02 *Adequate roadway capacity should be provided at a signalized location. Before an intersection is widened, the additional green time pedestrians need to cross the widened roadways should be considered to determine if it will exceed the green time saved through improved vehicular flow.*

03 *Other methods of increasing the roadway capacity at signalized locations that do not involve roadway widening, such as revisions to the pavement markings and the careful evaluation of proper lane-use assignments (including varying the lane use by time of day), should be considered where appropriate. Such consideration should include evaluation of any impacts that changes to pavement markings and lane assignments will have on bicycle travel.*

Section 4B.101(CA) Traffic Signal Development Procedures – Introduction

Support:

01 General requirements for the development of traffic signal, lighting and electrical systems projects are noted in Caltrans' Project Development Procedures Manual. See Section 1A.11 for information regarding this publication. The cost of traffic signals on Federal Aid highway projects is eligible for federal participation under certain conditions.

Option:

02 The preparation of a Project Study Report may be required for major traffic signal, lighting and/or electrical system projects for scoping and programming purposes.

Guidance:

03 *Caltrans' Project Development Procedures Manual and the appropriate Program Advisor should be consulted to determine specific reporting requirements.*

Section 4B.102(CA) Project Report

Standard:

01 **The Caltrans' District shall prepare a project report of the investigation of conditions at locations where a new traffic signal is to be installed, an existing traffic signal is to be modified or an existing traffic signal is to be removed on the State highway. Caltrans District Directors are authorized to approve project reports in accordance with the current departmental policies contained in the Project Development Procedures Manual. Three copies of the District-approved project report shall be forwarded to Caltrans' Chief, State and Local Project Development. A project report shall be prepared whether the work is performed by the State or by others, if the traffic signal is located on the State highway.**

Guidance:

02 *General requirements for project reports are noted in Caltrans' Project Development Procedures Manual. A project report for the installation, modification (except for upgrading projects involving specific equipment) or removal of a traffic signal should include the following specific information:*

1. *Traffic Counts.*
   a) *Both pedestrian and vehicular traffic counts should include the periods of the average day when the signals would appear to be needed most. The counts should be at least eight hours in duration, not necessarily consecutive, but including a.m. and p.m. peak hours.*
   b) *Traffic counts for a new signal shall be shown on appropriate Traffic Signal Warrant Sheets and a Directional Traffic Count Sheet. See Figures 4C-101(CA) thru 4C-103(CA).*
   c) *Where pedestrian volumes are significant, show the volume on each crosswalk for the same periods as the vehicle count.*
   d) *When estimated traffic volumes are used in establishing traffic signal warrants, they should be prepared on Form TS-10D. See Figure 4C-103(CA).*
2. *Collision Diagram.*
   A collision diagram for the intersection covering the recent collision experience history. The diagram should cover a 3-year interval.

3. *Condition Diagram.*
   A condition diagram showing existing roadway conditions. Any railroad grade crossing within 200 feet of the intersection should be shown.
4. *Improvement Diagram.*
   A diagram showing existing and proposed signals, phasing, channelization and other proposed improvements. This may be combined with 1, 2 and/or 3 on a single plan.
5. *Estimate.*
   An estimate of the cost of the project (including State furnished materials) and the proposed method of financing.
6. *Other Specialized Data When Appropriate:*
   a. *Classification of Vehicles. The classification is required when it is a significant factor in affecting intersection capacity.*
   b. *Critical Speed (85th percentile) of Approaching Vehicles. This is the speed at a point unaffected by existing controls.*
   c. *Time-Space Diagram. When the project involves a coordinated traffic signal system.*

Section 4B.103(CA) Submittals

Support:

01 General requirements for the submittal of plans, specifications and estimates are noted in the Caltrans' Project Development Procedures Manual and the Ready to List and Construction Contract Award Guide. See Section 1A.11 for information regarding these publications.

Standard:

02 **All electrical plans shall bear the following: "Note: This plan accurate for electrical work only."**

Section 4B.104(CA) Financing

Guidance:

01 *Unless previously budgeted, the financing of a project should be considered only after receipt of the PS&E Report and cooperative agreements.*

Support:

02 Normally, the costs of a new traffic signal or the modification of a signal or signal system are to be shared with a local agency.

Option:

03 In situations where a new traffic signal or a modification to an existing traffic signal or traffic signal system is urgently needed to improve safety or traffic flow on the State highway and the local agencies are unable to finance their prorated share of the cost, the State may accept a lesser participation, or even no participation, by the local authorities.

Standard:

04 **The definition of "urgently needed" shall be made by the Caltrans District Director.**

05 **The cost of small projects such as modifications to existing traffic signals (detectors, signal heads, mast arms, etc.) where the prorated share of the local agency is $3,000 or less, shall be at 100% State expense.**

Section 4B.105(CA) Design Cost

Standard:

01 **The following criteria shall apply in determining the amount of participation in the design cost by the State and a local agency:**

A. **Where the State prepares plans for the installation or modification of a traffic signal or a traffic signal system on a State highway, the design costs should be shared with the local agency. Where the local agency is to prepare the plans, the State may participate in the design costs. Participation should be the same as construction cost participation and be covered by a cooperative agreement.**

Guidance:

B. *Estimated design costs should be determined on the basis of an agreed fixed percentage of the total project costs. The fixed percentage should be based on historical design costs for projects in the price range concerned.*

Standard:

C. Where the State is requested by a local agency to prepare plans and specifications for a traffic signal project that does not involve State participation in the construction costs, the design costs shall be borne entirely by the local agency or others. The State may, however, assume the design engineering costs and the construction engineering costs, where the local agency agrees to pay all of the construction costs for a warranted project and where all of the costs would normally be shared on a prorated basis.

Section 4B.106(CA) Construction Costs - Conventional Highways

Standard:

01 **The following criteria shall apply in determining the amount of the construction costs by the State and local agency for a traffic signal, safety lighting, and channelization or widening project on conventional State highways.**

02 **Channelization and/or Widening Costs. On cooperatively financed projects, the channelization and/or widening costs shall be shared as follows:**

A. Channelization on and/or widening of the State highway shall be at 100% State expense.

B. Channelization on and/or widening of the local street shall be at 100% local agency expense.

C. Where the local agency's portion of the channelization or widening is a minor part of the channelization or widening being constructed by the State and the local agency's share of the work amounts to $3,000, or less, the State may assume the entire cost of the channelization or widening.

03 **Channelization and/or widening required, as a part of the conditions of a permit by a private party shall be at 100% expense of the private party.**

04 **In Cases A, B, and D listed below, the costs of constructing the electrical facilities are to be shared by the State and local agencies. The costs shall be shared on a prorated basis in the same ratio as the number of legs in the intersection under each agency's jurisdiction bears to the total number of legs.**

Case A. Installation or Modification of a Traffic Signal and/or Safety Lighting at an Existing Intersection. When a traffic signal and/or safety lighting is to be installed or modified at the intersection of a State highway and a local road, local agency participation in the installation or modification costs shall be sought.

Guidance:

Case B. Existing Driveways at Existing Signalized Intersections. A private driveway that constitutes a leg at an existing signalized intersection should be treated as follows:

1. *If the driveway does not generate appreciable traffic, no control is required.*
2. *If the driveway serves an area that generates sufficient traffic to constitute a problem, it should be controlled. One example of control is the use of a red flashing beacon and/or a Right Turn Arrow ONLY (R3-5R) sign to control egress from the private driveway. Another would be to provide signal indications for the private driveway.*

Standard:

3. **Costs shall be as in Case D.**

Case C. A New Road or Driveway at an Existing Signalized Intersection. Where a new road or driveway is to be constructed to enter an existing "T" intersection, the cost of necessary right-of-way, traffic signal and/or safety lighting shall be at 100% local agency or permittee expense. The cost shall include the signal faces and detectors for the new approach and signal faces and detectors for left turns into the new approach and channelization, if necessary.

Case D. Installation of a Traffic Signal and/or Safety Lighting at an existing intersection with a Driveway. Where a traffic signal and/or safety lighting is to be installed at an existing intersection serving an area which generates sufficient traffic to constitute a problem that includes a private driveway as the fourth approach, the cost of signal and lighting equipment for the driveway approach shall be included in the cost of the entire installation.

Where one or more legs of the intersection are under the jurisdiction of a local agency, the construction costs shall be shared with the local agency. The cost of the driveway leg shall be included with the local agency's share. It shall be the responsibility of the local agency to obtain the right-of-way, right-of-entry or easement necessary to install and maintain the signal equipment to be located on private property.

Case E. Reconstruction of a Conventional State Highway. When it is necessary to widen or reconstruct a State highway, the reconstruction and relocation of traffic control devices and safety lighting systems, shall be at 100% State expense. Local participation for purposes of expediting a project should be accepted. Additional

traffic control devices installed in connection with reconstruction of a conventional highway are to be treated as in Case A.

Case F. Relocation of a Conventional State Highway. When an existing State highway is relocated, the State will install warranted traffic control devices and safety lighting at State expense. Local participation will not be required. If, however, a local authority wishes to participate in a project in order to expedite it, local participation should be accepted.

Case G. Installation of a Traffic Signal and/or Safety Lighting at a Private Driveway or Privately Owned Street. The cost of a new traffic signal and/or safety lighting installed at a private driveway or privately owned street (i.e., not under the jurisdiction of a city or county) shall be entirely at the expense of the property owner or developer.

The permittee shall grant the State access rights to the private property at any time for the purpose of maintaining or timing the signal and lighting.

Upon installation, all rights, title and interest in the traffic signal equipment shall be granted to the State by the permittee. In the event that the State finds it advisable for the signals to be removed, the State will remove and salvage the equipment.

Case H. Reconstruction of Existing Facilities. When affected by State highway construction, existing roadway lighting, police and fire alarm systems, and similar systems owned by a city, county or publicly owned service district shall be relocated at the sole expense of the owner, unless prior rights can be established.

Case I. School Traffic Signals and Flashing Beacons. Where traffic signals and/or flashing beacons are justified only by the School Area Traffic Signal Warrant on a State highway, the installation shall be at 100% State expense. When any other warrant is met also, the cost is shared in the usual manner.

Section 4B.107(CA) Construction Costs – Freeways

Standard:

01 **The installation of electrical work and channelization at an intersection of a freeway ramp and a local road shall be at 100% State expense if such improvements are warranted at the time the freeway is to be opened to traffic, or if they are estimated to be warranted within five years after the date the freeway is opened to traffic.**

Support:

02 It can be difficult to accurately predict the traffic pattern at interchanges at the time of the freeway design. Therefore, the need for signals at the ramp connections to local roads cannot always be anticipated.

Standard:

03 **If within five years after the date of completion of the freeway, the interchange does not operate in the manner intended, and signal warrants are met, it shall be the policy to provide signals, lighting, channelization or roadway widening as necessary to facilitate the flow of traffic through the interchange. This work shall be done entirely at State expense in the same manner as it would have been done had it been planned in the original freeway project. This shall include widening of roadway approaches to proposed signalized ramp intersections in accordance with present design practice entirely at State expense.**

04 **After the five-year period, the cost of installation shall be financed in the same manner as for existing intersections.**

Guidance:

05 *Approval by local agencies should be obtained for changes to roads under their jurisdiction.*

Option:

06 In lieu of treating each ramp intersection individually and sharing the costs on the basis of the number of legs under each jurisdiction, the concept of the overall facility as described in Caltrans' Maintenance Manual may be used. See Section 1A.11 for information regarding this publication.

Standard:

07 **Frontage roads or portions of frontage roads, which serve as connections between ramps to or from the freeway and existing public roads and which are retained under State jurisdiction, shall be considered as freeway ramps and electrical work at the intersections shall be financed as described above.**

08 **Any time the interchange is revised by adding or relocating ramps, it is considered a new interchange and the cost of signals at the ramp terminals and/or the connection to the local road shall be at 100% State expense.**

Section 4B.108(CA) Roadway Improvements by Local Agencies

Standard:

01 **Any new connection of a local street to a State highway, including any electrical work, widening and/or channelization required within the State highway right of way, shall be at 100% local agency expense.**

02 **At existing intersections any relocation or improvement of electrical facilities due to widening and/or channelization of the local street shall be at 100% local agency expense.**

Section 4B.109(CA) Cooperative Agreements

Support:

01 When a local agency participates in the various project costs, a cooperative agreement is required.

Standard:

02 **Each agreement shall include a statement of ownership, maintenance and operation.**

Support:

03 Pre-approved agreement forms and procedure details are available.

Section 4B.110(CA) Engineering Services for Local Agencies

Standard:

01 **Contracts with local agencies for the State to provide traffic signal control system engineering services shall include a clause relating to "Legal Relationships and Responsibilities".**

Support:

02 Pre-approved wording is available.

Section 4B.111(CA) Salvaged Electrical Equipment

Support:

01 A construction project sometimes includes the removal of traffic signal, lighting or other electrical equipment that is not to be reused on the particular project.

Guidance:

02 *The determination as to whether particular electrical equipment is salvable should be made at the Caltrans District level. The determination as to whether or not to salvage existing equipment should be made on the basis of the economic benefit to the State and on the conservation of energy and/or materials that would result from salvaging and/or reinstallation. Equipment should be salvaged if it falls within one of the following categories:*

A. It is an item for which there is a foreseeable use.
B. It is part of an electrical installation owned jointly with another agency and the other agency has requested the salvaged equipment.
C. It is usable in some other Caltrans District.
D. It can be immediately disposed of by other means.

Standard:

03 **All electrical equipment removed and determined not to be salvable shall become the property of the contractor.**

04 **Equipment determined to be salvable shall be disposed of as follows:**

A. If the electrical installation is jointly owned by the State and one or more local agencies, each of the owners shall share in the salvage value. The local agencies shall be given first choice in obtaining the salvaged equipment. The agency obtaining the salvaged equipment shall reimburse the other agency in accordance with the proportionate ownership.

B. Where the State or local agency is replacing existing electrical equipment without the other agency participating in the cost of the new equipment, the salvaged equipment shall belong to the party or parties who bore the cost of the new equipment unless otherwise specified in an agreement or encroachment permit.

05 **The salvage value shall be determined at the Caltrans District level during preparation of the preliminary report.**

Guidance:

06 *The salvage value should be such that if the equipment were taken into State storage it could be used economically for maintenance or as State-furnished material on contracts. The estimated salvage value should make the equipment more attractive to local agencies than the money representing the other partner's share of the salvage value. Wire and wiring*

supplies such as conduit, junction boxes, and connectors, and other materials should be considered as a lot at no value, or in any case, not more than the nominal sum of $1.

Support:

07 Often, salvaged electrical equipment is available for use on new installations; in many cases this will result in considerable savings.

Section 4B.112(CA) Encroachment Permits

Standard:

01 **Encroachment permits shall be required for a local agency or a private party to install or modify traffic signals and roadway lighting on a State highway.**

Guidance:

02 *Plans and Specifications prepared by Permittees should conform to State Standard Specifications, Standard Plans and be submitted to the Caltrans District for review and approval.*

Standard:

03 **In each case, a statement of ownership, maintenance and operation shall be included in the permit.**

Support:

04 A Permit Engineering Evaluation Report (PEER) may be prepared in lieu of a project report for all projects estimated to cost $1,000,000 or less, as part of the encroachment permit review process. Instructions for PEER's are found in Caltrans' Project Development Procedures Manual and the Encroachment Permits Manual. See Section 1A.11 for information regarding these publications.

Standard:

05 **All projects financed, in whole or in part, from retail transactions and use taxes and projects costing more than $1,000,000 requires a cooperative agreement.**

Section 4B.113(CA) Modifications of Existing Signals

Guidance:

01 *Where existing signals are to be modified, construction plans should include a separate plan of the existing system as well as a plan showing the modifications.*

Option:

02 It may also be necessary to include a tabulation on the plan showing such appurtenances as backplates and special signal faces that may be difficult to discern on a complicated plan.

Guidance:

03 *The design of any signal modification project should include adequate consideration for keeping the existing signals in operation while the modification work is being done.*

Section 4B.114(CA) Signals on Poles Owned by Others

Option:

01 Traffic signal equipment may be attached to poles owned by utility companies or other agencies when it is desired to keep the number of poles at an intersection to a minimum.

Guidance:

02 *In such cases, the Agency should enter into an agreement with the owner of the pole. The agreement should be written to hold the owner of the pole free of liability relative to operation of the traffic signal or damage to the pole and to make the State or Local Transportation Agency responsible for moving the equipment in the event the pole is removed or relocated.*

CHAPTER 4C. TRAFFIC CONTROL SIGNAL NEEDS STUDIES

Section 4C.01 Studies and Factors for Justifying Traffic Control Signals

Standard:

01 **An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.**

01a **On State highways, the engineering study shall include consideration of a roundabout (yield control). If a roundabout is determined to provide a viable and practical solution, it shall be studied in lieu of, or in addition to a traffic control signal.**

Guidance:

01b *On local streets and highways, the engineering study should include consideration of a roundabout (yield control). If a roundabout is determined to provide a viable and practical solution, it should be studied in lieu of, or in addition to a traffic control signal.*

Support:

01c Refer to Caltrans' website (http://www.dot.ca.gov/hq/traffops/liaisons/ice.html) for more information on the Traffic Operations Policy Directive 13-02, Intersection Control Evaluation (ICE), and other resources for the evaluation of intersection traffic control strategies.

02 **The investigation of the need for a traffic control signal shall include an analysis of factors related to the existing operation and safety at the study location and the potential to improve these conditions, and the applicable factors contained in the following traffic signal warrants:**

Warrant 1, Eight-Hour Vehicular Volume
Warrant 2, Four-Hour Vehicular Volume
Warrant 3, Peak Hour
Warrant 4, Pedestrian Volume
Warrant 5, School Crossing
Warrant 6, Coordinated Signal System
Warrant 7, Crash Experience
Warrant 8, Roadway Network
Warrant 9, Intersection Near a Grade Crossing

03 **The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.**

Support:

04 Sections 8C.09 and 8C.10 contain information regarding the use of traffic control signals instead of gates and/ or flashing-light signals at highway-rail grade crossings and highway-light rail transit grade crossings, respectively.

Guidance:

05 *A traffic control signal should not be installed unless one or more of the factors described in this Chapter are met.*

06 *A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.*

07 *A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.*

08 *The study should consider the effects of the right-turn vehicles from the minor-street approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count when evaluating the count against the signal warrants listed in Paragraph 2.*

09 *Engineering judgment should also be used in applying various traffic signal warrants to cases where approaches consist of one lane plus one left-turn or right-turn lane. The site-specific traffic characteristics should dictate whether an approach is considered as one lane or two lanes. For example, for an approach with one lane for through and right-turning traffic plus a left-turn lane, if engineering judgment indicates that it should be considered a one-lane approach because the traffic using the left-turn lane is minor, the total traffic volume approaching the intersection should be applied against the signal warrants as a one-lane approach. The*

approach should be considered two lanes if approximately half of the traffic on the approach turns left and the left-turn lane is of sufficient length to accommodate all left-turn vehicles.

10 *Similar engineering judgment and rationale should be applied to a street approach with one through/left-turn lane plus a right-turn lane. In this case, the degree of conflict of minor-street right-turn traffic with traffic on the major street should be considered. Thus, right-turn traffic should not be included in the minor-street volume if the movement enters the major street with minimal conflict. The approach should be evaluated as a one-lane approach with only the traffic volume in the through/left-turn lane considered.*

11 *At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants. Except for locations where the engineering study uses the satisfaction of Warrant 8 to justify a signal, a traffic control signal installed under projected conditions should have an engineering study done within 1 year of putting the signal into stop-and-go operation to determine if the signal is justified. If not justified, the signal should be taken out of stop-and-go operation or removed.*

12 *For signal warrant analysis, a location with a wide median, even if the median width is greater than 30 feet, should be considered as one intersection.*

Option:

13 At an intersection with a high volume of left-turn traffic from the major street, the signal warrant analysis may be performed in a manner that considers the higher ~~of the major-street left-turn volumes as the "minor-street" volume and the corresponding single direction of opposing traffic on the major street as the "major-street" volume~~ volume of the major-street left-turn volumes plus the higher volume minor-street approach as the "minor street" volume and both approaches of the major street minus the higher of the major-street left-turn volume as "major street" volume.

14 For signal warrants requiring conditions to be present for a certain number of hours in order to be satisfied, any four sequential 15-minute periods may be considered as 1 hour if the separate 1-hour periods used in the warrant analysis do not overlap each other and both the major-street volume and the minor-street volume are for the same specific one-hour periods.

15 For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians.

Support:

16 When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.

Option:

17 Engineering study data may include the following:

A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.
B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15-minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B and during hours of highest pedestrian volume. Where young, elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.
D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
E. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions,

pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.

G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

18 The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods described in Item B of Paragraph 17:

A. Vehicle-hours of stopped time delay determined separately for each approach.

B. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.

C. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.

D. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.

E. Queue length on stop-controlled approaches.

Standard:

19 **Delay, congestion, approach conditions, driver confusion, future land use or other evidence of the need for right of way assignment beyond that which could be provided by stop sign shall be demonstrated.**

Support:

20 Figure 4C–101(CA) and 4C-103(CA) are examples of warrant sheets.

Guidance:

21 *Figure 4C-103(CA) should be used only for new intersections or other locations where it is not reasonable to count actual traffic volumes.*

Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume

Support:

01 The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

02 The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

03 It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then Warrant 1 is satisfied and analyses of Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then Warrant 1 is satisfied and an analysis of the combination of Conditions A and B is not needed.

Standard:

04 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:**

A. The vehicles per hour given in both of the 100 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or

B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

In applying each condition the major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.

Option:

05 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 4C-1 may be used in place of the 100 percent columns.

Guidance:

06 *The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.*

Standard:

07 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:**

A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and

B. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

These major-street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Option:

08 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.03 Warrant 2, Four-Hour Vehicular Volume

Support:

01 The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that, for each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) all fall above the applicable curve in Figure 4C-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these 4 hours.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-2 may be used in place of Figure 4C-1.

Section 4C.04 Warrant 3, Peak Hour

Support:

01 The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.

Standard:

02 **This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.**

03 **The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:**

A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:

1. The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach; and

2. The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes; and

3. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.

Option:

04 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-4 may be used in place of Figure 4C-3 to evaluate the criteria in the second category of the Standard.

05 If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal may be operated in the flashing mode during the hours that the volume criteria of this warrant are not met.

Guidance:

06 *If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal should be traffic-actuated.*

Section 4C.05 Warrant 4, Pedestrian Volume

Support:

01 The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Standard:

02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**

A. For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or

B. For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-6 may be used in place of Figure 4C-5 to evaluate Criterion A in Paragraph 2, and Figure 4C-8 may be used in place of Figure 4C-7 to evaluate Criterion B in Paragraph 2.

Standard:

04 **The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal or STOP sign controlling the street that pedestrians desire to cross is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

05 **If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E.**

Guidance:

06 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

A. If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.

B. If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site

accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.

C. Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.

Option:

07 The criterion for the pedestrian volume crossing the major street may be reduced as much as 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 feet per second.

08 A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street.

Section 4C.06 Warrant 5, School Crossing

Support:

01 The School Crossing signal warrant is intended for application where the fact that schoolchildren cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word "schoolchildren" includes elementary through high school students.

Standard:

02 **The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of schoolchildren at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the schoolchildren are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 schoolchildren during the highest crossing hour.**

03 **Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.**

04 **The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

05 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

A. If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.

B. If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.

C. Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

01 Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**

A. On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.

B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.

Guidance:

03 *The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*

Section 4C.08 Warrant 7, Crash Experience

Support:

01 The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:**

A. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and

B. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and

C. For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.09 Warrant 8, Roadway Network

Support:

01 Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:**

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).

03 **A major route as used in this signal warrant shall have at least one of the following characteristics:**

A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow.

B. It includes rural or suburban highways outside, entering, or traversing a city.

C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.

Section 4C.10 Warrant 9, Intersection Near a Grade Crossing

Support:

01 The Intersection Near a Grade Crossing signal warrant is intended for use at a location where none of the conditions described in the other eight traffic signal warrants are met, but the proximity to the intersection of a

grade crossing on an intersection approach controlled by a STOP or YIELD sign is the principal reason to consider installing a traffic control signal.

Guidance:

02 *This signal warrant should be applied only after adequate consideration has been given to other alternatives or after a trial of an alternative has failed to alleviate the safety concerns associated with the grade crossing. Among the alternatives that should be considered or tried are:*

A. Providing additional pavement that would enable vehicles to clear the track or that would provide space for an evasive maneuver, or

B. Reassigning the stop controls at the intersection to make the approach across the track a non-stopping approach.

Standard:

03 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following criteria are met:**

A. A grade crossing exists on an approach controlled by a STOP or YIELD sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach; and

B. During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance D, which is the clear storage distance as defined in Section 1A.13.

Guidance:

04 *The following considerations apply when plotting the traffic volume data on Figure 4C-9 or 4C-10:*

A. Figure 4C-9 should be used if there is only one lane approaching the intersection at the track crossing location and Figure 4C-10 should be used if there are two or more lanes approaching the intersection at the track crossing location.

B. After determining the actual distance D, the curve for the distance D that is nearest to the actual distance D should be used. For example, if the actual distance D is 95 feet, the plotted point should be compared to the curve for D = 90 feet.

C. If the rail traffic arrival times are unknown, the highest traffic volume hour of the day should be used.

Option:

05 The minor-street approach volume may be multiplied by up to three adjustment factors as provided in Paragraphs 6 through 8.

06 Because the curves are based on an average of four occurrences of rail traffic per day, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-2 for the appropriate number of occurrences of rail traffic per day.

07 Because the curves are based on typical vehicle occupancy, if at least 2% of the vehicles crossing the track are buses carrying at least 20 people, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-3 for the appropriate percentage of high-occupancy buses.

08 Because the curves are based on tractor-trailer trucks comprising 10% of the vehicles crossing the track, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-4 for the appropriate distance and percentage of tractor-trailer trucks.

Standard:

09 **If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, then:**

A. The traffic control signal shall have actuation on the minor street;

B. Preemption control shall be provided in accordance with Sections 4D.27, 8C.09, and 8C.10; and

C. The grade crossing shall have flashing-light signals (see Chapter 8C).

Guidance:

10 *If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, the grade crossing should have automatic gates (see Chapter 8C).*

Section 4C.101(CA) Criterion for School Crossing Traffic Signals

01 **Standard:**

A. The signal shall be designed for full-time operation.

B. Pedestrian signal faces of the International Symbol type shall be installed at all marked crosswalks at signalized intersections along the "Suggested Route to School."

C. If an intersection is signalized under this guideline for school pedestrians, the entire intersection shall be signalized.

D. School area traffic signals shall be traffic actuated type with push buttons or other detectors for pedestrians.

Option:

02 Non-intersection school pedestrian crosswalk locations may be signalized when justified.

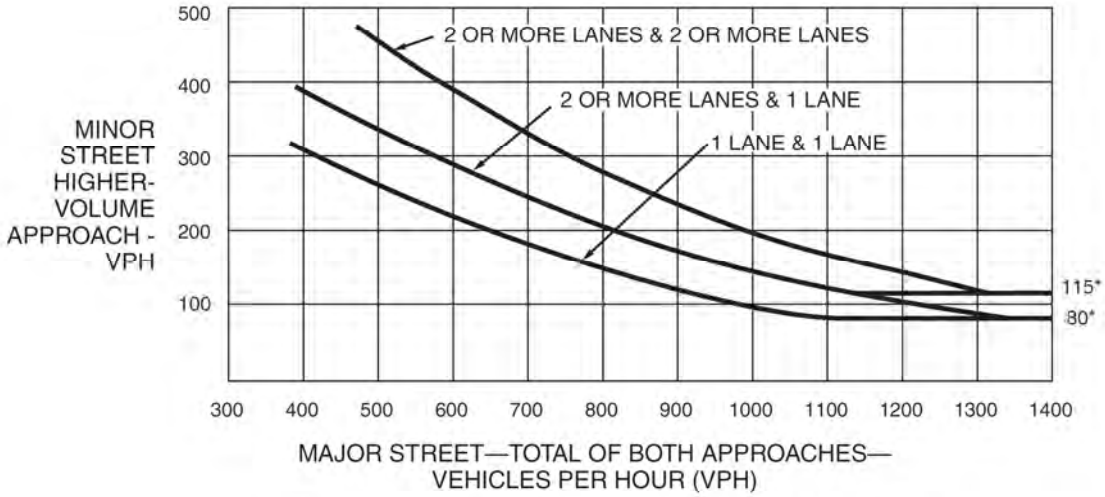
Section 4C.102(CA) Bicycle Signal Warrant

Guidance:

01 *A bicycle signal should be considered for use only when the volume and collision or volume and geometric warrants have been met:*

1. *Volume; When W = B x V and W ≥ 50,000 and B ≥ 50.*
   Where: W is the volume warrant. B is the number of bicycles at the peak hour entering the intersection. V is the number of vehicles at the peak hour entering the intersection. B and V shall use the same peak hour.
2. *Collision; When 2 or more bicycle/vehicle collisions of types susceptible to correction by a bicycle signal have occurred over a 12-month period and the responsible public works official determines that a bicycle signal will reduce the number of collisions.*
3. *Geometric;*
   (a) Where a separate bicycle/ multi use path intersects a roadway.
   (b) At other locations to facilitate a bicycle movement that is not permitted for a motor vehicle.

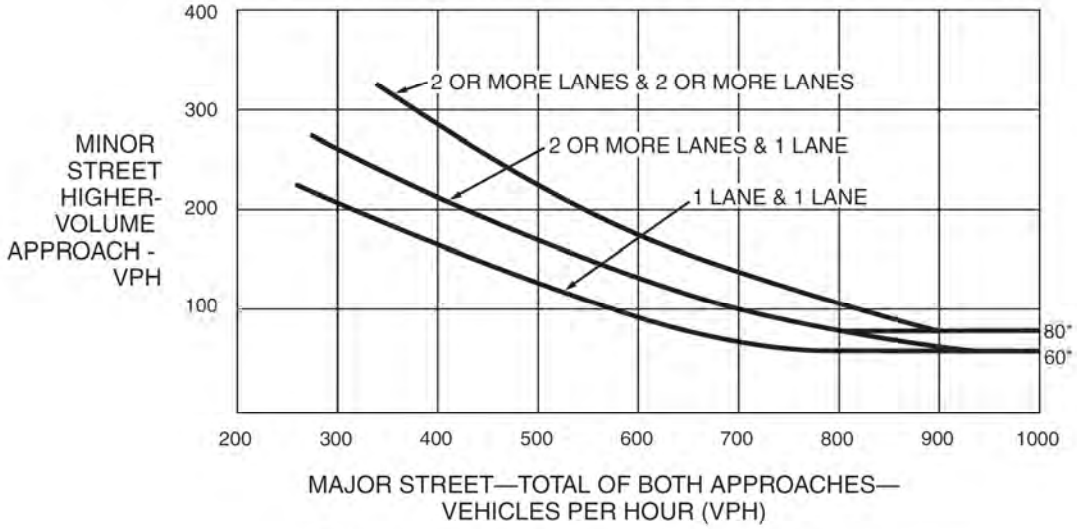
Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

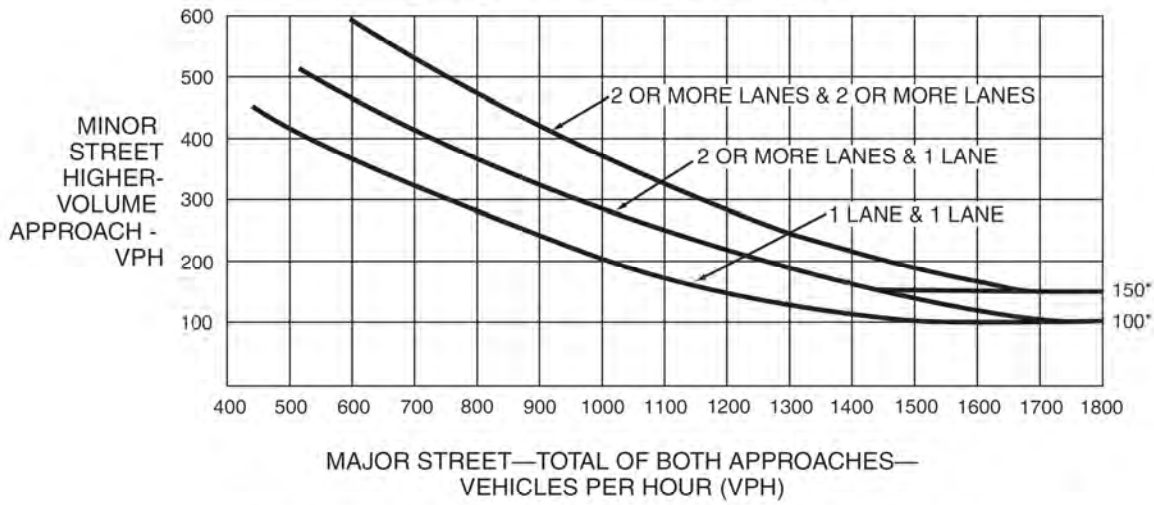
Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane.

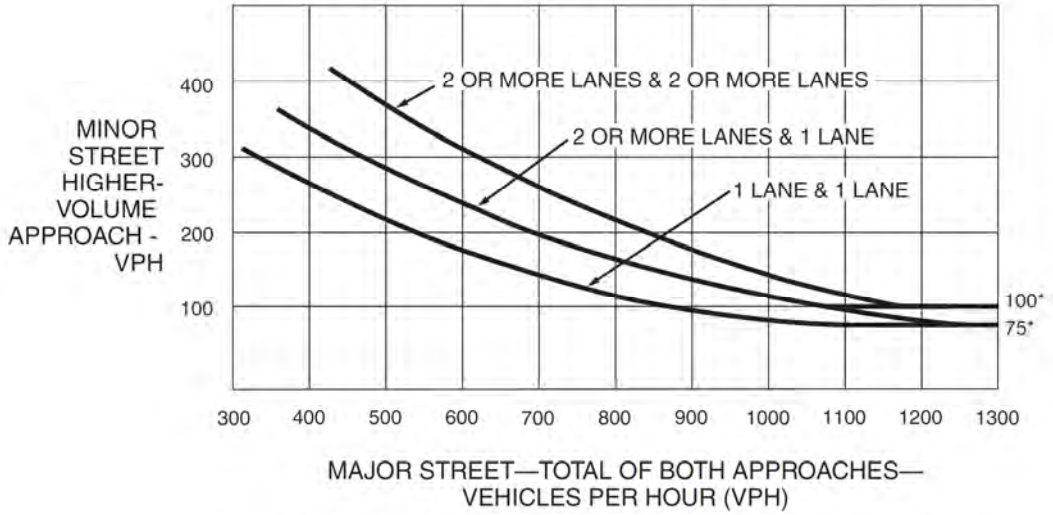
Figure 4C-3. Warrant 3, Peak Hour



*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

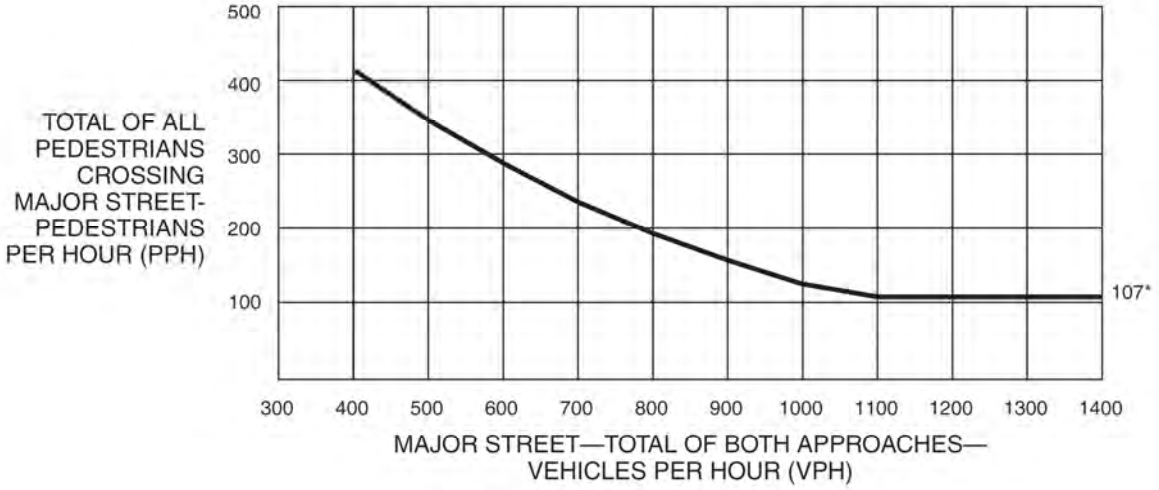
Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



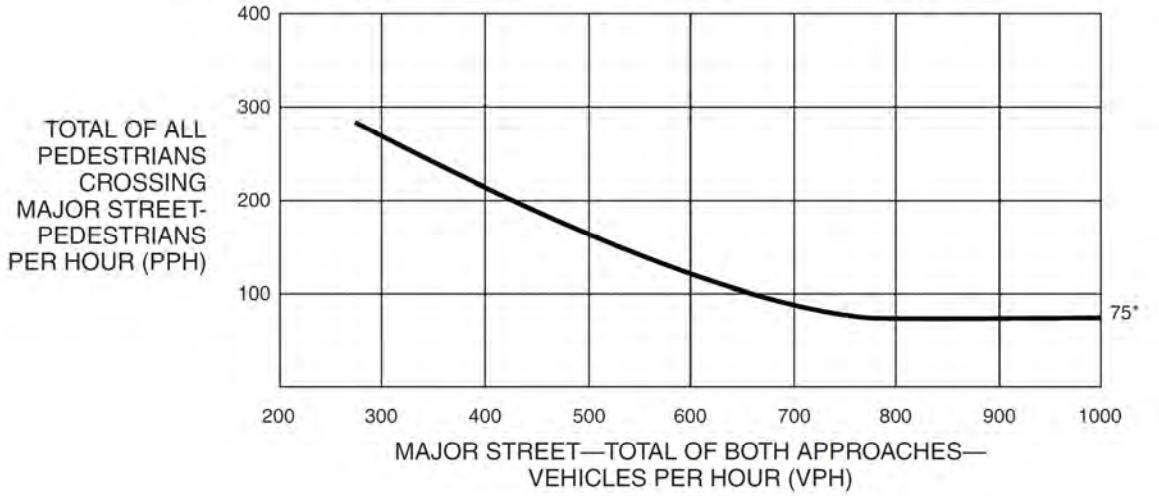
*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



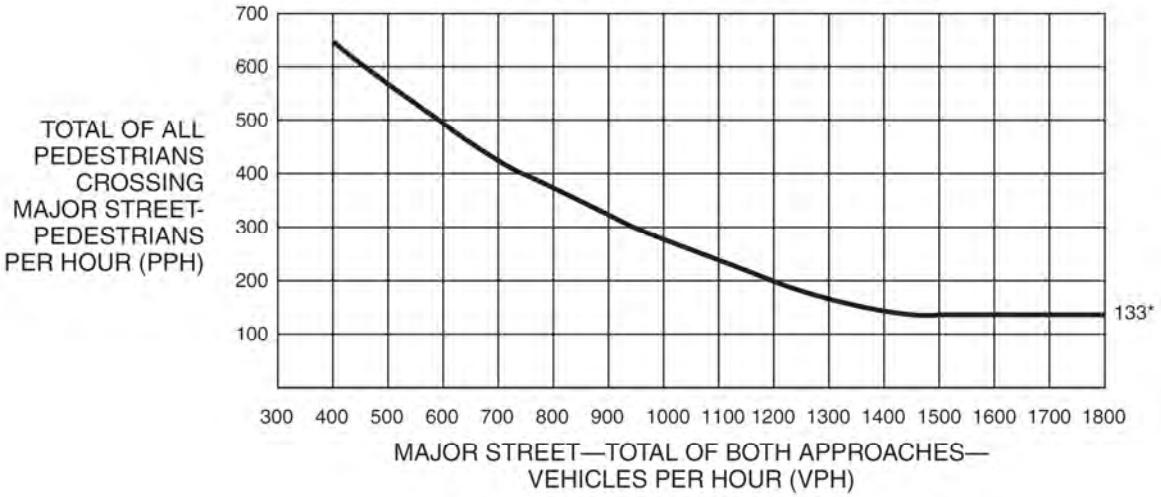
*Note: 107 pph applies as the lower threshold volume.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



*Note: 75 pph applies as the lower threshold volume.

Figure 4C-7. Warrant 4, Pedestrian Peak Hour

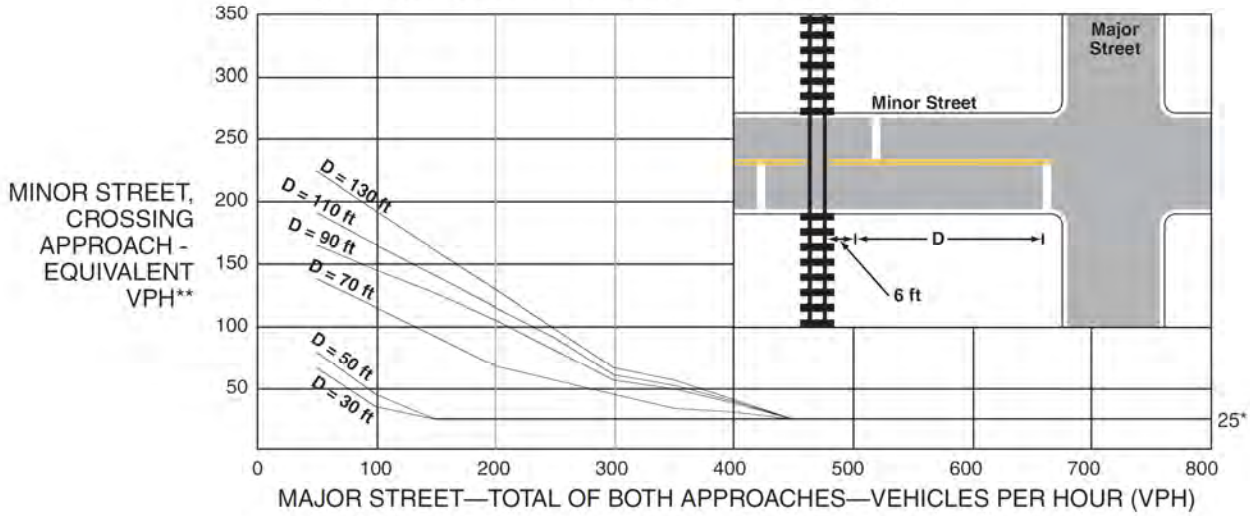


*Note: 133 pph applies as the lower threshold volume.

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)

*Note: 93 pph applies as the lower threshold volume.

Figure 4C-9. Warrant 9, Intersection Near a Grade Crossing (One Approach Lane at the Track Crossing)



* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

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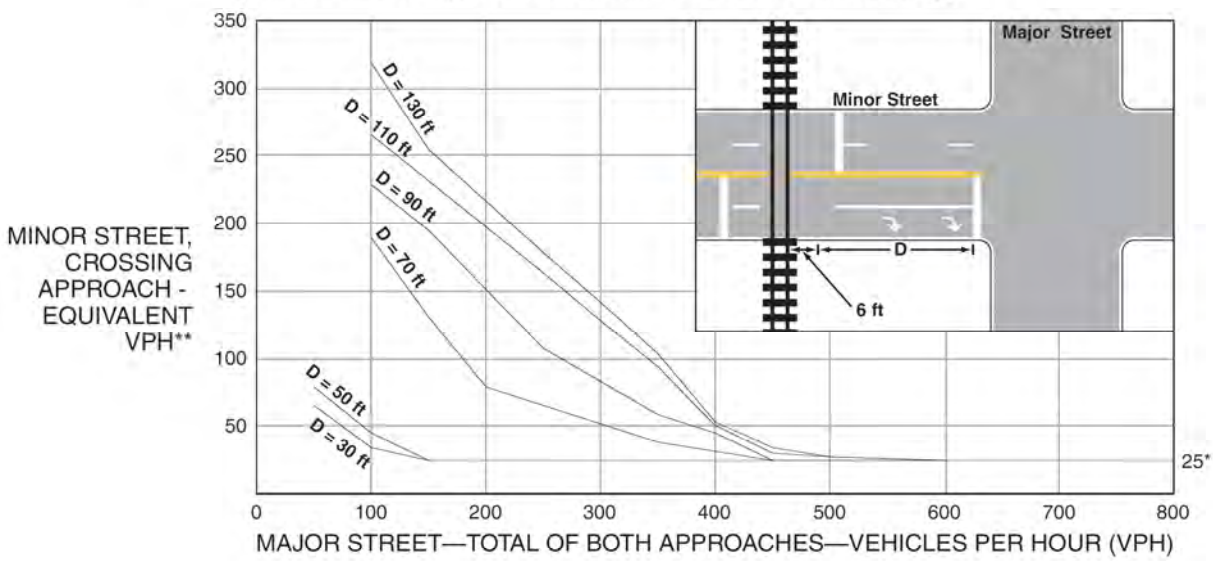
Figure 4C-10. Warrant 9, Intersection Near a Grade Crossing (Two or More Approach Lanes at the Track Crossing)



* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

Figure 4C-101 (CA). Traffic Signal Warrants Worksheet (Sheet 1 of 5)

COUNT DATE _____

_____ DIST _____ CO _____ RTE _____ PM

CALC _____ DATE _____
CHK _____ DATE _____

Major St: _____ Critical Approach Speed _____ mph
Minor St: _____ Critical Approach Speed _____ mph

Speed limit or critical speed on major street traffic > 40 mph..... ☐
or
In built up area of isolated community of < 10,000 population..... ☐
} **RURAL (R)**

☐ **URBAN (U)**

WARRANT 1 - Eight Hour Vehicular Volume **SATISFIED YES ☐ NO ☐**
(Condition A or Condition B or combination of A and B must be satisfied)

Condition A - Minimum Vehicle Volume **100% SATISFIED YES ☐ NO ☐**
80% SATISFIED YES ☐ NO ☐

	MINIMUM REQUIREMENTS (80% SHOWN IN BRACKETS)												Hour
	U	R	U	R									
APPROACH LANES	1		2 or More										
Both Approaches Major Street	500 (400)	350 (280)	600 (480)	420 (336)									
Highest Approach Minor Street	150 (120)	105 (84)	200 (160)	140 (112)									

Condition B - Interruption of Continuous Traffic **100% SATISFIED YES ☐ NO ☐**
80% SATISFIED YES ☐ NO ☐

	MINIMUM REQUIREMENTS (80% SHOWN IN BRACKETS)												Hour
	U	R	U	R									
APPROACH LANES	1		2 or More										
Both Approaches Major Street	750 (600)	525 (420)	900 (720)	630 (504)									
Highest Approach Minor Street	75 (60)	53 (42)	100 (80)	70 (56)									

Combination of Conditions A & B **SATISFIED YES ☐ NO ☐**

REQUIREMENT	CONDITION	✓	FULFILLED
TWO CONDITIONS SATISFIED 80%	A. MINIMUM VEHICULAR VOLUME		Yes ☐ No ☐
	AND, B. INTERRUPTION OF CONTINUOUS TRAFFIC		
AND, AN ADEQUATE TRIAL OF OTHER ALTERNATIVES THAT COULD CAUSE LESS DELAY AND INCONVENIENCE TO TRAFFIC HAS FAILED TO SOLVE THE TRAFFIC PROBLEMS			Yes ☐ No ☐

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Figure 4C-101 (CA). Traffic Signal Warrants Worksheet (Sheet 2 of 5)

WARRANT 2 - Four Hour Vehicular Volume **SATISFIED* YES ☐ NO ☐**

Record hourly vehicular volumes for any four hours of an average day.

APPROACH LANES	One	2 or More				Hour
Both Approaches - Major Street						
Higher Approach - Minor Street						

*All plotted points fall above the applicable curve in Figure 4C-1. (URBAN AREAS)	Yes ☐	No ☐
OR, All plotted points fall above the applicable curve in Figure 4C-2. (RURAL AREAS)	Yes ☐	No ☐

WARRANT 3 - Peak Hour **SATISFIED YES ☐ NO ☐**
(Part A or Part B must be satisfied)

PART A **SATISFIED YES ☐ NO ☐**

(All parts 1, 2, and 3 below must be satisfied for the same one hour, for any four consecutive 15-minute periods)

1. The total delay experienced by traffic on one minor street approach (one direction only) controlled by a STOP sign equals or exceeds four vehicle-hours for a one-lane approach, or five vehicle-hours for a two-lane approach; AND	Yes ☐	No ☐
2. The volume on the same minor street approach (one direction only) equals or exceeds 100 vph for one moving lane of traffic or 150 vph for two moving lanes; AND	Yes ☐	No ☐
3. The total entering volume serviced during the hour equals or exceeds 800 vph for intersections with four or more approaches or 650 vph for intersections with three approaches.	Yes ☐	No ☐

PART B **SATISFIED YES ☐ NO ☐**

APPROACH LANES	One	2 or More		Hour
Both Approaches - Major Street				
Higher Approach - Minor Street				

The plotted point falls above the applicable curve in Figure 4C-3. (URBAN AREAS)	Yes ☐	No ☐
OR, The plotted point falls above the applicable curve in Figure 4C-4. (RURAL AREAS)	Yes ☐	No ☐

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Figure 4C-101 (CA). Traffic Signal Warrants Worksheet (Sheet 3 of 5)

WARRANT 4 - Pedestrian Volume
(Parts 1 and 2 Must Be Satisfied)

SATISFIED YES ☐ NO ☐

Part 1 **(Parts A or B must be satisfied)**

	Hours - - ->				
A.	Vehicles per hour for any 4 hours				
	Pedestrians per hour for any 4 hours				

Figure 4C-5 or Figure 4C-6
SATISFIED YES ☐ NO ☐

	Hours - - ->				
B.	Vehicles per hour for any 1 hour				
	Pedestrians per hour for any 1 hour				

Figure 4C-7 or Figure 4C-8
SATISFIED YES ☐ NO ☐

Part 2 **SATISFIED YES ☐ NO ☐**

AND, The distance to the nearest traffic signal along the major street is greater than 300 ft	Yes ☐ No ☐
OR, The proposed traffic signal will not restrict progressive traffic flow along the major street.	Yes ☐ No ☐

WARRANT 5 - School Crossing
(Parts A and B Must Be Satisfied)

SATISFIED YES ☐ NO ☐

Part A **SATISFIED YES ☐ NO ☐**
Gap/Minutes and # of Children

		Hour
Gaps vs Minutes	Minutes Children Using Crossing	
	Number of Adequate Gaps	
School Age Pedestrians Crossing Street / hr		

Gaps < Minutes YES ☐ NO ☐
AND Children > 20/hr YES ☐ NO ☐

AND, Consideration has been given to less restrictive remedial measures.	Yes ☐ No ☐

Part B **SATISFIED YES ☐ NO ☐**

The distance to the nearest traffic signal along the major street is greater than 300 ft	Yes ☐ No ☐
OR, The proposed signal will not restrict the progressive movement of traffic.	Yes ☐ No ☐

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Figure 4C-101 (CA). Traffic Signal Warrants Worksheet (Sheet 4 of 5)

WARRANT 6 - Coordinated Signal System **SATISFIED YES ☐ NO ☐**
(All Parts Must Be Satisfied)

MINIMUM REQUIREMENTS	DISTANCE TO NEAREST SIGNAL	
≥ 1000 ft	N _____ ft, S _____ ft, E _____ ft, W _____ ft	Yes ☐ No ☐
On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning. OR, On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.		Yes ☐ No ☐

WARRANT 7 - Crash Experience Warrant **SATISFIED YES ☐ NO ☐**
(All Parts Must Be Satisfied)

Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency.			Yes ☐ No ☐
REQUIREMENTS	Number of crashes reported within a 12 month period susceptible to correction by a traffic signal, and involving injury or damage exceeding the requirements for a reportable crash.		Yes ☐ No ☐
5 OR MORE			
REQUIREMENTS	CONDITIONS	✓	
ONE CONDITION SATISFIED 80%	Warrant 1, Condition A - Minimum Vehicular Volume		Yes ☐ No ☐
	OR, Warrant 1, Condition B - Interruption of Continuous Traffic		
	OR, Warrant 4, Pedestrian Volume Condition Ped Vol ≥ 80% of Figure 4C-5 through Figure 4C-8		

WARRANT 8 - Roadway Network **SATISFIED YES ☐ NO ☐**
(All Parts Must Be Satisfied)

MINIMUM VOLUME REQUIREMENTS	ENTERING VOLUMES - ALL APPROACHES		✓	FULFILLED
1000 Veh/Hr	During Typical Weekday Peak Hour _____ Veh/Hr and has 5-year projected traffic volumes that meet one or more of Warrants 1, 2, and 3 during an average weekday.			Yes ☐ No ☐
	OR During Each of Any 5 Hrs. of a Sat. or Sun _____ Veh/Hr			
CHARACTERISTICS OF MAJOR ROUTES		MAJOR ROUTE A	MAJOR ROUTE B	
Hwy. System Serving as Principal Network for Through Traffic				
Rural or Suburban Highway Outside Of, Entering, or Traversing a City				
Appears as Major Route on an Official Plan				
Any Major Route Characteristics Met, Both Streets				Yes ☐ No ☐

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Figure 4C-101 (CA). Traffic Signal Warrants Worksheet (Sheet 5 of 5)

WARRANT 9 - Intersection Near a Grade Crossing **SATISFIED YES ☐ NO ☐**
(Both Parts A and B Must Be Satisfied)

PART A A grade crossing exists on an approach controlled by a STOP or YIELD sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach. Track Center Line to Limit Line _____ ft	Yes ☐ No ☐
PART B **There is one minor street approach lane at the track crossing -** During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point falls above the applicable curve in Figure 4C-9. Major Street - Total of both approaches: _____ VPH Minor Street - Crosses the track (one direction only, approaching the intersection): _____ VPH X AF (Use Tables 4C-2, 3, & 4 below to calculate AF) = _____ VPH	Yes ☐ No ☐
OR, There are two or more minor street approach lanes at the track crossing - During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point falls above the applicable curve in Figure 4C-10. Major Street - Total of both approaches : _____ VPH Minor Street - Crosses the track (one direction only, approaching the intersection): _____ VPH X AF (Use Tables 4C-2, 3, & 4 below to calcualte AF) = _____ VPH	

The minor street approach volume may be multiplied by up to three following adjustment factors (AF) as described in Section 4C.10.

1- Number of Rail Traffic per Day_____ Adjustment factor from table 4C-2____

2- Percentage of High-Occupancy Buses on Minor Street Approach_____ Adjustment factor from table 4C-3____

3- Percentage of Tractor-Trailer Trucks on Minor Street Approach_____ Adjustment factor from table 4C-4____

NOTE: If no data is availale or known, then use AF = 1 (no adjustment)

Figure 4C-102 (CA). Traffic Count Worksheet

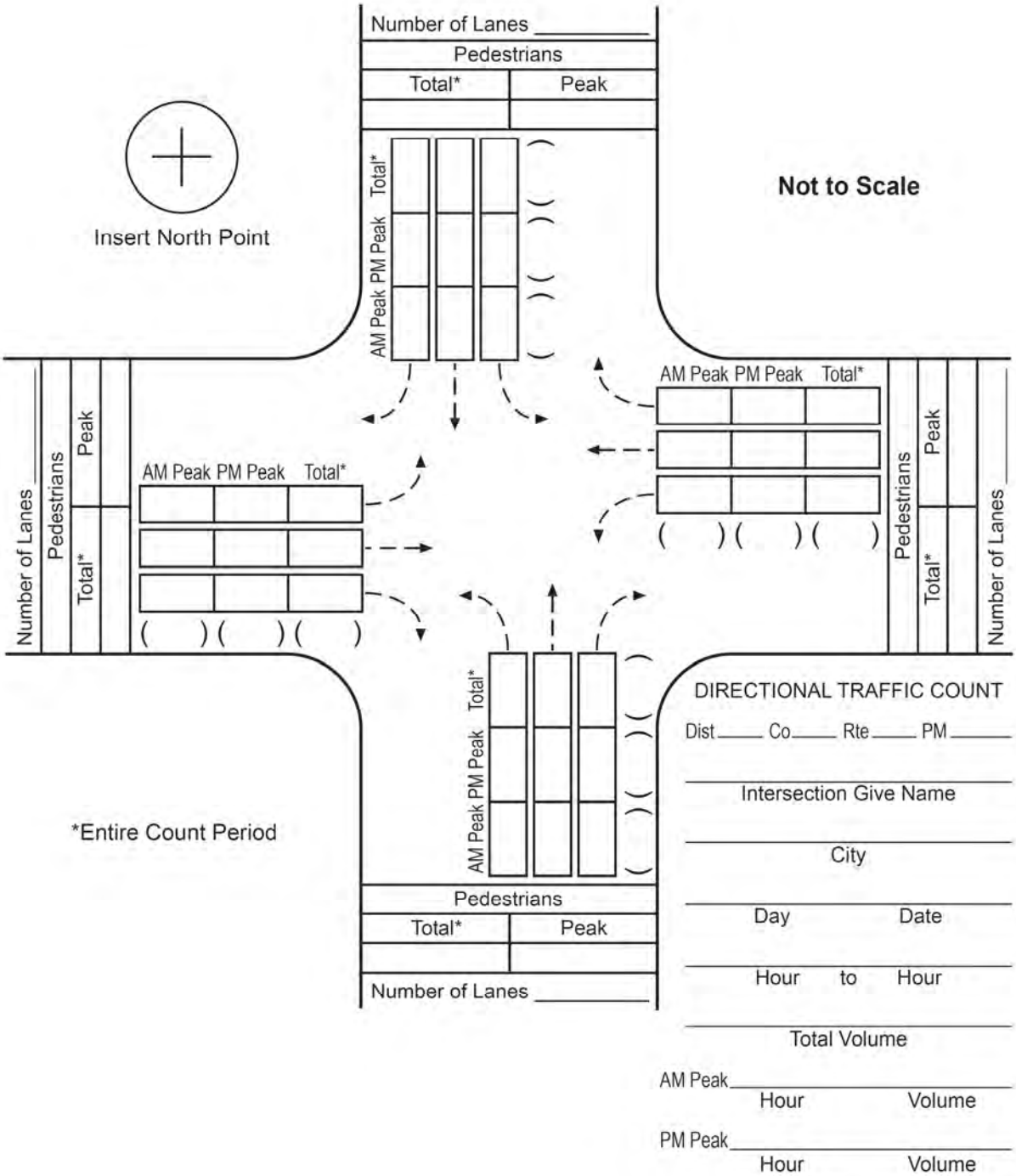


Figure 4C-103 (CA). Traffic Signal Warrants Worksheet (Average Traffic Estimate Form)

COUNT DATE _____

_____ DIST _____ CO _____ RTE _____ PM

CALC _____ DATE _____
CHK _____ DATE _____

Major St: _____ Critical Approach Speed _____ mph
Minor St: _____ Critical Approach Speed _____ mph

Speed limit or critical speed on major street traffic > 40 mph..... ☐
or
In built up area of isolated community of < 10,000 population..... ☐
} **RURAL (R)**

☐ **URBAN (U)**

(Based on Estimated Average Daily Traffic - See Note)

URBAN..... RURAL.....	Minimum Requirements EADT			
CONDITION A - Minimum Vehicular Volume Satisfied _____ Not Satisfied _____	Vehicles Per Day on Major Street (Total of Both Approaches)		Vehicles Per Day on Higher-Volume Minor Street Approach (One Direction Only)	
Number of lanes for moving traffic on each approach Major Street / Minor Street	Urban	Rural	Urban	Rural
1..... / 1.....	8,000	5,600	2,400	1,680
2 or More..... / 1.....	9,600	6,720	2,400	1,680
2 or More..... / 2 or More.....	9,600	6,720	3,200	2,240
1..... / 2 or More.....	8,000	5,600	3,200	2,240
CONDITION B - Interruption of Continuous Traffic Satisfied _____ Not Satisfied _____	Vehicles Per Day on Major Street (Total of Both Approaches)		Vehicles Per Day on Higher-Volume Minor Street Approach (One Direction Only)	
Number of lanes for moving traffic on each approach Major Street / Minor Street	Urban	Rural	Urban	Rural
1..... / 1.....	12,000	8,400	1,200	850
2 or More..... / 1.....	14,400	10,080	1,200	850
2 or More..... / 2 or More.....	14,400	10,080	1,600	1,120
1..... / 2 or More.....	12,000	8,400	1,600	1,120
Combination of CONDITIONS A + B Satisfied _____ Not Satisfied _____ No one condition satisfied, but following conditions fulfilled 80% or more..... _____ A _____ B	2 CONDITIONS 80%		2 CONDITIONS 80%	

Note: To be used only for NEW INTERSECTIONS or other locations where it is not reasonable to count actual traffic volumes.

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume
[b] Used for combination of Conditions A and B after adequate trial of other remedial measures
[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000
[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Table 4C-2. Warrant 9, Adjustment Factor for Daily Frequency of Rail Traffic

Rail Traffic per Day	Adjustment Factor
1	0.67
2	0.91
3 to 5	1.00
6 to 8	1.18
9 to 11	1.25
12 or more	1.33

Table 4C-3. Warrant 9, Adjustment Factor for Percentage of High-Occupancy Buses

% of High-Occupancy Buses* on Minor-Street Approach	Adjustment Factor
0%	1.00
2%	1.09
4%	1.19
6% or more	1.32

* A high-occupancy bus is defined as a bus occupied by at least 20 people.

Table 4C-4. Warrant 9, Adjustment Factor for Percentage of Tractor-Trailer Trucks

% of Tractor-Trailer Trucks on Minor-Street Approach	Adjustment Factor	
	D less than 70 feet	D of 70 feet or more
0% to 2.5%	0.50	0.50
2.6% to 7.5%	0.75	0.75
7.6% to 12.5%	1.00	1.00
12.6% to 17.5%	2.30	1.15
17.6% to 22.5%	2.70	1.35
22.6% to 27.5%	3.28	1.64
More than 27.5%	4.18	2.09

CHAPTER 4D. TRAFFIC CONTROL SIGNAL FEATURES

Section 4D.01 General

Support:

01 The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in this Manual, is especially important for the safety and efficiency of operations.

02 Traffic control signals can be operated in pre-timed, semi-actuated, or full-actuated modes. For isolated (non-interconnected) signalized locations on rural high-speed highways, full-actuated mode with advance vehicle detection on the high-speed approaches is typically used. These features are designed to reduce the frequency with which the onset of the yellow change interval is displayed when high-speed approaching vehicles are in the "dilemma zone" such that the drivers of these high-speed vehicles find it difficult to decide whether to stop or proceed.

Standard:

03 **When a traffic control signal is not in operation, such as before it is placed in service, during seasonal shutdowns, or when it is not desirable to operate the traffic control signal, the signal faces shall be covered, turned, or taken down to clearly indicate that the traffic control signal is not in operation.**

Support:

04 Seasonal shutdown is a condition in which a permanent traffic signal is turned off or otherwise made non-operational during a particular season when its operation is not justified. This might be applied in a community where tourist traffic during most of the year justifies the permanent signalization, but a seasonal shutdown of the signal during an annual period of lower tourist traffic would reduce delays; or where a major traffic generator, such as a large factory, justifies the permanent signalization, but the large factory is shut down for an annual factory vacation for a few weeks in the summer.

Standard:

05 **A traffic control signal shall control traffic only at the intersection or midblock location where the signal faces are placed.**

06 **Midblock crosswalks shall not be signalized if they are located within 300 feet from the nearest traffic control signal, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

07 *A midblock crosswalk location should not be controlled by a traffic control signal if the crosswalk is located within 100 feet from side streets or driveways that are controlled by STOP signs or YIELD signs.*

08 *Engineering judgment should be used to determine the proper phasing and timing for a traffic control signal. Since traffic flows and patterns change, phasing and timing should be reevaluated regularly and updated if needed.*

09 *Traffic control signals within 1/2 mile of one another along a major route or in a network of intersecting major routes should be coordinated, preferably with interconnected controller units. Where traffic control signals that are within 1/2 mile of one another along a major route have a jurisdictional boundary or a boundary between different signal systems between them, coordination across the boundary should be considered.*

Support:

10 Signal coordination need not be maintained between control sections that operate on different cycle lengths.

11 For coordination with grade crossing signals and movable bridge signals, see Sections 4D.27, 4J.03, 8C.09, and 8C.10.

Section 4D.02 Responsibility for Operation and Maintenance

Guidance:

01 *Prior to installing any traffic control signal, the responsibility for the maintenance of the signal and all of the appurtenances, hardware, software, and the timing plan(s) should be clearly established. The responsible agency should provide for the maintenance of the traffic control signal and all of its appurtenances in a competent manner.*

02 *To this end the agency should:*

A. Keep every controller assembly in effective operation in accordance with its predetermined timing schedule; check the operation of the controller assembly frequently enough to verify that it is operating in accordance with the predetermined timing schedule; and establish a policy to maintain a record of all timing changes and that only authorized persons are permitted to make timing changes;

B. Clean the optical system of the signal sections and replace the light sources as frequently as experience proves necessary;

C. Clean and service equipment and other appurtenances (i.e. cameras and preemption devices) as frequently as experience proves necessary;

D. Provide for alternate operation of the traffic control signal during a period of failure, using flashing mode or manual control, or manual traffic direction by proper authorities as might be required by traffic volumes or congestion, or by erecting other traffic control devices;

E. Have properly skilled maintenance personnel available without undue delay for all signal malfunctions and signal indication failures;

F. Provide spare equipment to minimize the interruption of traffic control signal operation as a result of equipment failure;

G. Provide for the availability of properly skilled maintenance personnel for the repair of all components; and

H. Maintain the appearance of the signal displays and equipment.

Support:

03 Caltrans 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:

04 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.

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

Section 4D.03 Provisions for Pedestrians

Support:

01 Chapter 4E contains additional information regarding pedestrian signals and Chapter 4F contains additional information regarding pedestrian hybrid beacons.

Standard:

02 **The design and operation of traffic control signals shall take into consideration the needs of pedestrian as well as vehicular traffic.**

03 **If engineering judgment indicates the need for provisions for a given pedestrian movement, signal faces conveniently visible to pedestrians shall be provided by pedestrian signal heads (see Chapter 4E) or a vehicular signal face(s) for a concurrent vehicular movement.**

Guidance:

04 *Accessible pedestrian signals (see Sections 4E.09 through 4E.13) that provide information in non-visual formats (such as audible tones, speech messages, and/or vibrating surfaces) should be provided where determined appropriate by engineering judgment.*

05 *Where pedestrian movements regularly occur, pedestrians should be provided with sufficient time to cross the roadway by adjusting the traffic control signal operation and timing to provide sufficient crossing time every cycle or by providing pedestrian detectors.*

06 *If it is necessary or desirable to prohibit certain pedestrian movements at a traffic control signal location, No Pedestrian Crossing (R9-3) signs (see Section 2B.51) should be used if it is not practical to provide a barrier or other physical feature to physically prevent the pedestrian movements.*

Section 4D.04 Meaning of Vehicular Signal Indications

Support:

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

02 The physical area that is defined as being "within the intersection" is dependent upon the conditions that are described in the definition of intersection in Section 1A.13.

Standard:

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

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

1. Vehicular traffic facing a CIRCULAR GREEN signal indication is permitted to proceed straight through or turn right or left or make a U-turn movement except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, roadway design, separate turn signal indications, or other traffic control devices.

Such vehicular traffic, including vehicles turning right or left or making a U-turn movement, shall yield the right-of-way to:

(a) Pedestrians lawfully within an associated crosswalk, and

(b) Other vehicles lawfully within the intersection.

In addition, vehicular traffic turning left or making a U-turn movement to the left shall yield the right-of-way to other vehicles approaching from the opposite direction so closely as to constitute an immediate hazard during the time when such turning vehicle is moving across or within the intersection.

2. Vehicular traffic facing a GREEN ARROW signal indication, displayed alone or in combination with another signal indication, is permitted to cautiously enter the intersection only to make the movement indicated by such arrow, or such other movement as is permitted by other signal indications displayed at the same time.

Such vehicular traffic, including vehicles turning right or left or making a U-turn movement, shall yield the right-of-way to:

(a) Pedestrians lawfully within an associated crosswalk, and

(b) Other vehicles lawfully within the intersection.

3. Pedestrians facing a CIRCULAR GREEN signal indication, unless otherwise directed by a pedestrian signal indication or other traffic control device, are permitted to proceed across the roadway within any marked or unmarked associated crosswalk. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection or so close as to create an immediate hazard at the time that the green signal indication is first displayed.

4. Pedestrians facing a GREEN ARROW signal indication, unless otherwise directed by a pedestrian signal indication or other traffic control device, shall not cross the roadway.

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

1. Vehicular traffic facing a steady CIRCULAR YELLOW signal indication is thereby warned that the related green movement or the related flashing arrow movement is being terminated or that a steady red signal indication will be displayed immediately thereafter when vehicular traffic shall not enter the intersection. The rules set forth concerning vehicular operation under the movement(s) being terminated shall continue to apply while the steady CIRCULAR YELLOW signal indication is displayed.

2. Vehicular traffic facing a steady YELLOW ARROW signal indication is thereby warned that the related GREEN ARROW movement or the related flashing arrow movement is being terminated. The rules set forth concerning vehicular operation under the movement(s) being terminated shall continue to apply while the steady YELLOW ARROW signal indication is displayed.

3. Pedestrians facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication, unless otherwise directed by a pedestrian signal indication or other traffic control device shall not start to cross the roadway.

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

1. Vehicular traffic facing a steady CIRCULAR RED signal indication, unless entering the intersection to make another movement permitted by another signal indication, shall stop at a clearly marked stop line; but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, then before entering the intersection; and shall remain stopped until a signal indication to proceed is displayed, or as provided below. Except when a traffic control device is in place prohibiting a turn on red or a steady RED ARROW signal indication is displayed, vehicular traffic facing a steady CIRCULAR RED signal indication is permitted to enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping. The right to proceed with the turn shall be subject to the rules applicable after making a stop at a STOP sign.

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

~~When a traffic control device is in place permitting a turn on a steady RED ARROW signal indication, vehicular traffic facing a steady RED ARROW signal indication is permitted to enter the intersection to make the movement indicated by the arrow signal indication, after stopping. The right to proceed with the turn shall be limited to the direction indicated by the arrow and shall be subject to the rules applicable after making a stop at a STOP sign.~~ The R10-17a sign shall not be used in California. Turning on a steady red arrow is not permitted in California.

3. Unless otherwise directed by a pedestrian signal indication or other traffic control device, pedestrians facing a steady CIRCULAR RED or steady RED ARROW signal indication shall not enter the roadway.

D. A flashing green signal indication has no meaning and shall not be used.

E. Flashing yellow signal indications shall have the following meanings:

1. Vehicular traffic, on an approach to an intersection, facing a flashing CIRCULAR YELLOW signal indication is permitted to cautiously enter the intersection to proceed straight through or turn right or left or make a U-turn except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, roadway design, separate turn signal indications, or other traffic control devices.

Such vehicular traffic, including vehicles turning right or left or making a U-turn, shall yield the right-of-way to:

(a) Pedestrians lawfully within an associated crosswalk, and

(b) Other vehicles lawfully within the intersection.

In addition, vehicular traffic turning left or making a U-turn to the left shall yield the right-of way to other vehicles approaching from the opposite direction so closely as to constitute an immediate hazard during the time when such turning vehicle is moving across or within the intersection.

2. Vehicular traffic, on an approach to an intersection, facing a flashing YELLOW ARROW signal indication, displayed alone or in combination with another signal indication, is permitted to cautiously enter the intersection only to make the movement indicated by such arrow, or other such movement as is permitted by other signal indications displayed at the same time.

Such vehicular traffic, including vehicles turning right or left or making a U-turn, shall yield the right-of-way to:

(a) Pedestrians lawfully within an associated crosswalk, and

(b) Other vehicles lawfully within the intersection.

In addition, vehicular traffic turning left or making a U-turn to the left shall yield the right-of-way to other vehicles approaching from the opposite direction so closely as to constitute an

immediate hazard during the time when such turning vehicle is moving across or within the intersection.

3. Pedestrians facing any flashing yellow signal indication at an intersection, unless otherwise directed by a pedestrian signal indication or other traffic control device, are permitted to proceed across the roadway within any marked or unmarked associated crosswalk. Pedestrians shall yield the right-of-way to vehicles lawfully within the intersection at the time that the flashing yellow signal indication is first displayed.

4. When a flashing CIRCULAR YELLOW signal indication(s) is displayed as a beacon (see Chapter 4L) to supplement another traffic control device, road users are notified that there is a need to pay extra attention to the message contained thereon or that the regulatory or warning requirements of the other traffic control device, which might not be applicable at all times, are currently applicable.

F. Flashing red signal indications shall have the following meanings:

1. Vehicular traffic, on an approach to an intersection, facing a flashing CIRCULAR RED signal indication shall stop at a clearly marked stop line; but if there is no stop line, before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. The right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.

2. Vehicular traffic, on an approach to an intersection, facing a flashing RED ARROW signal indication if intending to turn in the direction indicated by the arrow shall stop at a clearly marked stop line; but if there is no stop line, before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. The right to proceed with the turn shall be limited to the direction indicated by the arrow and shall be subject to the rules applicable after making a stop at a STOP sign.

3. Pedestrians facing any flashing red signal indication at an intersection, unless otherwise directed by a pedestrian signal indication or other traffic control device, are permitted to proceed across the roadway within any marked or unmarked associated crosswalk. Pedestrians shall yield the right-of-way to vehicles lawfully within the intersection at the time that the flashing red signal indication is first displayed.

4. When a flashing CIRCULAR RED signal indication(s) is displayed as a beacon (see Chapter 4L) to supplement another traffic control device, road users are notified that there is a need to pay extra attention to the message contained thereon or that the regulatory requirements of the other traffic control device, which might not be applicable at all times, are currently applicable. Use of this signal indication shall be limited to supplementing STOP (R1-1), DO NOT ENTER (R5-1), or WRONG WAY (R5-1a) signs, and to applications where compliance with the supplemented traffic control device requires a stop at a designated point.

Section 4D.05 Application of Steady Signal Indications

Standard:

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

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

03 **Steady signal indications shall be applied as follows:**

A. A steady CIRCULAR RED signal indication:

1. Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area. Turning after stopping is permitted as stated in Item C.1 in Paragraph 3 of Section 4D.04.

2. Shall be displayed with the appropriate GREEN ARROW signal indications when it is intended to permit traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the intersection or other controlled area, except in protected only mode operation

(see Sections 4D.19 and 4D.23), or in protected/permissive mode operation with separate turn signal faces (see Sections 4D.20 and 4D.24).

B. A steady CIRCULAR YELLOW signal indication:

1. Shall be displayed following a CIRCULAR GREEN or straight-through GREEN ARROW signal indication in the same signal face.

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

3. Shall be followed by a CIRCULAR RED signal indication except that, when entering preemption operation, the return to the previous CIRCULAR GREEN signal indication shall be permitted following a steady CIRCULAR YELLOW signal indication (see Section 4D.27).

4. Shall not be displayed to an approach from which drivers are turning left permissively or making a U-turn to the left permissively unless one of the following conditions exists:

(a) A steady CIRCULAR YELLOW signal indication is also simultaneously being displayed to the opposing approach;

~~(b) An engineering study has determined that, because of unique intersection conditions, the condition described in Item (a) cannot reasonably be implemented without causing significant operational or safety problems and that the volume of impacted left-turning or U-turning traffic is relatively low, and those left-turning or U-turning drivers are advised that a steady CIRCULAR YELLOW signal indication is not simultaneously being displayed to the opposing traffic if this operation occurs continuously by the installation near the left-most signal head of a W25-1 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC HAS EXTENDED GREEN; or~~ W25-1 sign shall not be used in California.

~~(c) Drivers are advised of the operation if it occurs only occasionally, such as during a preemption sequence, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN.~~ W25-2 sign shall not be used in California

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

D. A steady RED ARROW signal indication shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area to make the indicated turn. ~~Except as described in Item C.2 in Paragraph 3 of Section 4D.04,~~ turning on a steady RED ARROW signal indication shall not be permitted.

E. A steady YELLOW ARROW signal indication:

1. Shall be displayed in the same direction as a GREEN ARROW signal indication following a GREEN ARROW signal indication in the same signal face, unless:

(a) The GREEN ARROW signal indication and a CIRCULAR GREEN (or straight-through GREEN ARROW) signal indication terminate simultaneously in the same signal face, or

(b) The green arrow is a straight-through GREEN ARROW (see Item B.1).

2. Shall be displayed in the same direction as a flashing YELLOW ARROW signal indication or flashing RED ARROW signal indication following a flashing YELLOW ARROW signal indication or flashing RED ARROW signal indication in the same signal face, when the flashing arrow indication is displayed as part of a steady mode operation, if the signal face will subsequently display a steady red signal indication.

3. Shall not be displayed in conjunction with the change from a steady RED ARROW, flashing RED ARROW, or flashing YELLOW ARROW signal indication to a GREEN ARROW signal indication, except when entering preemption operation as provided in Item 5(a).

4. Shall not be displayed when any conflicting vehicular movement has a green or yellow signal indication ~~(except for the situation regarding U-turns to the left provided in Paragraph 4)~~ or any conflicting pedestrian movement has a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication, except that a steady left-turn (or U-turn to the left) YELLOW ARROW signal indication used to terminate a flashing left-turn (or U-turn to the left) YELLOW ARROW or a flashing left-turn (or U-turn to the left) RED ARROW signal indication in a signal face controlling a permissive left-turn (or U-turn to the left)

movement as described in Sections 4D.18 and 4D.20 shall be permitted to be displayed when a CIRCULAR YELLOW signal indication is displayed for the opposing through movement. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.

5. Shall not be displayed to terminate a flashing arrow signal indication on an approach from which drivers are turning left permissively or making a U-turn to the left permissively unless one of the following conditions exists:

(a) A steady CIRCULAR YELLOW or CIRCULAR RED **signal indication is also simultaneously being displayed to the opposing approach;**

~~**(b) An engineering study has determined that, because of unique intersection conditions, the condition described in Item (a) cannot reasonably be implemented without causing significant operational or safety problems and that the volume of impacted left-turning or U-turning traffic is relatively low, and those left-turning or U-turning drivers are advised that a steady CIRCULAR YELLOW signal indication is not simultaneously being displayed to the opposing traffic if this operation occurs continuously by the installation near the left-most signal head of a W25-1 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC HAS EXTENDED GREEN; or**~~ W25-1 sign shall not be used in California.

~~**(c) Drivers are advised of the operation if it occurs only occasionally, such as during a preemption sequence, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN.**~~ W25-2 sign shall not be used in California.

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

(a) When entering preemption operation, the display of a GREEN ARROW signal indication or a flashing arrow signal indication shall be permitted following a steady YELLOW ARROW signal indication.

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

F. A steady GREEN ARROW signal indication:

1. Shall be displayed only to allow vehicular movements, in the direction indicated, that are not in conflict with other vehicles moving on a green or yellow signal indication and are not in conflict with pedestrians crossing in compliance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.

2. Shall be displayed on a signal face that controls a left-turn movement when said movement is not in conflict with other vehicles moving on a green or yellow signal indication (except for the situation regarding U-turns provided in Paragraph 4) and is not in conflict with pedestrians crossing in compliance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.

3. Shall not be required on the stem of a T-intersection or for turns from a one-way street.

~~Option:~~

~~04 If U-turns are permitted from the approach and a right-turn GREEN ARROW signal indication is simultaneously being displayed to road users making a right turn from the conflicting approach to the left, road users making a U-turn may be advised of the operation by the installation near the left-turn signal face of a U-TURN YIELD TO RIGHT TURN (R10-16) sign (see Section 2B.53).~~

Standard:

04a When a RIGHT TURN ARROW controls the Right Turn movement, a conflicting U-turn approach shall be prohibited.

Option:

05 If not otherwise prohibited, a steady straight-through green arrow signal indication may be used instead of a circular green signal indication in a signal face on an approach intersecting a one-way street to discourage wrong-way turns.

06 If not otherwise prohibited, steady red, yellow, and green turn arrow signal indications may be used instead of steady circular red, yellow, and green signal indications in a signal face on an approach where all traffic is required to turn or where the straight-through movement is not physically possible.

Support:

07 Section 4D.25 contains information regarding the signalization of approaches that have a shared left-turn/right-turn lane and no through movement.

Standard:

08 **If supplemental signal faces are used, the following limitations shall apply:**

A. Left-turn arrows and U-turn arrows to the left shall not be used in near-right signal faces.

B. Right-turn arrows and U-turn arrows to the right shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

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

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

A. CIRCULAR RED with CIRCULAR YELLOW;

B. CIRCULAR GREEN with CIRCULAR RED; or

C. Straight-through GREEN ARROW with CIRCULAR RED;

11 **Additionally, the above combinations shall not be simultaneously displayed on an approach as a result of the combination of displays from multiple signal faces unless the display is created by a signal face(s) devoted exclusively to the control of a right-turning movement and:**

A. The signal face(s) controlling the right-turning movement is visibility-limited from the adjacent through movement or positioned to minimize potential confusion to approaching road users, or

B. A RIGHT TURN SIGNAL (R10-10) sign (see Sections 4D.21 through 4D.24) is mounted adjacent to the signal face(s) controlling the right-turning movement.

12 **The following combinations of signal indications shall not be simultaneously displayed on any one signal face or as a result of the combination of displays from multiple signal faces on an approach:**

A. CIRCULAR GREEN with CIRCULAR YELLOW;

B. Straight-through GREEN ARROW with CIRCULAR YELLOW;

C. GREEN ARROW with YELLOW ARROW pointing in the same direction;

D. RED ARROW with YELLOW ARROW pointing in the same direction; or

E. GREEN ARROW with RED ARROW pointing in the same direction.

13 **Except as otherwise provided in Sections 4F.03 and 4G.04, the same signal section shall not be used to display both a flashing yellow and a steady yellow indication during steady mode operation. Except as otherwise provided in Sections 4D.18, 4D.20, 4D.22, and 4D.24, the same signal section shall not be used to display both a flashing red and a steady red indication during steady mode operation.**

Guidance:

14 *No movement that creates an unexpected crossing of pathways of moving vehicles or pedestrians should be allowed during any green or yellow interval, except when all three of the following conditions are met:*

A. The movement involves only slight conflict, and

B. Serious traffic delays are substantially reduced by permitting the conflicting movement, and

C. Drivers and pedestrians subjected to the unexpected conflict are effectively warned thereof by a sign.

Section 4D.06 Signal Indications – Design, Illumination, Color, and Shape

Standard:

01 **Each signal indication, except those used for pedestrian signal heads and lane-use control signals, shall be circular or arrow.**

02 **Letters or numbers (including those associated with countdown displays) shall not be displayed as part of a vehicular signal indication.**

03 **Strobes shall not be used within or adjacent to any signal indication.**

04 **Except for the flashing signal indications and the pre-emption confirmation lights that are expressly allowed by the provisions of this Chapter, flashing displays shall not be used within or adjacent to any signal indications.**

05 **Each circular signal indication shall emit a single color: red, yellow, or green.**

06 **Each arrow signal indication shall emit a single color: red, yellow, or green except that the alternate display (dual-arrow signal section) of a GREEN ARROW and a YELLOW ARROW signal indication, both pointing in the same direction, shall be permitted, provided that they are not displayed simultaneously.**

07 **The arrow, which shall show only one direction, shall be the only illuminated part of an arrow signal indication.**

08 **Arrows shall be pointed:**

A. Vertically upward to indicate a straight-through movement, or

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

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

D. In a manner that directs the driver through the turn if a U-turn arrow is used (see Figure 4D-1).

09 **Except as provided in Paragraph 10, the requirements of the publication entitled "Vehicle Traffic Control Signal Heads" (see Section 1A.11) that pertain to the aspects of the signal head design that affect the display of the signal indications shall be met.**

Guidance:

10 *The intensity and distribution of light from each illuminated signal lens should comply with the publications entitled "Vehicle Traffic Control Signal Heads" and "Traffic Signal Lamps" (see Section 1A.11).*

Standard:

11 **References to signal lenses in this section shall not be used to limit signal optical units to incandescent lamps within optical assemblies that include lenses.**

Support:

12 Research has resulted in signal optical units that are not lenses, such as, but not limited to, light emitting diode (LED) traffic signal modules. Some units are practical for all signal indications, and some are practical for specific types such as visibility-limited signal indications.

Guidance:

13 *If a signal indication is so bright that it causes excessive glare during nighttime conditions, some form of automatic dimming should be used to reduce the brilliance of the signal indication.*

Section 4D.07 Size of Vehicular Signal Indications

Standard:

01 **There shall be two nominal diameter sizes for vehicular signal indications: 8 inches and 12 inches.**

02 **Except as provided in Paragraph 3 below, 12-inch signal indications shall be used for all signal sections in all new signal faces.**

Option:

03 Eight-inch circular signal indications may be used in new signal faces only for:

A. The green or flashing yellow signal indications in an emergency-vehicle traffic control signal (see Section 4G.02);

B. The circular indications in signal faces controlling the approach to the downstream location where two adjacent signalized locations are close to each other and it is not practical because of factors such as high

approach speeds, horizontal or vertical curves, or other geometric factors to install visibility-limited signal faces for the downstream approach;

C. The circular indications in a signal face that is located less than 120 feet from the stop line on a roadway with a posted or statutory speed limit of 30 mph or less;

D. The circular indications in a supplemental near-side signal face:

E. The circular indications in a supplemental signal face installed for the sole purpose of controlling pedestrian movements (see Section 4D.03) rather than vehicular movements; and

F. The circular indications in a signal face installed for the sole purpose of controlling a bikeway or a bicycle movement.

04 Existing 8-inch circular signal indications that are not included in Items A through F in Paragraph 3 may be retained for the remainder of their useful service life.

Section 4D.08 Positions of Signal Indications Within a Signal Face – General

Support:

01 Standardization of the number and arrangements of signal sections in vehicular traffic control signal faces enables road users who are color vision deficient to identify the illuminated color by its position relative to other signal sections.

Standard:

02 **Unless otherwise provided in this Manual for a particular application, each signal face at a signalized location shall have three, four, or five signal sections. Unless otherwise provided in this Manual for a particular application, if a vertical signal face includes a cluster (see Section 4D.09), the signal face shall have at least three vertical positions.**

03 **A single-section signal face shall be permitted at a traffic control signal if it consists of a continuously-displayed GREEN ARROW signal indication that is being used to indicate a continuous movement.**

04 **The signal sections in a signal face shall be arranged in a vertical or horizontal straight line, except as otherwise provided in Section 4D.09.**

05 **The arrangement of adjacent signal sections in a signal face shall follow the relative positions listed in Sections 4D.09 or 4D.10, as applicable.**

06 **If a signal section that displays a CIRCULAR YELLOW signal indication is used, it shall be located between the signal section that displays the red signal indication and all other signal sections.**

07 **If a U-turn arrow signal section is used in a signal face for a U-turn to the left, its position in the signal face shall be the same as stated in Sections 4D.09 and 4D.10 for a left-turn arrow signal section of the same color. If a U-turn arrow signal section is used in a signal face for a U-turn to the right, its position in the signal face shall be the same as stated in Sections 4D.09 and 4D.10 for a right-turn arrow signal section of the same color.**

08 **A U-turn arrow signal indication pointing to the left shall not be used in a signal face that also contains a left-turn arrow signal indication. A U-turn arrow signal indication pointing to the right shall not be used in a signal face that also contains a right-turn arrow signal indication.**

Option:

09 Within a signal face, two identical CIRCULAR RED or RED ARROW signal indications may be displayed immediately horizontally adjacent to each other in a vertical or horizontal signal face (see Figure 4D-2) for emphasis.

10 Horizontally-arranged and vertically-arranged signal faces may be used on the same approach provided they are separated to meet the lateral separation spacing required in Section 4D.13.

Support:

11 Figure 4D-2 illustrates some of the typical arrangements of signal sections in signal faces that do not control separate turning movements. Figures 4D-6 through 4D-12 illustrate the typical arrangements of signal sections in left-turn signal faces. Figures 4D-13 through 4D-19 illustrate the typical arrangements of signal sections in right-turn signal faces.

Standard:

12 There shall be at least two signal faces for each movement on each signal-controlled approach.

Guidance:

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

A. *The area is rural.*
B. *The area is urban and the signal is the first one on a particular highway.*
C. *The roadway is striped for two or more approach lanes.*
D. *Where visibility of the signal is affected by alignment* or obstructions.

Support:

14 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:

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

Support:

16 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:

17 *Separate standards should be considered whenever the curb return radius is greater than 10 feet.*

18 *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:

19 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.

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

A. The signal phasing provides a protected left turn movement; or
B. 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
C. It is not facing a left turn storage lane; or
D. LEFT TURN YIELD ON GREEN (symbolic circular green) (R10-12) sign is installed below the said signal face.

21 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.

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

Section 4D.09 Positions of Signal Indications Within a Vertical Signal Face

Standard:

01 **In each vertically-arranged signal face, all signal sections that display red signal indications shall be located above all signal sections that display yellow and green signal indications.**

02 **In vertically-arranged signal faces, each signal section that displays a YELLOW ARROW signal indication shall be located above the signal section that displays the GREEN ARROW signal indication to which it applies.**

03 **The relative positions of signal sections in a vertically-arranged signal face, from top to bottom, shall be as follows:**

CIRCULAR RED
Steady and/or flashing left-turn RED ARROW
Steady and/or flashing right-turn RED ARROW
CIRCULAR YELLOW
CIRCULAR GREEN
Straight-through GREEN ARROW
Steady left-turn YELLOW ARROW
Flashing left-turn YELLOW ARROW
Left-turn GREEN ARROW

Steady right-turn YELLOW ARROW
Flashing right-turn YELLOW ARROW
Right-turn GREEN ARROW

04 **If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used in a vertically-arranged signal face, the dual-arrow signal section shall occupy the same position relative to the other sections as the signal section that displays the GREEN ARROW signal indication in a vertically-arranged signal face would occupy.**

Option:

05 In a vertically-arranged signal face, signal sections that display signal indications of the same color may be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement to form a clustered signal face (see Figures 4D-2, 4D-8, 4D-9, 4D-11, 4D-15, 4D-16, ~~and~~ 4D-18, and 4D-20).

Standard:

06 **Such clusters shall be limited to the following:**

A. Two identical signal sections,
B. Two or three different signal sections that display signal indications of the same color, or
C. For only the specific case described in Section 4D.25 (see Drawing B of Figure 4D-20), two signal sections, one of which displays a GREEN ARROW signal indication and the other of which displays a flashing YELLOW ARROW signal indication.

07 **The signal section that displays a flashing yellow signal indication during steady mode operation:**

A. Shall not be placed in the same vertical position as the signal section that displays a steady yellow signal indication, and
B. Shall be placed below the signal section that displays a steady yellow signal indication.

Support:

08 Sections 4F.02 and 4G.04 contain exceptions to the provisions of this Section that are applicable to hybrid beacons.

Section 4D.10 Positions of Signal Indications Within a Horizontal Signal Face

Standard:

01 **In each horizontally-arranged signal face, all signal sections that display red signal indications shall be located to the left of all signal sections that display yellow and green signal indications.**

02 **In horizontally-arranged signal faces, each signal section that displays a YELLOW ARROW signal indication shall be located to the left of the signal section that displays the GREEN ARROW signal indication to which it applies.**

03 **The relative positions of signal sections in a horizontally-arranged signal face, from left to right, shall be as follows:**

CIRCULAR RED
Steady and/or flashing left-turn RED ARROW
Steady and/or flashing right-turn RED ARROW
CIRCULAR YELLOW
Steady left-turn YELLOW ARROW
Flashing left-turn YELLOW ARROW
Left-turn GREEN ARROW
CIRCULAR GREEN
Straight-through GREEN ARROW
Steady right-turn YELLOW ARROW
Flashing right-turn YELLOW ARROW
Right-turn GREEN ARROW

04 **If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used in a horizontally-arranged signal face, the signal section that displays the dual left-turn arrow signal indication shall be located immediately to the right of the signal section that displays the CIRCULAR YELLOW signal indication, the signal section that displays the straight-through GREEN ARROW signal indication shall be located immediately to the right of the signal**

section that displays the CIRCULAR GREEN signal indication, and the signal section that displays the dual right-turn arrow signal indication shall be located to the right of all other signal sections.

05 **The signal section that displays a flashing yellow signal indication during steady mode operation:**

A. Shall not be placed in the same horizontal position as the signal section that displays a steady yellow signal indication, and

B. Shall be placed to the right of the signal section that displays a steady yellow signal indication.

Section 4D.11 Number of Signal Faces on an Approach

Standard:

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

A. If a signalized through movement exists on an approach, a minimum of two primary signal faces shall be provided for the through movement. If a signalized through movement does not exist on an approach, a minimum of two primary signal faces shall be provided for the signalized turning movement that is considered to be the major movement from the approach (also see Section 4D.25).

B. See Sections 4D.17 through 4D.20 for left-turn (and U-turn to the left) signal faces.

C. See Sections 4D.21 through 4D.24 for right-turn (and U-turn to the right) signal faces.

Option:

02 Where a movement (or a certain lane or lanes) at the intersection never conflicts with any other signalized vehicular or pedestrian movement, a continuously-displayed single-section GREEN ARROW signal indication may be used to inform road users that the movement is free-flow and does not need to stop.

Support:

03 In some circumstances where the through movement never conflicts with any other signalized vehicular or pedestrian movement at the intersection, such as at T-intersections with appropriate geometrics and/or pavement markings and signing, an engineering study might determine that the through movement (or certain lanes of the through movement) can be free-flow and not signalized.

Guidance:

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

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

Support:

06 Locating primary signal faces overhead on the far side of the intersection has been shown to ~~provide safer~~ improve operation by reducing intersection entries late in the yellow interval and by reducing red signal violations, as compared to post-mounting signal faces at the roadside or locating signal faces overhead within the intersection on a diagonally-oriented mast arm or span wire. On approaches with two or more lanes for the through movement, one signal face per through lane, centered over each through lane, has ~~also~~ been shown to ~~provide safer operation~~ be effective in reducing excessive red signal violations.

Guidance:

07 *If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal faces should be provided as follows for ~~all~~ new or reconstructed signal installations, where there is a documented pattern of excessive red signal violations (see Figure 4D-3):*

A. The minimum number and location of primary (non-supplemental) signal faces for through traffic should be provided in accordance with Table 4D-1.

B. If the number of overhead primary signal faces for through traffic is equal to the number of through lanes on an approach, one overhead signal face should be located approximately over the center of each through lane.

C. Except for shared left-turn and right-turn signal faces, any primary signal face required by Sections 4D.17 through 4D.25 for an exclusive turn lane should be located overhead approximately over the center of each exclusive turn lane.

D. All primary signal faces should be located on the far side of the intersection.

E. In addition to the primary signal faces, one or more supplemental pole-mounted or overhead signal faces should be considered to provide added visibility for approaching traffic that is traveling behind large vehicles.

F. All signal faces should have backplates.

08 *This layout of signal faces should also be considered for any major urban or suburban arterial street with four or more lanes and for other approaches with speeds of less than 45 mph.*

Section 4D.12 Visibility, Aiming, and Shielding of Signal Faces

Standard:

01 **The primary consideration in signal face placement, aiming, and adjustment shall be to optimize the visibility of signal indications to approaching traffic.**

02 **Road users approaching a signalized intersection or other signalized area, such as a midblock crosswalk, shall be given a clear and unmistakable indication of their right-of-way assignment.**

03 **The geometry of each intersection to be signalized, including vertical grades, horizontal curves, and obstructions as well as the lateral and vertical angles of sight toward a signal face, as determined by typical driver-eye position, shall be considered in determining the vertical, longitudinal, and lateral position of the signal face.**

Guidance:

04 *The two primary signal faces required as a minimum for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance provided in Table 4D-2 in advance of and measured to the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or unless another signalized location is within this range.*

05 *There should be legal authority to prohibit the display of any unauthorized sign, signal, marking, or device that interferes with the effectiveness of any official traffic control device (see Section 11-205 of the "Uniform Vehicle Code").*

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

Standard:

07 **If approaching traffic does not have a continuous view of at least two signal faces for at least the minimum sight distance shown in Table 4D-2, a sign (see Section 2C.36) shall be installed to warn approaching traffic of the traffic control signal.**

Option:

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

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

10 If the sight distance to the signal faces for an approach is limited by horizontal or vertical alignment, supplemental signal faces aimed at a point on the approach at which the signal indications first become visible may be used.

Guidance:

11 *Supplemental signal faces should be used if engineering judgment has shown that they are needed to achieve intersection visibility both in advance and immediately before the signalized location.*

12 *If supplemental signal faces are used, they should be located to provide optimum visibility for the movement to be controlled.*

Standard:

13 **In cases where irregular street design necessitates placing signal faces for different street approaches with a comparatively small angle between their respective signal indications, each signal indication shall, to the extent practical, be visibility-limited by signal visors, signal louvers, or other means so that an**

approaching road user's view of the signal indication(s) controlling movements on other approaches is minimized.

14 **Signal visors exceeding 12 inches in length shall not be used on free-swinging signal faces.**

Guidance:

15 *Signal visors should be used on signal faces to aid in directing the signal indication specifically to approaching traffic, as well as to reduce "sun phantom," which can result when external light enters the lens.*

16 *The use of signal visors, or the use of signal faces or devices that direct the light without a reduction in intensity, should be considered as an alternative to signal louvers because of the reduction in light output caused by signal louvers.*

Option:

17 Special signal faces, such as visibility-limited signal faces, may be used such that the road user does not see signal indications intended for other approaches before seeing the signal indications for their own approach, if simultaneous viewing of both signal indications could cause the road user to be misdirected.

Guidance:

18 *If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal backplates should be used on all of the signal faces that face the approach. Signal backplates should also be considered for use on signal faces on approaches with posted or statutory speed limits or 85th-percentile speeds of less than 45 mph where sun glare, bright sky, and/or complex or confusing backgrounds indicate a need for enhanced signal face target value.*

Support:

19 The use of backplates enhances the contrast between the traffic signal indications and their surroundings for both day and night conditions, which is also helpful to older drivers.

Standard:

20 **The inside of signal visors (hoods), the entire surface of louvers and fins, and the front surface of backplates shall have a dull black finish to minimize light reflection and to increase contrast between the signal indication and its background.**

Option:

21 A yellow retroreflective strip with a minimum width of 1 inch and a maximum width of 3 inches may be placed along the perimeter of the face of a signal backplate to project a rectangular appearance at night.

Section 4D.13 Lateral Positioning of Signal Faces

Standard:

01 **At least one and preferably both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach shall be located between two lines intersecting with the center of the approach at a point 10 feet behind the stop line, one making an angle of approximately 20 degrees to the right of the center of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended. The signal face that satisfies this requirement shall simultaneously satisfy the longitudinal placement requirement described in Section 4D.14 (see Figure 4D-4).**

02 **If both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach are post-mounted, they shall both be on the far side of the intersection, one on the right and one on the left of the approach lane(s).**

03 **The required signal faces for through traffic on an approach shall be located not less than 8 feet apart measured horizontally perpendicular to the approach between the centers of the signal faces.**

04 **If more than one separate turn signal face is provided for a turning movement and if one or both of the separate turn signal faces are located over the roadway, the signal faces shall be located not less than 8 feet apart measured horizontally perpendicular to the approach between the centers of the signal faces.**

Guidance:

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

Support:

06 Section 4D.11 contains additional provisions regarding lateral positioning of signal faces for approaches having a posted or statutory speed limit or an 85th-percentile speed of 45 mph or higher.

Standard:

07 **If an exclusive left-turn, right-turn, or U-turn lane is present on an approach and if a primary separate turn signal face controlling that lane is mounted over the roadway, the primary separate turn signal face shall not be positioned any further to the right than the extension of the right-hand edge of the exclusive turn lane or any further to the left than the extension of the left-hand edge of the exclusive turn lane.**

08 **Supplemental turn signal faces mounted over the roadway shall not be subject to the positioning requirements in the previous paragraph.**

Guidance:

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

Standard:

10 **If supplemental ~~post-mounted~~ signal faces are used, the following limitations shall apply:**

A. Left-turn arrows and U-turn arrows to the left shall not be used in near-right signal faces.

B. Right-turn arrows and U-turn arrows to the right shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

Section 4D.14 Longitudinal Positioning of Signal Faces

Standard:

01 **Except where the width of an intersecting roadway or other conditions make it physically impractical, the signal faces for each approach to an intersection or a midblock location shall be provided as follows:**

A. A signal face installed to satisfy the requirements for primary left-turn signal faces (see Sections 4D.17 through 4D.20) and primary right-turn signal faces (see Sections 4D.21 through 4D.24), and at least one and preferably both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach shall be located:

1. No less than 40 feet beyond the stop line,

2. No more than 180 feet beyond the stop line unless a supplemental near-side signal face is provided, and

3. As near as practical to the line of the driver's normal view, if mounted over the roadway. The primary signal face that satisfies this requirement shall simultaneously satisfy the lateral placement requirement described in Section 4D.13 (see Figure 4D-4).

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

Support:

02 Section 4D.11 contains additional provisions regarding longitudinal positioning of signal faces for approaches having a posted or 85th-percentile speed of 45 mph or higher.

Guidance:

03 *Supplemental near-side signal faces should be located as near as practical to the stop line.*

Section 4D.15 Mounting Height of Signal Faces

Standard:

01 **The top of the signal housing of a vehicular signal face located over any portion of a highway that can be used by motor vehicles shall not be more than 25.6 feet above the pavement.**

02 **For viewing distances between 40 and 53 feet from the stop line, the maximum mounting height to the top of the signal housing shall be as shown in Figure 4D-5.**

03 **The bottom of the signal housing and any related attachments to a vehicular signal face located over any portion of a highway that can be used by motor vehicles shall be at least 15 feet above the pavement.**

Guidance:

03a *The bottom of the signal housing and any related attachments to a vehicular signal face located over a roadway should be at least 17 feet. Refer to Caltrans' Standard Plans publication. See Section 1A.11 for information regarding this publication.*

Standard:

04 **The bottom of the signal housing (including brackets) of a vehicular signal face that is vertically arranged and not located over a roadway:**

A. Shall be a minimum of 8 feet and a maximum of 19 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.

B. Shall be a minimum of 4.5 feet and a maximum of 19 feet above the median island grade of a center median island if located on the near side of the intersection.

05 **The bottom of the signal housing (including brackets) of a vehicular signal face that is horizontally arranged and not located over a roadway:**

A. Shall be a minimum of 8 feet and a maximum of 22 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.

B. Shall be a minimum of 4.5 feet and a maximum of 22 feet above the median island grade of a center median island if located on the near side of the intersection.

Section 4D.16 Lateral Offset (Clearance) of Signal Faces

Standard:

01 **Signal faces mounted at the side of a roadway with curbs at less than 15 feet from the bottom of the housing and any related attachments shall have a horizontal offset of not less than 2 feet from the face of a vertical curb, or if there is no curb, not less than 2 feet from the edge of a shoulder.**

Section 4D.17 Signal Indications for Left-Turn Movements – General

Standard:

01 **In Sections 4D.17 through 4D.20, provisions applicable to left-turn movements and left-turn lanes shall also apply to signal indications for U-turns to the left that are provided at locations where left turns are prohibited or not geometrically possible.**

Support:

02 Left-turning traffic is controlled by one of four modes as follows:

A. Permissive Only Mode—turns made on a CIRCULAR GREEN signal indication, a flashing left-turn YELLOW ARROW signal indication, or a flashing left-turn RED ARROW signal indication after yielding to pedestrians, if any, and/or opposing traffic, if any.

B. Protected Only Mode—turns made only when a left-turn GREEN ARROW signal indication is displayed.

C. Protected/Permissive Mode—both modes can occur on an approach during the same cycle.

D. Variable Left-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change.

Option:

03 In areas having a high percentage of older drivers, special consideration may be given to the use of protected only mode left-turn phasing, when appropriate.

Standard:

04 **During a permissive left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display green or steady yellow signal indications. If pedestrians crossing the lane or lanes used by the permissive left-turn movement to depart the intersection are controlled by pedestrian signal heads, the signal indications displayed by those pedestrian signal heads shall not be limited to any particular display during the permissive left-turn movement.**

05 **During a protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display steady CIRCULAR RED signal indications. If pedestrians crossing the lane or**

lanes used by the protected left-turn movement to depart the intersection are controlled by pedestrian signal heads, the pedestrian signal heads shall display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication during the protected left-turn movement.

06 **A protected only mode left-turn movement that does not begin and terminate at the same time as the adjacent through movement shall not be provided on an approach unless an exclusive left-turn lane exists.**

07 **A yellow change interval for the left-turn movement shall not be displayed when the status of the left-turn operation is changing from permissive to protected within any given signal sequence.**

08 **If the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change, the requirements in Sections 4D.18 through 4D.20 that are appropriate to that mode of operation shall be met, subject to the following:**

A. The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected only mode.

B. The left-turn GREEN ARROW and left-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

Option:

09 Additional static signs or changeable message signs may be used to meet the requirements for the variable left-turn mode or to inform drivers that left-turn green arrows will not be available during certain times of the day.

Support:

10 Sections 4D.17 through 4D.20 describe the use of the following two types of signal faces for controlling left-turn movements:

A. Shared signal face – This type of signal face controls both the left-turn movement and the adjacent movement (usually the through movement) and can serve as one of the two required primary signal faces for the adjacent movement. A shared signal face always displays the same color of circular indication that is displayed by the signal face or faces for the adjacent movement. If a shared signal face that provides protected/permissive mode left turns is mounted overhead at the intersection, it is usually positioned over or slightly to the right of the extension of the lane line separating the left-turn lane from the adjacent lane.

B. Separate left-turn signal face – This type of signal face controls only the left-turn movement and cannot serve as one of the two required primary signal faces for the adjacent movement (usually the through movement) because it displays signal indications that are applicable only to the left-turn movement. If a separate left-turn signal face is mounted overhead at the intersection, it is positioned over the extension of the left-turn lane. In a separate left-turn signal face, a flashing left-turn YELLOW ARROW signal indication or a flashing left-turn RED ARROW signal indication is used to control permissive left-turning movements.

11 Section 4D.13 contains provisions regarding the lateral positioning of signal faces that control left-turn movements.

12 It is not necessary that the same mode of left-turn operation or same type of left-turn signal face be used on every approach to a signalized location. Selecting different modes and types of left-turn signal faces for the various approaches to the same signalized location is acceptable.

Option:

13 A signal face that is shared by left-turning and right-turning traffic may be provided for a shared left-turn/right-turn lane on an approach that has no through traffic (see Section 4D.25).

Section 4D.18 Signal Indications for Permissive Only Mode Left-Turn Movements

Standard:

01 **If a shared signal face is provided for a permissive only mode left turn, it shall meet the following requirements (see Figure 4D-6):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, and CIRCULAR GREEN. Only one of the three indications shall be displayed at any given time.

B. During the permissive left-turn movement, a CIRCULAR GREEN signal indication shall be displayed.

C. A permissive only shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the permissive only mode is not the only left-turn mode used for the approach, the signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.20) except that the left-turn GREEN ARROW and left-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

02 **If a separate left-turn signal face is being operated in a permissive only left-turns mode, a CIRCULAR GREEN signal indication shall not be used in that face.**

03 **If a separate left-turn signal face is being operated in a permissive only left-turn mode and a flashing left-turn YELLOW ARROW signal indication is provided, it shall meet the following requirements (see Figure 4D-7):**

A. It shall be capable of displaying the following signal indications: steady left-turn RED ARROW, steady left-turn YELLOW ARROW, and flashing left-turn YELLOW ARROW. Only one of the three indications shall be displayed at any given time.

B. During the permissive left-turn movement, a flashing left-turn YELLOW ARROW signal indication shall be displayed.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn YELLOW ARROW signal indication.

D. It shall be permitted to display a flashing left-turn YELLOW ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

E. During steady mode (stop-and-go) operation, the signal section that displays the steady left-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing left-turn YELLOW ARROW signal indication for permissive left turns.

F. During flashing mode operation (see Section 4D.30), the display of a flashing left-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady left-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

G. If the permissive only mode is not the only left-turn mode used for the approach, the signal face shall be the same separate left-turn signal face with a flashing YELLOW ARROW signal indication that is used for the protected/permissive mode (see Section 4D.20) except that the left-turn GREEN ARROW signal indication shall not be displayed when operating in the permissive only mode.

Option:

04 A separate left-turn signal face with a flashing left-turn RED ARROW signal indication during the permissive left-turn movement may be used for unusual geometric conditions, such as wide medians with offset left-turn lanes, but only when an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive left turn.

Standard:

05 **If a separate left-turn signal face is being operated in a permissive only left-turn mode and a flashing left-turn RED ARROW signal indication is provided, it shall meet the following requirements (see Figure 4D-8):**

A. It shall be capable of displaying the following signal indications: steady or flashing left-turn RED ARROW, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. The GREEN ARROW indication is required in order to provide a three-section signal face, but shall not be displayed during the permissive only mode.

B. During the permissive left-turn movement, a flashing left-turn RED ARROW signal indication shall be displayed, thus indicating that each and every vehicle must successively come to a full stop before making a permissive left turn.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn RED ARROW signal indication.

D. It shall be permitted to display a flashing left-turn RED ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady

CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

E. A supplementary sign shall not be required. ~~If used, it shall be a LEFT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).~~

Option:

06 The requirements of Item A in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two left-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-8).

Section 4D.19 Signal Indications for Protected Only Mode Left-Turn Movements

Standard:

01 **A shared signal face shall not be used for protected only mode left turns unless the CIRCULAR GREEN and left-turn GREEN ARROW signal indications always begin and terminate together. If a shared signal face is provided for a protected only mode left turn, it shall meet the following requirements (see Figure 4D-9):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR GREEN, and left-turn GREEN ARROW. Only one of the three colors shall be displayed at any given time.

B. During the protected left-turn movement, the shared signal face shall simultaneously display both a CIRCULAR GREEN signal indication and a left-turn GREEN ARROW signal indication.

C. The shared signal face shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the protected only mode is not the only left-turn mode used for the approach, the signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.20).

Option:

02 A straight-through GREEN ARROW signal indication may be used instead of the CIRCULAR GREEN signal indication in Items A and B in Paragraph 1 on an approach where right turns are prohibited and a straight-through GREEN ARROW signal indication is also used instead of a CIRCULAR GREEN signal indication in the other signal face(s) for through traffic.

Standard:

03 **If a separate left-turn signal face is provided for a protected only mode left turn, it shall meet the following requirements (see Figure 4D-10):**

A. It shall be capable of displaying, the following signal indications: steady left-turn RED ARROW, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a LEFT ON GREEN ARROW ONLY (R10-5) sign (see Figure 2B-27).

B. During the protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication.

D. If the protected only mode is not the only left-turn mode used for the approach, the signal face shall be the same separate left-turn signal face that is used for the protected/permissive mode (see Section 4D.20 and Figures 4D-8 and 4D-12) except that the flashing left-turn YELLOW ARROW or flashing left-turn RED ARROW signal indication shall not be displayed when operating in the protected only mode.

Guidance:

04 *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:

05 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.20 for the requirements of protected-permissive or permissive-protected left turn operation.

Guidance:

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

1. *Collisions - Five or more left turn collisions 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 pre-timed 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 100,000 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.20 Signal Indications for Protected/Permissive Mode Left-Turn Movements

Standard:

01 **If a shared signal face is provided for a protected/permissive mode left turn, it shall meet the following requirements (see Figure 4D-11):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR green, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three circular indications shall be displayed at any given time. Only one of the two arrow indications shall be displayed at any given time. If the left-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are always terminated together, the steady left-turn YELLOW ARROW signal indication shall not be required.

B. During the protected left-turn movement, the shared signal face shall simultaneously display a left-turn GREEN ARROW signal indication and a circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected left turn.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication, unless the left-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are being terminated together. When the left-turn GREEN ARROW and CIRCULAR GREEN signal indications are being terminated together, the required display following the left-turn GREEN ARROW signal indication shall be either the display of a CIRCULAR YELLOW signal indication alone or the simultaneous display of the CIRCULAR YELLOW and left-turn YELLOW ARROW signal indications.

D. During the permissive left-turn movement, the shared signal face shall display only a CIRCULAR GREEN signal indication.

E. A protected/permissive shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

F. A supplementary sign shall not be required. If used, it shall be a LEFT TURN YIELD ON GREEN (symbolic circular green) (R10-12) sign (see Figure 2B-27).

02 **If a separate left-turn signal face is being operated in a protected/permissive left-turn mode, a CIRCULAR GREEN signal indication shall not be used in that face.**

03 **If a separate left-turn signal face is being operated in a protected/permissive left-turn mode and a flashing left-turn yellow arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-12):**

A. It shall be capable of displaying the following signal indications: steady left-turn RED ARROW, steady left-turn YELLOW ARROW, flashing left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the four indications shall be displayed at any given time.

B. During the protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication.

D. During the permissive left-turn movement, a flashing left-turn YELLOW ARROW signal indication shall be displayed.

E. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn YELLOW ARROW signal indication if the permissive left-turn movement is being terminated and the separate left-turn signal face will subsequently display a steady left-turn RED ARROW indication.

F. It shall be permitted to display a flashing left-turn YELLOW ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

G. When a permissive left-turn movement is changing to a protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing left-turn YELLOW ARROW signal indication. A steady left-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing left-turn YELLOW ARROW signal indication and the display of the steady left-turn GREEN ARROW signal indication.

H. The display shall be a four-section signal face except that a three-section signal face containing a dual-arrow signal section shall be permitted where signal head height limitations (or lateral positioning limitations for a horizontally-mounted signal face) will not permit the use of a foursection signal face. The dual-arrow signal section, where used, shall display a GREEN ARROW for the protected left-turn movement and a flashing YELLOW ARROW for the permissive left-turn movement.

I. During steady mode (stop-and-go) operation, the signal section that displays the steady left-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing left-turn YELLOW ARROW signal indication for permissive left turns.

J. During flashing mode operation (see Section 4D.30), the display of a flashing left-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady left-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

Option:

04 A separate left-turn signal face with a flashing left-turn RED ARROW signal indication during the permissive left-turn movement may be used for unusual geometric conditions, such as wide medians with offset left-turn lanes, but only when an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive left turn.

Standard:

05 **If a separate left-turn signal face is being operated in a protected/permissive left-turn mode and a flashing left-turn RED arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-8):**

A. It shall be capable of displaying the following signal indications: steady or flashing left-turn RED ARROW, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time.

B. During the protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication.

D. During the permissive left-turn movement, a flashing left-turn RED ARROW signal indication shall be displayed.

E. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn RED ARROW signal indication if the permissive left-turn movement is being terminated and the separate left-turn signal face will subsequently display a steady left-turn RED ARROW indication.

F. When a permissive left-turn movement is changing to a protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing left-turn RED ARROW signal indication. A steady left-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing left-turn RED ARROW signal indication and the display of the steady left-turn GREEN ARROW signal indication.

G. It shall be permitted to display a flashing left-turn RED ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

H. A supplementary sign shall not be required. ~~If used, it shall be a LEFT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).~~

Option:

06 The requirements of Item A in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two left-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-8).

Standard:

07 Protected/permissive mode left-turn shall not be used for left turn movements that oppose phases that require preemption for rail traffic.

Section 4D.21 Signal Indications for Right-Turn Movements – General

Standard:

01 **In Sections 4D.21 through 4D.24, provisions applicable to right-turn movements and right-turn lanes shall also apply to signal indications for U-turns to the right that are provided at locations where right turns are prohibited or not geometrically possible.**

Support:

02 Right-turning traffic is controlled by one of four modes as follows:

A. Permissive Only Mode—turns made on a CIRCULAR GREEN signal indication, a flashing right-turn YELLOW ARROW signal indication, or a flashing right-turn RED ARROW signal indication after yielding to pedestrians, if any.

B. Protected Only Mode—turns made only when a right-turn GREEN ARROW signal indication is displayed.

C. Protected/Permissive Mode—both modes occur on an approach during the same cycle.

D. Variable Right-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change.

Standard:

03 **During a permissive right-turn movement, the signal faces, if any, that exclusively control U-turn traffic that conflicts with the permissive right-turn movement (see Item F.1 in Section 4D.05) shall simultaneously display steady U-turn RED ARROW signal indications. If pedestrians crossing the lane or lanes used by the permissive right-turn movement to depart the intersection are controlled by pedestrian signal heads, the signal indications displayed by those pedestrian signal heads shall not be limited to any particular display during the permissive right-turn movement.**

04 **During a protected right-turn movement, the signal faces for left-turn traffic, if any, on the opposing approach shall not simultaneously display a steady left-turn GREEN ARROW or steady left-turn**

YELLOW ARROW signal indication, and signal faces, if any, that exclusively control U-turn traffic that conflicts with the protected right-turn movement (see Item F.1 in Section 4D.05) shall simultaneously display steady U-turn RED ARROW signal indications. If pedestrians crossing the lane or lanes used by the protected right-turn movement to depart the intersection are controlled by pedestrian signal heads, the pedestrian signal heads shall display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication during the protected right-turn movement.

05 **A protected only mode right-turn movement that does not begin and terminate at the same time as the adjacent through movement shall not be provided on an approach unless an exclusive right-turn lane exists.**

06 **A yellow change interval for the right-turn movement shall not be displayed when the status of the right-turn operation is changing from permissive to protected within any given signal sequence.**

07 **If the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change, the requirements in Sections 4D.22 through 4D.24 that are appropriate to that mode of operation shall be met, subject to the following:**

A. The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected only mode.

B. The right-turn GREEN ARROW and right-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

Option:

08 Additional static signs or changeable message signs may be used to meet the requirements for the variable right-turn mode or to inform drivers that right-turn green arrows will not be available during certain times of the day.

Support:

09 Sections 4D.21 through 4D.24 describe the use of the following two types of signal faces for controlling right-turn movements:

A. Shared signal face – This type of signal face controls both the right-turn movement and the adjacent movement (usually the through movement) and can serve as one of the two required primary signal faces for the adjacent movement. A shared signal face always displays the same color of circular indication that is displayed by the signal face or faces for the adjacent movement.

B. Separate right-turn signal face – This type of signal face controls only the right-turn movement and cannot serve as one of the two required primary signal faces for the adjacent movement (usually the through movement) because it displays signal indications that are applicable only to the right-turn movement. If a separate right-turn signal face is mounted overhead at the intersection, it is positioned over the extension of the right-turn lane. In a separate right-turn signal face, a flashing right-turn YELLOW ARROW signal indication or a flashing right-turn RED ARROW signal indication is used to control permissive right-turning movements.

10 Section 4D.13 contains provisions regarding the lateral positioning of signal faces that control right-turn movements.

11 It is not necessary that the same mode of right-turn operation or same type of right-turn signal face be used on every approach to a signalized location. Selecting different modes and types of right-turn signal faces for the various approaches to the same signalized location is acceptable.

Option:

12 A signal face that is shared by left-turning and right-turning traffic may be provided for a shared left-turn/right-turn lane on an approach that has no through traffic (see Section 4D.25).

Guidance:

13 *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.22 Signal Indications for Permissive Only Mode Right-Turn Movements

Standard:

01 **If a shared signal face is provided for a permissive only mode right turn, it shall meet the following requirements (see Figure 4D-13):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, and CIRCULAR GREEN. Only one of the three indications shall be displayed at any given time.

B. During the permissive right-turn movement, a CIRCULAR GREEN signal indication shall be displayed.

C. A permissive only shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the permissive only mode is not the only right-turn mode used for the approach, the signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.24) except that the right-turn GREEN ARROW and right-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

02 **If a separate right-turn signal face is being operated in a permissive only right-turn mode, a CIRCULAR GREEN signal indication shall not be used in that face.**

03 **If a separate right-turn signal face is being operated in a permissive only right-turn mode and a flashing right-turn yellow arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-14):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. Steady right-turn RED ARROW, steady right-turn YELLOW ARROW, and flashing right-turn YELLOW ARROW. Only one of the three indications shall be displayed at any given time.

2. Steady CIRCULAR RED, steady right-turn YELLOW ARROW, and flashing right-turn YELLOW ARROW. Only one of the three indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the permissive right-turn movement, a flashing right-turn YELLOW ARROW signal indication shall be displayed.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn YELLOW ARROW signal indication.

D. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

E. It shall be permitted to display a flashing right-turn YELLOW ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications.

F. During steady mode (stop-and-go) operation, the signal section that displays the steady right-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing right-turn YELLOW ARROW signal indication for permissive right turns.

G. During flashing mode operation (see Section 4D.30), the display of a flashing right-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady right-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

H. If the permissive only mode is not the only right-turn mode used for the approach, the signal face shall be the same separate right-turn signal face with a flashing YELLOW ARROW signal indication

that is used for the protected/permissive mode (see Section 4D.24) except that the right-turn GREEN ARROW signal indication shall not be displayed when operating in the permissive only mode.

Option:

04 When an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive right turn, a separate right-turn signal face with a flashing right-turn RED ARROW signal indication during the permissive right-turn movement may be used.

Standard:

05 **If a separate right-turn signal face is being operated in a permissive only right-turn mode and a flashing right-turn RED arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-15):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. Steady or flashing right-turn RED ARROW, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. The GREEN ARROW indication is required in order to provide a three-section signal face, but shall not be displayed during permissive only mode.

2. Steady CIRCULAR RED on the left and steady right-turn RED ARROW on the right of the top position, steady right-turn YELLOW ARROW in the middle position, and right-turn GREEN ARROW in the bottom position. Only one of the four indications shall be displayed at any given time. The GREEN ARROW indication is required in order to provide three vertical positions, but shall not be displayed during permissive only mode. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the permissive right-turn movement, a flashing right-turn RED ARROW signal indication shall be displayed, thus indicating that each and every vehicle must successively come to a full stop before making a permissive right turn.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn RED ARROW signal indication.

D. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

E. The display of a flashing right-turn RED ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement shall be permitted.

F. A supplementary sign shall not be required. ~~If used, it shall be a RIGHT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).~~

Option:

06 The requirements of Item A.1 in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two right-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-15).

Section 4D.23 Signal Indications for Protected Only Mode Right-Turn Movements

Standard:

01 **A shared signal face shall not be used for protected only mode right turns unless the CIRCULAR GREEN and right-turn GREEN ARROW signal indications always begin and terminate together. If a shared signal face is provided for a protected only right turn, it shall meet the following requirements (see Figure 4D-16):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR GREEN, and right-turn GREEN ARROW. Only one of the three colors shall be displayed at any given time.

B. During the protected right-turn movement, the shared signal face shall simultaneously display both a CIRCULAR GREEN signal indication and a right-turn GREEN ARROW signal indication.

C. The shared signal face shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the protected only mode is not the only right-turn mode used for the approach, the signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.24).

Option:

02 A straight-through GREEN ARROW signal indication may be used instead of the CIRCULAR GREEN signal indication in Items A and B in Paragraph 1 on an approach where left turns are prohibited and a straight-through GREEN ARROW signal indication is also used instead of a CIRCULAR GREEN signal indication in the other signal face(s) for through traffic.

Standard:

03 **If a separate right-turn signal face is provided for a protected only mode right turn, it shall meet the following requirements (see Figure 4D-17):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. Steady right-turn RED ARROW, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a RIGHT ON GREEN ARROW ONLY (R10-5a) sign (see Figure 2B-27).

2. Steady CIRCULAR RED, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of three indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication.

D. When the separate signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

E. If the protected only mode is not the only right-turn mode used for the approach, the signal face shall be the same separate right-turn signal face that is used for the protected/permissive mode (see Section 4D.24 and Figure 4D-19) except that a flashing right-turn YELLOW ARROW or flashing right-turn RED ARROW signal indication shall not be displayed when operating in the protected only mode.

Section 4D.24 <u>Signal Indications for Protected/Permissive Mode Right-Turn Movements</u>

Standard:

01 **If a shared signal face is provided for a protected/permissive mode right turn, it shall meet the following requirements (see Figure 4D-18):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR green, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three circular indications shall be displayed at any given time. Only one of the two arrow indications shall be displayed at any given time. If the right-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through

movement are always terminated together, the steady right-turn YELLOW ARROW signal indication shall not be required.

B. During the protected right-turn movement, the shared signal face shall simultaneously display a right-turn GREEN ARROW signal indication and a circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected right turn.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication, unless the right-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are being terminated together. When the right-turn GREEN ARROW and CIRCULAR GREEN signal indications are being terminated together, the required display following the right-turn GREEN ARROW signal indication shall be either the display of a CIRCULAR YELLOW signal indication alone or the simultaneous display of the CIRCULAR YELLOW and right-turn YELLOW ARROW signal indications.

D. During the permissive right-turn movement, the shared signal face shall display only a CIRCULAR GREEN signal indication.

E. A protected/permissive shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

02 **If a separate right-turn signal face is being operated in a protected/permissive right-turn mode, a CIRCULAR GREEN signal indication shall not be used in that face.**

03 **If a separate right-turn signal face is being operated in a protected/permissive right-turn mode and a flashing right-turn yellow arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-19):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. Steady right-turn RED ARROW, steady right-turn YELLOW ARROW, flashing right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the four indications shall be displayed at any given time.

2. Steady CIRCULAR RED, steady right-turn YELLOW ARROW, flashing right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the four indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication.

D. During the permissive right-turn movement, a flashing right-turn YELLOW ARROW signal indication shall be displayed.

E. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn YELLOW ARROW signal indication if the permissive right-turn movement is being terminated and the separate right-turn signal face will subsequently display a steady red indication.

F. When a permissive right-turn movement is changing to a protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing right-turn YELLOW ARROW signal indication. A steady right-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing right-turn YELLOW ARROW signal indication and the display of the steady right-turn GREEN ARROW signal indication.

G. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED

ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

H. It shall be permitted to display a flashing right-turn YELLOW ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications.

I. A signal face containing a dual-arrow signal section in place of separate flashing right-turn YELLOW ARROW and right-turn GREEN ARROW signal sections shall be permitted where signal head height limitations (or lateral positioning limitations for a horizontally-mounted signal face) are a concern. The dual-arrow signal section, where used, shall display a GREEN ARROW for the protected right-turn movement and a flashing YELLOW ARROW for the permissive right-turn movement.

J. During steady mode (stop-and-go) operation, the signal section that displays the steady right-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing right-turn YELLOW ARROW signal indication for permissive right turns.

K. During flashing mode operation (see Section 4D.30), the display of a flashing right-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady right-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

Option:

04 When an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive right turn, a separate signal face that has a flashing right-turn RED ARROW signal indication during the permissive right-turn movement may be used.

Standard:

05 **If a separate right-turn signal face is being operated in a protected/permissive right-turn mode and a flashing right-turn RED arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-15):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. Steady or flashing right-turn RED ARROW, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time.

2. Steady CIRCULAR RED on the left and steady or flashing right-turn RED ARROW on the right of the top position, steady right-turn YELLOW ARROW in the middle position, and right-turn GREEN ARROW in the bottom position. Only one of the four indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication.

D. During the permissive right-turn movement, the separate right-turn signal face shall display a flashing right-turn RED ARROW signal indication.

E. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn RED ARROW signal indication if the permissive right-turn movement is being terminated and the separate right-turn signal face will subsequently display a steady red indication.

F. When a permissive right-turn movement is changing to a protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing right-turn RED ARROW signal indication. A steady right-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing right-turn RED ARROW signal indication and the display of the steady right-turn GREEN ARROW signal indication.

G. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED

ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

H. It shall be permitted to display a flashing right-turn RED ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

I. A supplementary sign shall not be required. ~~If used, it shall be a RIGHT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).~~

Option:

06 The requirements of Item A.1 in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two right-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-15).

Section 4D.25 Signal Indications for Approaches With Shared Left-Turn/Right-Turn Lanes and No Through Movement

Support:

01 A lane that is shared by left-turn and right-turn movements is sometimes provided on an approach that has no through movement, such as the stem of a T-intersection or where the opposite approach is a one-way roadway in the opposing direction.

Standard:

02 **When a shared left-turn/right-turn lane exists on a signalized approach, the left-turn and right-turn movements shall start and terminate simultaneously and the red signal indication used in each of the signal faces on the approach shall be a CIRCULAR RED.**

Support:

03 This requirement for the use of CIRCULAR RED signal indications in signal faces for approaches having a shared lane for left-turn and right-turn movements is a specific exception to other provisions in this Chapter that would otherwise require the use of RED ARROW signal indications.

Standard:

04 **The signal faces provided for an approach with a shared left-turn/right-turn lane and no through movement shall be one of the following:**

A. Two or more signal faces, each capable of displaying CIRCULAR RED, CIRCULAR YELLOW, and CIRCULAR GREEN signal indications, shall be provided for the approach. This display shall be permissible regardless of number of exclusive left-turn and/or right-turn lanes that exist on the approach in addition to the shared left-turn/right-turn lane and regardless of whether or not there are pedestrian or opposing vehicular movements that conflict with the left-turn or right-turn movements. However, if there is an opposing approach and the signal phasing protects the left-turn movement on the approach with the shared left-turn/right-turn lane from conflicts with the opposing vehicular movements and any signalized pedestrian movements, a left-turn GREEN ARROW signal indication shall also be included in the left-most signal face and shall be displayed simultaneously with the CIRCULAR GREEN signal indication.

B. If the approach has one or more exclusive turn lanes in addition to the shared left-turn/right-turn lane and there is no conflict with a signalized vehicular or pedestrian movement, and GREEN ARROW signal indications are used in place of CIRCULAR GREEN signal indications on the approach, the signal faces for the approach shall be:

1. A signal face(s) capable of displaying CIRCULAR RED, YELLOW ARROW, and GREEN ARROW signal indications for the exclusive turn lane(s), with the arrows pointing in the direction of the turn, and

2. A shared left-turn/right-turn signal face capable of displaying CIRCULAR RED, left-turn YELLOW ARROW, left-turn GREEN ARROW, right-turn YELLOW ARROW, and right-turn GREEN ARROW signal indications, in an arrangement of signal sections that complies with the provisions of Section 4D.09 or 4D.10.

C. If the approach has one or more exclusive turn lanes in addition to the shared left-turn/right-turn lane and there is a conflict with a signalized vehicular or pedestrian movement, and flashing YELLOW ARROW signal indications are used in place of CIRCULAR GREEN signal indications on the approach, the signal faces for the approach shall be as described in Items B.1 and B.2, except that flashing YELLOW ARROW signal indications shall be used in place of the GREEN ARROW signal indications for the turning movement(s) that conflicts with the signalized vehicular or pedestrian movement.

Support:

05 Figure 4D-20 illustrates application of these Standards on approaches that have only a shared left-turn/right-turn lane, and on approaches that have one or more exclusive turn lanes in addition to the shared left-turn/right-turn lane.

Option:

06 If the lane-use regulations on an approach are variable such that at certain times all of the lanes on the approach are designated as exclusive turn lanes and no lane is designated as a shared left-turn/right-turn lane:

A. During the times that no lane is designated as a shared left-turn/right-turn lane, the left-turn and right-turn movements may start and terminate independently, and the left-turn and right-turn movements may be operated in one or more of the modes of operation as described in Sections 4D.17 through 4D.24; and

B. If a protected-permissive mode is used, the shared left-turn/right-turn signal face provided in Paragraph 4 may be modified to include a dual-arrow signal section capable of displaying both a GREEN ARROW signal indication and a flashing YELLOW ARROW signal indication for a turn movement(s) in order to not exceed the maximum of five sections per signal face provided in Section 4D.08.

Section 4D.26 Yellow Change and Red Clearance Intervals

Standard:

01 **A steady yellow signal indication shall be displayed following every CIRCULAR GREEN or GREEN ARROW signal indication and following every flashing YELLOW ARROW or flashing RED ARROW signal indication displayed as a part of a steady mode operation. This requirement shall not apply when a CIRCULAR GREEN, a flashing YELLOW ARROW, or a flashing RED ARROW signal indication is followed immediately by a GREEN ARROW signal indication.**

02 **The exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment.**

03 **The duration of the yellow change interval shall be determined using engineering practices.**

Support:

04 Section 4D.05 contains provisions regarding the display of steady CIRCULAR YELLOW signal indications to approaches from which drivers are allowed to make permissive left turns.

Guidance:

05 *When indicated by the application of engineering practices, the yellow change interval should be followed by a red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released.*

Standard:

06 **When used, the duration of the red clearance interval shall be determined using engineering practices.**

Support:

07 Engineering practices for determining the duration of yellow change and red clearance intervals can be found in ITE's "Traffic Control Devices Handbook" and in ITE's "Manual of Traffic Signal Design" (see Section 1A.11).

Standard:

08 **The durations of yellow change intervals and red clearance intervals shall be consistent with the determined values within the technical capabilities of the controller unit.**

09 **The duration of a yellow change interval shall not vary on a cycle-by-cycle basis within the same signal timing plan.**

10 **Except as provided in Paragraph 12, the duration of a red clearance interval shall not be decreased or omitted on a cycle-by-cycle basis within the same signal timing plan.**

Option:

11 The duration of a red clearance interval may be extended from its predetermined value for a given cycle based upon the detection of a vehicle that is predicted to violate the red signal indication.

12 When an actuated signal sequence includes a signal phase for permissive/protected (lagging) left-turn movements in both directions, the red clearance interval may be shown during those cycles when the lagging left-turn signal phase is skipped and may be omitted during those cycles when the lagging left-turn signal phase is shown.

13 The duration of a yellow change interval or a red clearance interval may be different in different signal timing plans for the same controller unit.

Guidance:

14 *A yellow change interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds. The longer intervals should be reserved for use on approaches with higher speeds. Refer to Table 4D-102(CA).*

Support:

14a The purpose of the yellow signal indication is to warn traffic approaching a traffic signal that the related green movement is ending or that a steady red indication will be exhibited immediately thereafter and traffic will be required to stop when the red signal is exhibited.

Standard:

14b The minimum yellow change interval for through traffic movement shall be determined by using the 85th percentile speed of free-flow traffic rounded up to the next 5 mph increment. Where the posted or prima facie speed limit is higher than the rounded value, use the posted or prima facie speed limit for determination of the minimum yellow change interval for the through traffic movement. See Table 4D-102(CA) sub-heading "a".

14c If the 85th percentile speed data is not available, the minimum yellow change interval for through traffic movements shall be determined by adding 7 miles per hour to the posted or prima facie speed limits of 30 mph or higher, and by adding 10 miles per hour to the posted or prima facie speed limits of 25 mph or less. See Table 4D-102(CA) sub-heading "b".

Guidance:

14d *Practitioners should exercise engineering judgment for determination of the minimum yellow change interval. Judgment should be based on numerous factors including, but not limited to, field observation of traffic behavior, intersection geometrics, downhill grade, perception-reaction time of drivers in the area, and actually driving the protected left-turn or protected right-turn movements to assess the need for longer yellow change intervals. Particular attention should be paid where setting minimum yellow change interval timing when exclusive turn lane exceeds 150 feet in length excluding the transition..*

Option:

14e The minimum yellow change interval for the through movement and the protected left-turn or protected right-turn may be increased based on appropriate engineering judgment.

15 *Except when clearing a one-lane, two-way facility (see Section 4H.02) or when clearing an exceptionally wide intersection, a red clearance interval should have a duration not exceeding 6 seconds.*

Support:

15a When used, red clearance intervals normally range from 0.1 to 2.0 seconds.

Standard:

16 **Except for warning beacons mounted on advance warning signs on the approach to a signalized location (see Section 2C.36), signal displays that are intended to provide a "pre-yellow warning" interval, such as flashing green signal indications, vehicular countdown displays, or other similar displays, shall not be used at a signalized location.**

Support:

17 The use of signal displays (other than warning beacons mounted on advance warning signs) that convey a "pre-yellow warning" have been found by research to increase the frequency of crashes.

Section 4D.27 Preemption and Priority Control of Traffic Control Signals

Option:

01 Traffic control signals may be designed and operated to respond to certain classes of approaching vehicles by altering the normal signal timing and phasing plan(s) during the approach and passage of those vehicles. The alternative plan(s) may be as simple as extending a currently displayed green interval or as complex as replacing the entire set of signal phases and timing.

Support:

02 Preemption control (see definition in Section 1A.13) is typically given to trains, boats, emergency vehicles, and light rail ~~transit~~ vehicles.

03 Examples of preemption control include the following:

A. The prompt displaying of green signal indications at signalized locations ahead of fire vehicles, law enforcement vehicles, ambulances, and other official emergency vehicles;

B. A special sequence of signal phases and timing to expedite and/or provide additional clearance time for vehicles to clear the tracks prior to the arrival of rail traffic; and

C. A special sequence of signal phases to display a steady red indication to prohibit ~~turning~~ all movements toward the tracks during the approach or passage of rail traffic.

04 Priority control (see definition in Section 1A.13) is typically given to certain non-emergency vehicles such as light-rail transit vehicles operating in a mixed-use alignment and buses.

05 Examples of priority control include the following:

A. The displaying of early or extended green signal indications at an intersection to assist public transit vehicles in remaining on schedule, and

B. Special phasing to assist public transit vehicles in entering the travel stream ahead of the platoon of traffic.

06 Some types or classes of vehicles supersede others when a traffic control signal responds to more than one type or class. In general, a vehicle that is more difficult to control supersedes a vehicle that is easier to control.

Option:

07 Preemption or priority control of traffic control signals may also be a means of assigning priority right-of-way to specified classes of vehicles at certain non-intersection locations such as on approaches to one-lane bridges and tunnels, movable bridges, highway maintenance and construction activities, metered freeway entrance ramps, and transit operations.

Standard:

08 **During the transition into preemption control:**

A. The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.

B. The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted.

C. The return to the previous green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

09 **During preemption control and during the transition out of preemption control:**

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. A signal indication sequence from a steady yellow signal indication to a green signal indication shall not be permitted.

10 **During priority control and during the transition into or out of priority control:**

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. The shortening of any pedestrian walk interval below that time described in Section 4E.06 shall not be permitted.

C. The omission of a pedestrian walk interval and its associated change interval shall not be permitted unless the associated vehicular phase is also omitted or the pedestrian phase is exclusive.

D. The shortening or omission of any pedestrian change interval shall not be permitted.

E. A signal indication sequence from a steady yellow signal indication to a green signal indication shall not be permitted.

Guidance:

11 *Except for traffic control signals interconnected with light rail transit systems, traffic control signals with railroad preemption or coordinated with flashing-light signal systems should be provided with a back-up power supply.*

12 *When a traffic control signal that is returning to a steady mode from a dark mode (typically upon restoration from a power failure) receives a preemption or priority request, care should be exercised to minimize the possibility of vehicles or pedestrians being misdirected into a conflict with the vehicle making the request.*

Option:

13 During the change from a dark mode to a steady mode under a preemption or priority request, the display of signal indications that could misdirect road users may be prevented by one or more of the following methods:

A. Having the traffic control signal remain in the dark mode,
B. Having the traffic control signal remain in the flashing mode,
C. Altering the flashing mode,
D. Executing the normal start-up routine before responding, or
E. Responding directly to initial or dwell period.

Guidance:

14 *If a traffic control signal is installed near or within a grade crossing or if a grade crossing with active traffic control devices is within or near a signalized highway intersection, Chapter 8C should be consulted.*

15 *Traffic control signals operating under preemption control or under priority control should be operated in a manner designed to keep traffic moving.*

16 *Traffic control signals that are designed to respond under preemption or priority control to more than one type or class of vehicle should be designed to respond in the relative order of importance or difficulty in stopping the type or class of vehicle. The order of priority should be: train, boat, heavy vehicle (fire vehicle, emergency medical service), light vehicle (law enforcement), light rail transit, rubber-tired transit.*

Option:

17 A distinctive indication may be provided at the intersection to show that an emergency vehicle has been given control of the traffic control signal (see Section 11-106 of the "Uniform Vehicle Code"). In order to assist in the understanding of the control of the traffic signal, a common distinctive indication may be used where drivers from different agencies travel through the same intersection when responding to emergencies.

18 If engineering judgment indicates that light rail transit signal indications would reduce road user confusion that might otherwise occur if standard traffic signal indications were used to control these movements, light rail transit signal indications complying with Section 8C.11 and as illustrated in Figure ~~8C-3~~ 8C-3(CA) may be used for preemption or priority control of the following exclusive movements at signalized intersections:

A. Public transit buses in "queue jumper" lanes, and
B. Bus rapid transit in semi-exclusive or mixed-use alignments.

Guidance:

19 *Traffic control signals within 200 feet 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:

20 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 an extinguishable format include the R3-1, R3-2 and R3-27 signs.

Support:

21 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 an 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 an 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 an extinguishable R3-27 sign.

22 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.

23 Where the typical pre-emption period tends to be short, such as for light rail vehicles 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 except for the movements that approach the highway-rail crossing, is one such example.

24 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.

25 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.

26 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 road users stop to assess the railroad or light rail transit pre-emption operation.

27 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.

Railroad Preemption

Support:

28 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 initiated by a notification from the railroad grade crossing warning equipment.

Guidance:

29 *Typical circumstances where railroad preemption is required, 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 200 feet of a signalized intersection, preemption of the traffic signal should provide the following sequence of operation:*

Standard:

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.

Option:

The signal indication for the clearance interval may be either green or flashing red.

Guidance:

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.

Standard:

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.

Guidance:

2. *Where the railroad tracks run within a roadway and train speeds exceed 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.*

Standard:

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 steady red indications; pedestrian signal faces will display UPRAISED HAND.

Option:

3. Where the railroad tracks run along a roadway of a signalized intersection and train speeds do not exceed 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.

Emergency Vehicle Preemption

30 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:

31 *Emergency vehicle equipment should be capable of encoding IDs.*

32 *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.*

Standard:

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.

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.

33 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.

34 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.

35 When performed by a local agency, the installation of emergency vehicle preemption equipment shall be covered by an Encroachment Permit issued by the Caltrans 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 Caltrans.
2. The programming of the preemption equipment shall be as approved in advance by Caltrans and shall not be changed without written permission. The Permittee shall make any changes in programming, requested by Caltrans.
3. The Permittee shall assume all liability for the claims, which arise due to or because of the permit.

Support:

36 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:

37 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.

Bus/Transit Vehicle Priority

Support:

38 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.

Standard:

39 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.*

Section 4D.28 Flashing Operation of Traffic Control Signals – General

Standard:

01 **The light source of a flashing signal indication shall be flashed continuously at a rate of not less than 50 or more than 60 times per minute.**

02 **The displayed period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total flash cycle.**

03 **Flashing signal indications shall comply with the requirements of other Sections of this Manual regarding visibility-limiting or positioning of conflicting signal indications, except that flashing yellow signal indications for through traffic shall not be required to be visibility-limited or positioned to minimize visual conflict for road users in separately controlled turn lanes.**

04 **Each traffic control signal shall be provided with an independent flasher mechanism that operates in compliance with this Section.**

05 **The flashing operation shall not be terminated by removal or turn off of the controller unit or of the conflict monitor (malfunction management unit) or both.**

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

Option:

07 Based on engineering study or engineering judgment, traffic control signals may be operated in the flashing mode on a scheduled basis during one or more periods of the day rather than operated continuously in the steady (stop-and-go) mode.

Support:

08 Sections 4E.06 and 4E.09 contain information regarding the operation of pedestrian signal heads and accessible pedestrian signal detector pushbutton locator tones, respectively, during flashing operation.

Section 4D.29 Flashing Operation – Transition Into Flashing Mode

Standard:

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

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

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

B. Directly from a CIRCULAR GREEN signal indication to a flashing CIRCULAR YELLOW signal indication, or from a GREEN ARROW signal indication to a flashing YELLOW ARROW signal indication, or from a flashing YELLOW ARROW signal indication (see Sections 4D.17 to 4D.24) to a flashing YELLOW ARROW signal indication in a different signal section.

03 **During programmed changes into flashing mode, no green signal indication or flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication.**

Section 4D.30 Flashing Operation – Signal Indications During Flashing Mode

Guidance:

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

Standard:

02 **When a traffic control signal is operated in the flashing mode, all of the green signal indications at the signalized location shall be dark (non-illuminated) and shall not be displayed in either a steady or flashing manner, except for single-section GREEN ARROW signal indications as provided elsewhere in this Section.**

03 **Flashing yellow signal indications shall be used on more than one approach to a signalized location only if those approaches do not conflict with each other.**

04 **Except as provided in Paragraph 5, when a traffic control signal is operated in the flashing mode, one and only one signal indication in every signal face at the signalized location shall be flashed.**

Option:

05 If a signal face has two identical CIRCULAR RED or RED ARROW signal indications (see Section 4D.08), both of those identical signal indications may be flashed simultaneously.

Standard:

06 **No steady indications, other than a single-section signal face consisting of a continuously-displayed GREEN ARROW signal indication that is used alone to indicate a continuous movement in the steady (stop-and-go) mode, shall be displayed at the signalized location during the flashing mode. A single-section GREEN ARROW signal indication shall remain continuously-displayed when the traffic control signal is operated in the flashing mode.**

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

08 **All signal faces that are flashed on an approach shall flash the same color, either yellow or red, except that separate turn signal faces (see Sections 4D.17 and 4D.21) shall be permitted to flash a RED ARROW signal indication when the adjacent through movement signal indications are flashed yellow. Shared signal faces (see Sections 4D.17 and 4D.21) for turn movements shall not be permitted to flash a CIRCULAR RED signal indication when the adjacent through movement signal indications are flashed yellow.**

09 **The appropriate RED ARROW or YELLOW ARROW signal indication shall be flashed when a signal face consists entirely of arrow indications. A signal face that consists entirely of arrow indications and that provides a protected only turn movement during the steady (stop-and-go) mode or that provides a flashing yellow arrow or flashing red arrow signal indication for a permissive turn movement during the steady (stop-and-go) mode shall be permitted to flash the YELLOW ARROW signal indication during the flashing mode if the adjacent through movement signal indications are flashed yellow and if it is intended**

that a permissive turn movement not requiring a full stop by each turning vehicle be provided during the flashing mode.

Section 4D.31 Flashing Operation – Transition Out of Flashing Mode

Standard:

01 **All changes from flashing mode to steady (stop-and-go) mode shall be made under one of the following procedures:**

A. Yellow-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made at the beginning of the major-street green interval (when a green signal indication is displayed to through traffic in both directions on the major street), or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

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

Guidance:

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

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

Standard:

04 **During programmed changes out of flashing mode, no flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication.**

Option:

05 Because special midblock signals that rest in flashing circular yellow in the position normally occupied by the green signal indication do not have a green signal indication in the signal face, these signals may go directly from flashing circular yellow (in the position normally occupied by the green signal indication) to steady yellow without going first to a green signal indication.

Section 4D.32 Temporary and Portable Traffic Control Signals

Support:

01 A temporary traffic control signal is generally installed using methods that minimize the costs of installation, relocation, and/or removal. Typical temporary traffic control signals are for specific purposes, such as for one-lane, two-way facilities in temporary traffic control zones (see Chapter 4H), for a haul-road intersection, or for access to a site that will have a permanent access point developed at another location in the near future.

Standard:

02 **Advance signing shall be used when employing a temporary traffic control signal.**

03 **A temporary traffic control signal shall:**

A. Meet the physical display and operational requirements of a conventional traffic control signal.

B. Be removed when no longer needed.

C. Be placed in the flashing mode when not being used if it will be operated in the steady mode within 5 working days; otherwise, it shall be removed.

D. Be placed in the flashing mode during periods when it is not desirable to operate the signal, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation.

E. Each temporary signals plan shall include the equipment details.

F. Signal faces, detectors and control equipment shall be kept in good operating condition at all times.

G. Timing of the signals shall be determined by the agency having jurisdiction.

H. A Signal Ahead (W3-3) sign (and flashing beacon, if required) shall be placed on each approach of the highway in advance of the signal.
I. 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.
J. 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.
K. Failure to comply with any of the above or other specified conditions shall be justification for revoking the permit.

Guidance:

04 *A temporary traffic control signal should be used only if engineering judgment indicates that installing the signal will improve the overall safety and/or operation of the location.*

05 *The use of temporary traffic control signals by a work crew on a regular basis in their work area should be subject to the approval of the jurisdiction having authority over the roadway.*

06 *A temporary traffic control signal should not operate longer than 30 days unless associated with a longer-term temporary traffic control zone project.*

07 *For use of temporary traffic control signals in temporary traffic control zones, reference should be made to Section 6F.84.*

Option:

08 One-way traffic control signals may utilize semi- or fully-traffic-actuated controller units, or may be manually controlled.

09 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.

Section 4D.33 Lateral Offset of Signal Supports and Cabinets

Guidance:

01 *The following items should be considered when placing signal supports and cabinets:*

A. Reference should be made to the American Association of State Highway and Transportation Officials (AASHTO) "Roadside Design Guide" (see Section 1A.11) and to the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).
B. Signal supports should be placed as far as practical from the edge of the traveled way without adversely affecting the visibility of the signal indications.
C. Where supports cannot be located based on the recommended AASHTO clearances, consideration should be given to the use of appropriate safety devices.
D. No part of a concrete base for a signal support should extend more than 4 inches above the ground level at any point. This limitation does not apply to the concrete base for a rigid support.
E. In order to minimize hindrance to the passage of persons with physical disabilities, a signal support or controller cabinet should not obstruct the sidewalk, or access from the sidewalk to the crosswalk.
F. Controller cabinets should be located as far as practical from the edge of the roadway.
G. On medians, the minimum clearances provided in Items A through E for signal supports should be obtained if practical.

Guidance:

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

A. It should not be vulnerable to traffic.
B. Traffic movements at the intersection should be visible from the controller timing position.
C. The doors of the cabinet should open away from the curb or traveled way.
D. It should be possible to park a maintenance truck close to the cabinet.
E. It should not be located in a drainage ditch, in an area which could be under water or where subjected to water from sprinklers.
F. It should not obstruct sidewalks, wheelchair ramps, or store entrances.
G. It should be placed so as not to obstruct pedestrian or road user visibility.

Support:

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

Standard:

04 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.34 Use of Signs at Signalized Locations

Support:

01 Traffic signal signs are sometimes used at highway traffic signal locations to instruct or guide pedestrians, bicyclists, or motorists. Among the signs typically used at or on the approaches to signalized locations are movement prohibition signs (see Section 2B.18), lane control signs (see Sections 2B.19 to 2B.22), pedestrian crossing signs (see Section 2B.51), pedestrian actuation signs (see Section 2B.52), traffic signal signs (see Sections 2B.53 and 2C.48), Signal Ahead warning signs (see Section 2C.36), Street Name signs (see Section 2D.43), and Advance Street Name signs (see Section 2D.44).

Guidance:

02 *Regulatory, warning, and guide signs should be used at traffic control signal locations as provided in Part 2 and as specifically provided elsewhere in Part 4.*

03 *Traffic signal signs should be located adjacent to the signal face to which they apply.*

Support:

04 Section 2B.19 contains information regarding the use of overhead lane control signs on signalized approaches where lane drops, multiple-lane turns involving shared through-and-turn lanes, or other lane-use regulations that would be unexpected by unfamiliar road users are present.

Standard:

05 **If used, illuminated traffic signal signs shall be designed and mounted in such a manner as to avoid glare and reflections that seriously detract from the signal indications. Traffic control signal faces shall be given dominant position and brightness to maximize their priority in the overall display.**

06 **The minimum vertical clearance and horizontal offset of the total assembly of traffic signal signs (see Section 2B.53) shall comply with the provisions of Sections 4D.15 and 4D.16.**

07 Because the potential for conflicting commands could create driver confusion, YIELD or **STOP signs shall not be used in conjunction with any traffic control signal operation, ~~except in either of the following cases:~~**

~~A. If the signal indication for an approach is a flashing red at all times, or~~

~~B. If a minor street or driveway is located within or adjacent to the area controlled by the traffic control signal, but does not require separate traffic signal control because an extremely low potential for conflict exists.~~

08 STOP signs shall not be erected at any entrance to an intersection controlled by traffic signals. Refer to CVC 21355(a).

Option:

09 YIELD or STOP signs may be used at a channelized turn lane if it is separated from the adjacent travel lanes moving in same direction by an island and the channelized turn lane is not controlled by a traffic control signal.

Section 4D.35 Use of Pavement Markings at Signalized Locations

Support:

01 Pavement markings (see Part 3) that clearly communicate the operational plan of an intersection to road users play an important role in the effective operation of traffic control signals. By designating the number of lanes, the use of each lane, the length of additional lanes on the approach to an intersection, and the proper stopping points, the engineer can design the signal phasing and timing to best match the goals of the operational plan.

Guidance:

02 *Pavement markings should be used at traffic control signal locations as provided in Part 3. If the road surface will not retain pavement markings, signs should be installed to provide the needed road user information.*

Section 4D.101(CA) Traffic Signal Design and Operations

Support:

01 The design of traffic signals by Caltrans is based upon the following publications:

A. Standard Specifications.
B. Standard Plans.
C. Signal and Lighting Design Guide.
D. Ramp Meter Design Manual.
E. Highway Design Manual.

02 Additional references that can be used include:

A. Traffic Engineering Handbook.
B. Manual of Traffic Signal Design.
C. Traffic Control Systems Standards.
D. Traffic Control Devices Handbook.

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

Section 4D.102(CA) Signal Plan Schedules

Guidance:

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

A. 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-105(CA) and the Standard Plans.
B. 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-106(CA).

Support:

02 Dimensions of conductors and conduit and data for determining conduit size are shown in Tables 4D-107(CA) and 4D-108(CA).

Section 4D.103(CA) Vehicle Detectors

Support:

01 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:

A. 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.
B. Magnetometer- The magnetometer detector detects a standing vehicle, as well as a moving one, and has a detection area up to 3.3 feet in diameter over each sensing element.
C. Magnetic- The magnetic detector detects only vehicles moving in excess of 5 mph. One sensing element covers one or two traffic lanes.
D. 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.
E. Pressure Sensitive.

Standard:

02 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:

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

Guidance:

04 *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:

05 Typical installation details for inductive loop and magnetic 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(CA) for suggested setback from Limit lines.

Section 4D.104(CA) Bicycle Signals

Support:

01 A bicycle signal (see Figure 4D-112(CA)) 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. Refer to CVC 21450.

Standard:

02 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 Caltrans Bicycle Signal Warrants (see Section 4C.102(CA)).

03 A separate signal phase for bicycle movement shall be used.

Guidance:

04 *Alternative means of handling conflicts between bicycles and motor vehicles should be considered first.*

05 *Two alternatives that should be considered are:*

A. 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.

B. Redesigning the intersection to direct a bicyclist from an off-street path to a bicycle lane at a point removed from the signalized intersection.

06 *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(CA) Bicycle/Motorcycle Detection

Standard:

01 All new limit line detector installations and modifications to the existing limit line detection on a public or private road or driveway intersecting a public road (see Section 1A.13 for definitions) shall either provide a Limit Line Detection Zone in which the Reference Bicycle-Rider is detected or be placed on permanent recall or fixed time operation. Refer to CVC 21450.5.

02 All new and modified bike path approaches to a signalized intersection shall be equipped with either a Limit Line Detection Zone or a bicyclist pushbutton, or else the phase serving the bike path shall be placed on permanent recall or fixed time operation. A bicyclist pushbutton, if used, shall be located on the right side of the bike path and where it can be reached from the bike path. See Section 9B.11 for bicycle regulatory signs.

03 At new signalized intersections or when the advance detection is being replaced at existing signalized intersections, phases with advance detection only shall be placed on permanent recall.

Support:

04 The requirement to detect the Reference Bicycle-Rider in the Limit Line Detection Zone is technology-neutral.

Option:

05 The detection zone in a bike lane may be narrower than 6 feet. See Figure 4D-111(CA).

06 A Bicycle Detector Symbol may be used. See Sections 9B.13 and 9C.05.

07 A bicyclist pushbutton may be used to supplement the required limit line detection.

Support:

08 See Section 9B.10 for bicycle regulatory signs.

Guidance:

09 *If more than 50% of the limit line detectors need to be replaced at a signalized intersection, then the entire intersection should be upgraded so that every lane has a Limit Line Detection Zone.*

10 *The Reference Bicycle-Rider or the equivalent should be used to confirm bicycle detection under the following situations:*

A. A new detection system has been installed; or

B. The detection configuration has been modified.

Support:

11 CVC Section 21202(a) requires bicyclists traveling "at a speed less than the normal speed of traffic" to ride "as close as practicable to the right-hand curb or edge of the roadway" with exceptions, including when the bicyclist is "approaching a place where a right turn is authorized." This exception was intended to provide the bicyclist the flexibility to avoid having to ride against the right hand curb or edge of the road where a potential conflict would be created with a right turning road user.

12 A Limit Line Detection Zone provides for the detection of both bicycles and vehicles, including motorcycles.

Guidance:

13 *Where a Limit Line Detection Zone that detects the Reference Bicycle-Rider has been provided, minimum bicycle timing should be provided as follows:*

14 *For all phases, the sum of the minimum green, plus the yellow change interval, plus any red clearance interval should be sufficient to allow a bicyclist riding a bicycle 6 feet long to clear the last conflicting lane at a speed of 14.7 feet/sec plus an additional effective start-up time of 6 seconds, according the formula*

$$Gmin + Y + Rclear \geq 6\ sec + (W+6\ feet)/14.7\ feet/sec,$$

Where:

Gmin = Length of minimum green interval (sec)

Y = Length of yellow interval (sec)

Rclear = Length of red clearance interval (sec)

W = Distance from limit line to far side of last conflicting lane (feet)

Support:

15 Bicyclist crossing times are shown in Table 4D-109(CA). The speed of 14.7 feet/sec represents the final crossing speed and the effective start-up time of 6 seconds represents the time lost in reacting to the green light and then accelerating to full speed.

Option:

16 A limit line detection system that can discriminate between bicyclists and vehicles may be used to extend the length of the minimum green.

17 Supplemental Reference Bicycle-Rider detection zones, new technology, or various signal controller settings may be utilized to adjust the time (Gmin + Y + Rclear) and/or travel distance (W) that bicyclists are exposed to conflicting vehicular traffic.

Section 4D.106(CA) Selection of Traffic Signal Operation

Guidance:

01 *A prime factor to be considered in selection of the type of traffic signal operation is adequacy. Even though a sophisticated signal control should operate satisfactorily at any intersection, the intersection should not be provided with a type of control that is unnecessarily complex and expensive.*

Support:

02 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 pre-timed 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:

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

04 *Where the distance between signalized intersections is 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.*

05 *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(CA) Selection of Left-Turn Phasing

Support:

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

Guidance:

02 *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(CA) Dual Left-Turn Phasing

Support:

01 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. See Figure 4D-101(CA).

Section 4D.109(CA) Lead-Lag Left-Turn Phasing

Guidance:

01 *This operation can be either pre-timed or traffic-actuated. Normally, "Lead-Lag Left-Turn" 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. See Figure 4D-101(CA).*

Section 4D.110(CA) Opposite or Opposing (Six Phase Opposing Operation)

Guidance:

01 *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:

02 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. See Figure 4D-106(CA).

Section 4D.111(CA) Permissive Left-Turn Phasing

Guidance:

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

Standard:

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

Option:

03 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:

04 The extinguishable message shall say LEFT TURN YIELD in at least 6 inch 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.

05 The following apply to permissive left-turn phasing:

1. This operation shall not be initiated where the left turn collision 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.*
   - *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*
   - *A LEFT TURN YIELD ON GREEN (symbolic circular green) (R10-12) sign is installed below the said signal face.*

Support:

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

Section 4D.112(CA) Signals at Interchanges

Support:

01 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:

02 *Figures 4D-109(CA) and 4D-110(CA) 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(CA) to determine the timing of the splits and offsets for diamond interchange signals.*

Support:

03 The decision whether to use pre-timed 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(CA) Timing of Green Intervals

Guidance:

01 *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:

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

Support:

03 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(CA) Review of Traffic Signal Operations

Guidance:

01 *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.*

02 *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:

03 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:

04 Aids for timing are shown in Tables 4D-103(CA) and 4D-104(CA).

Figure 4D-1. Example of U-Turn Signal Face

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

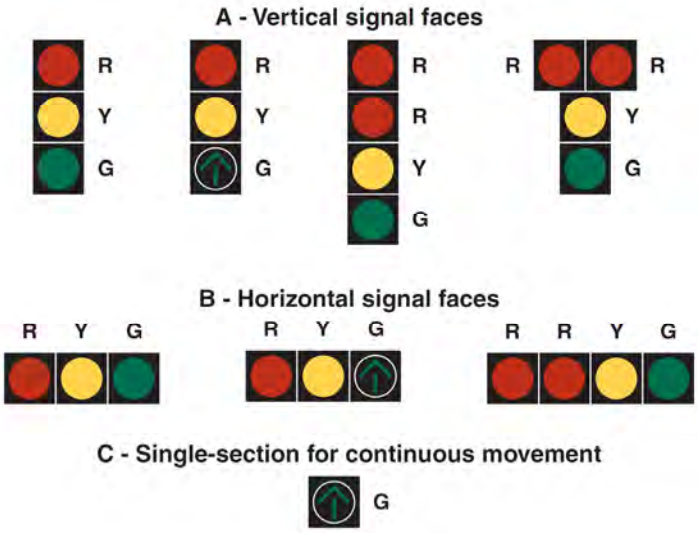
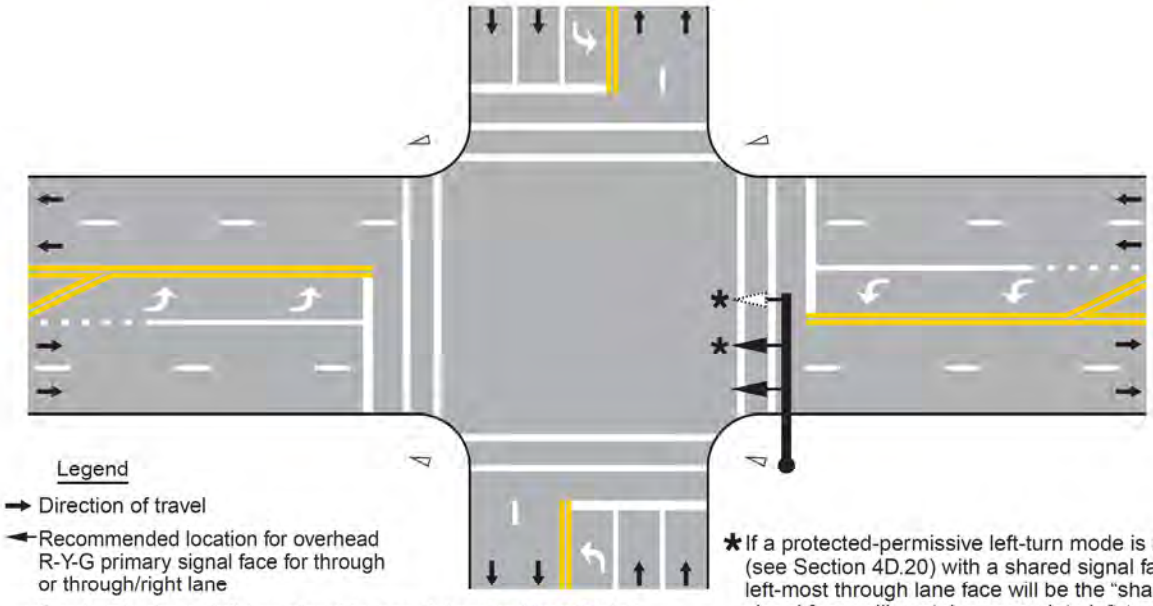


Figure 4D-3. Recommended Vehicular Signal Faces for Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher
(Where there are Excessive Red Signal Violations)



Legend

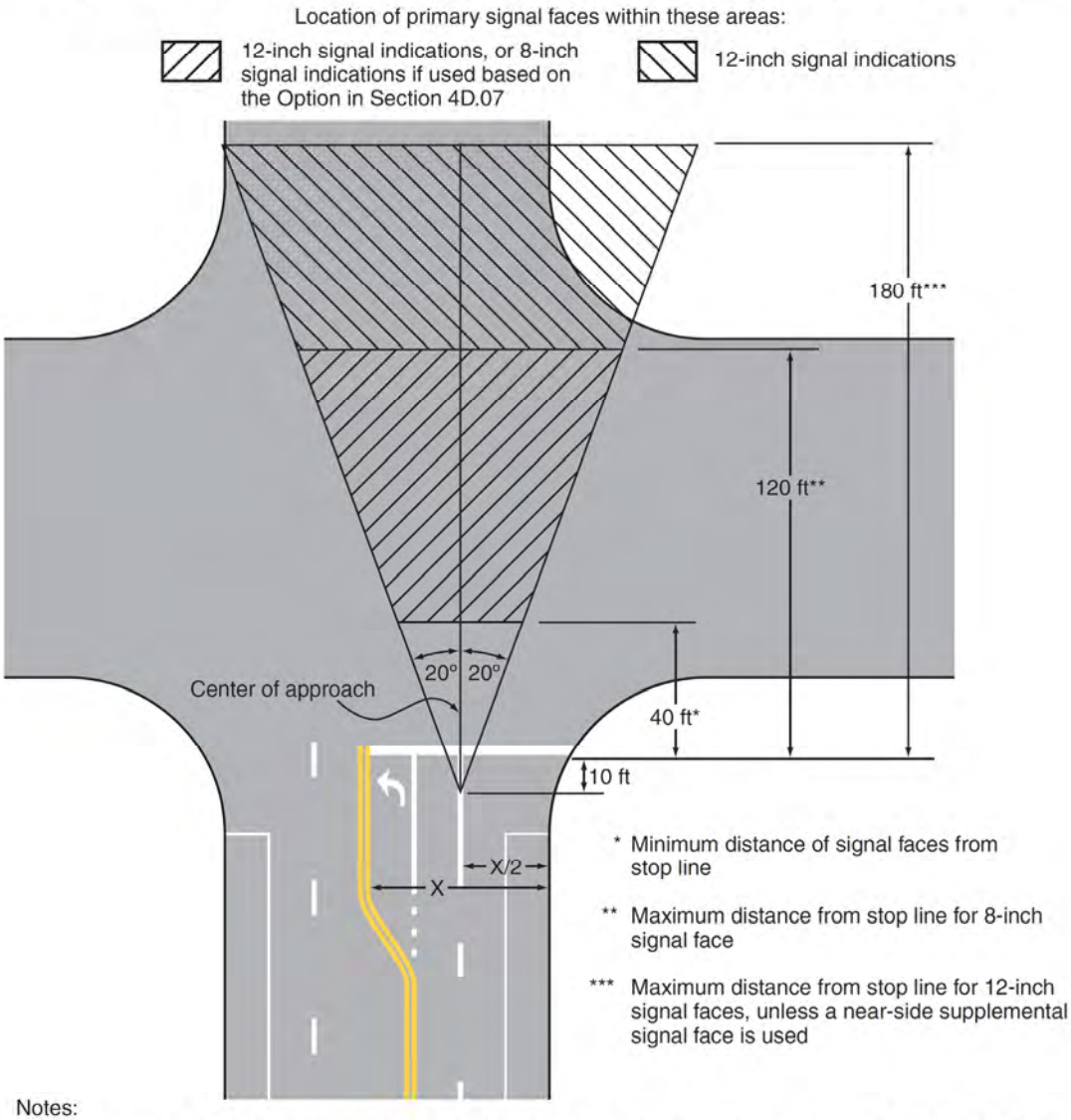
- Direction of travel
- Recommended location for overhead R-Y-G primary signal face for through or through/right lane
- Overhead primary left-turn signal face as determined by selected mode of left-turn operation
- Possible location for a supplemental R-Y-G signal face

* If a protected-permissive left-turn mode is used (see Section 4D.20) with a shared signal face, the left-most through lane face will be the "shared" signal face, will contain appropriate left-turn arrow indications in addition to circular R-Y-G, and will be located over the projection of the lane line between the left-turn and through lanes.

Notes:

1. Signal faces for only one direction and only one possible set of geometrics (number of lanes, etc.) are illustrated. If there are fewer or more than two through lanes on the approach, see Table 4D-2.
2. Any primary left-turn and/or right-turn signal faces, as determined by Sections 4D.17 through 4D.24, should be overhead for each exclusive turn lane.
3. One or more pole-mounted or overhead supplemental faces should be considered, based on the geometrics of the approach, to maximize visibility for approaching traffic.
4. All signal faces should have backplates.

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



Notes:

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

Figure 4D-5. Maximum Mounting Height of Signal Faces Located Between 40 Feet and 53 Feet from Stop Line

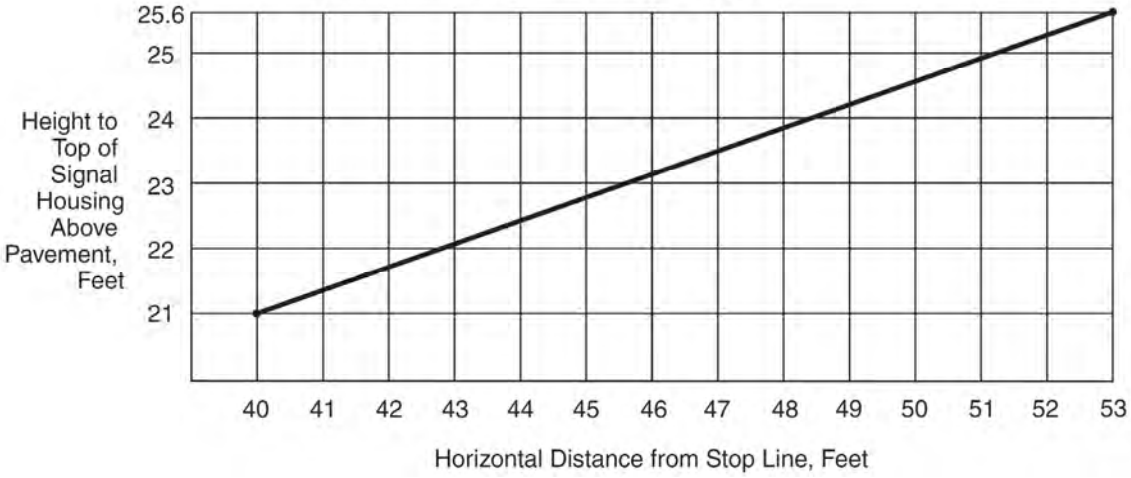


Figure 4D-6. Typical Position and Arrangements of Shared Signal Faces for Permissive Only Mode Left Turns

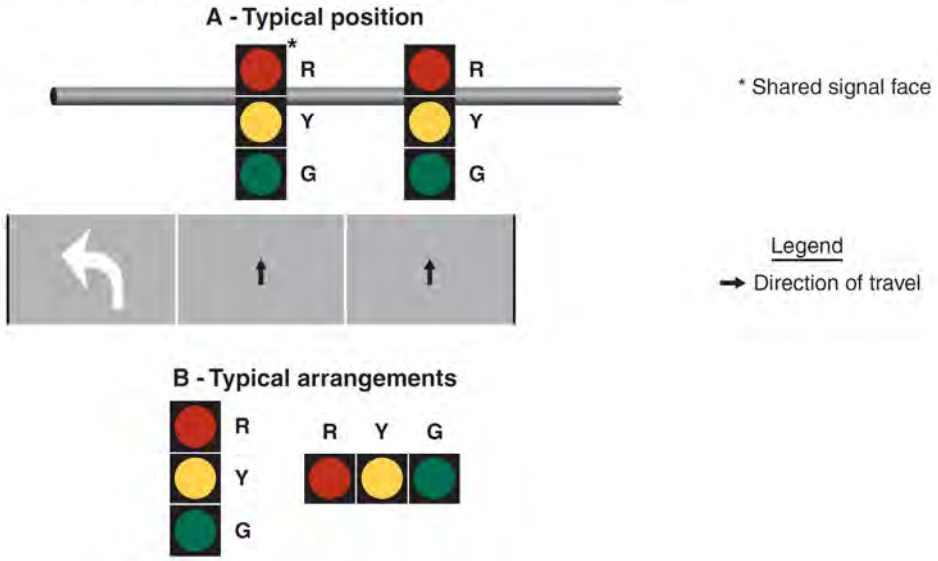


Figure 4D-7. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Permissive Only Mode Left Turns

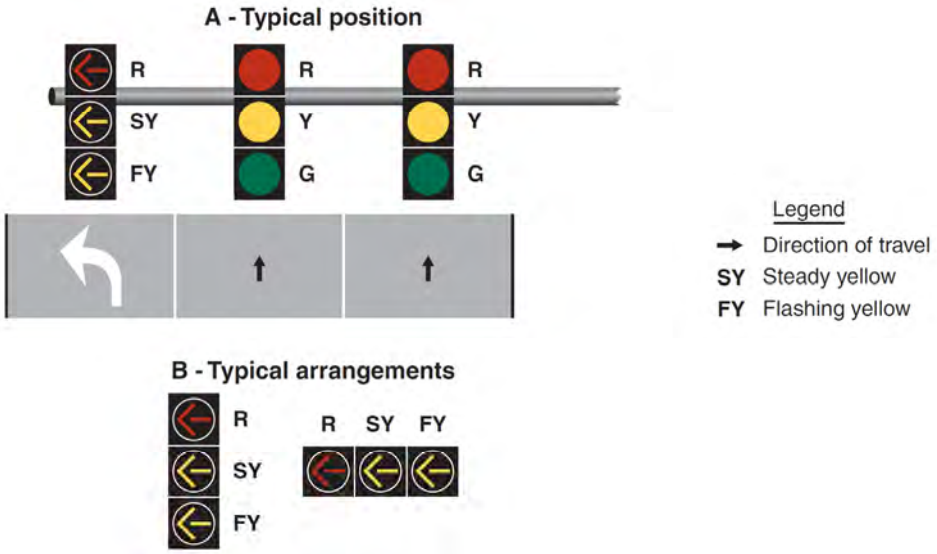


Figure 4D-8. Typical Position and Arrangements of Separate Signal Faces with Flashing Red Arrow for Permissive Only Mode and Protected/Permissive Mode Left Turns

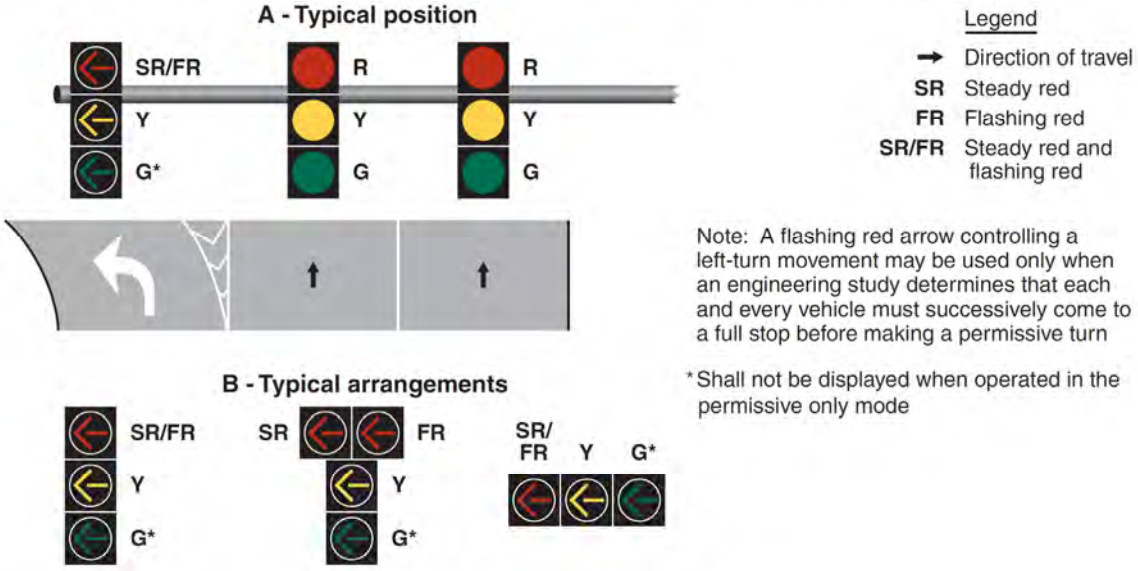
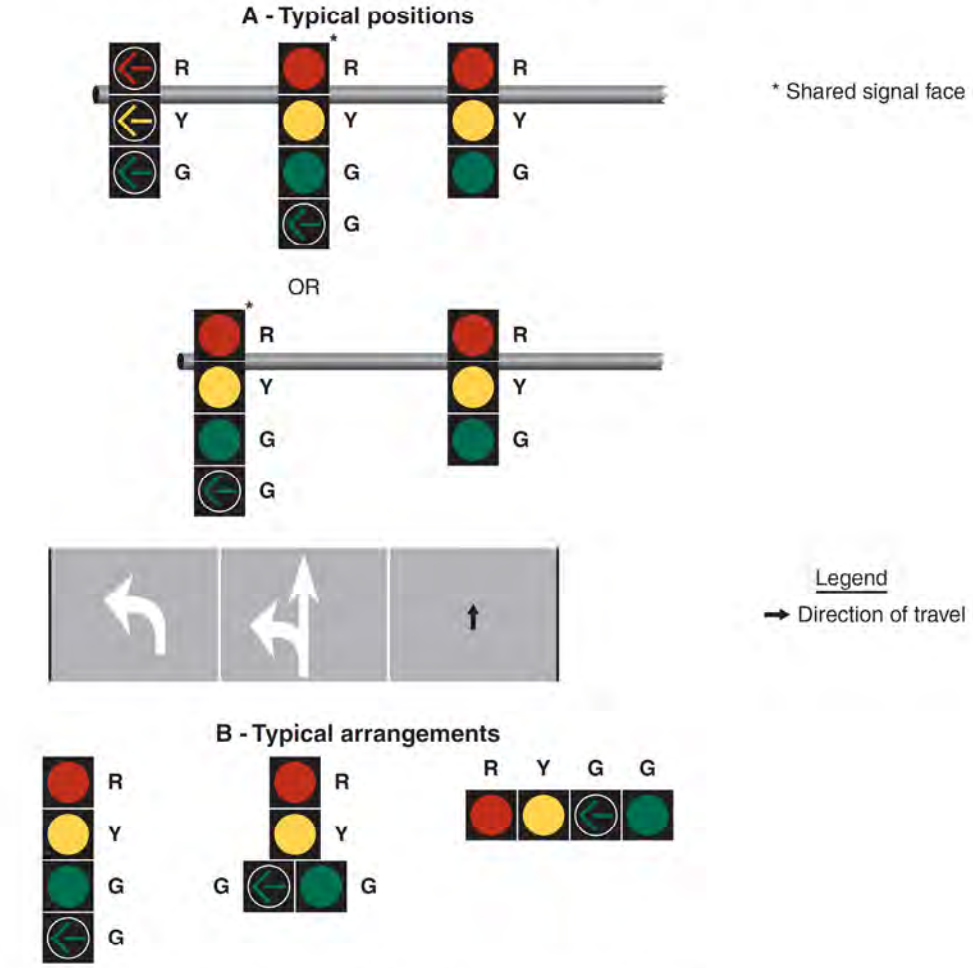


Figure 4D-9. Typical Positions and Arrangements of Shared Signal Faces for Protected Only Mode Left Turns



Note: Shared signal faces shall only be used for a protected-only mode left turn if the circular green and green left-turn arrow indications always begin and terminate together

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

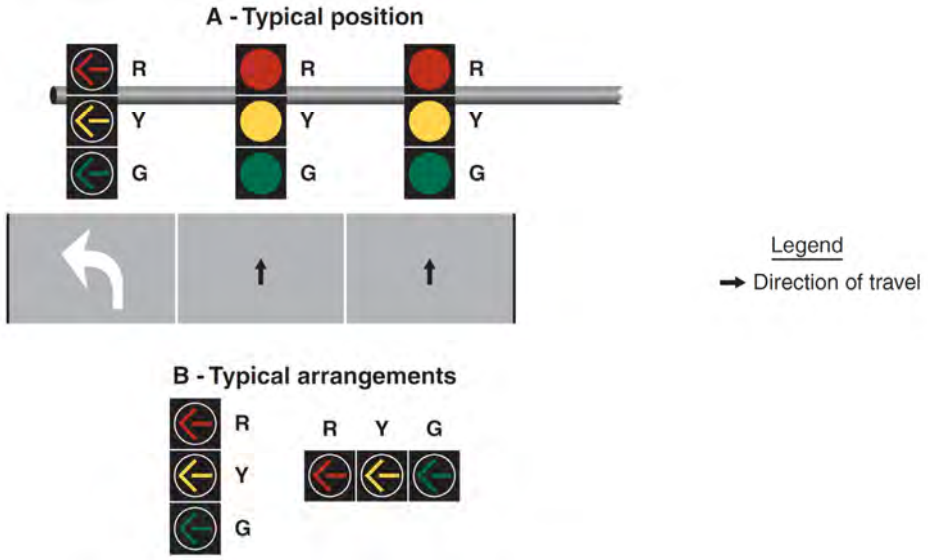


Figure 4D-11. Typical Position and Arrangements of Shared Signal Faces for Protected/Permissive Mode Left Turns

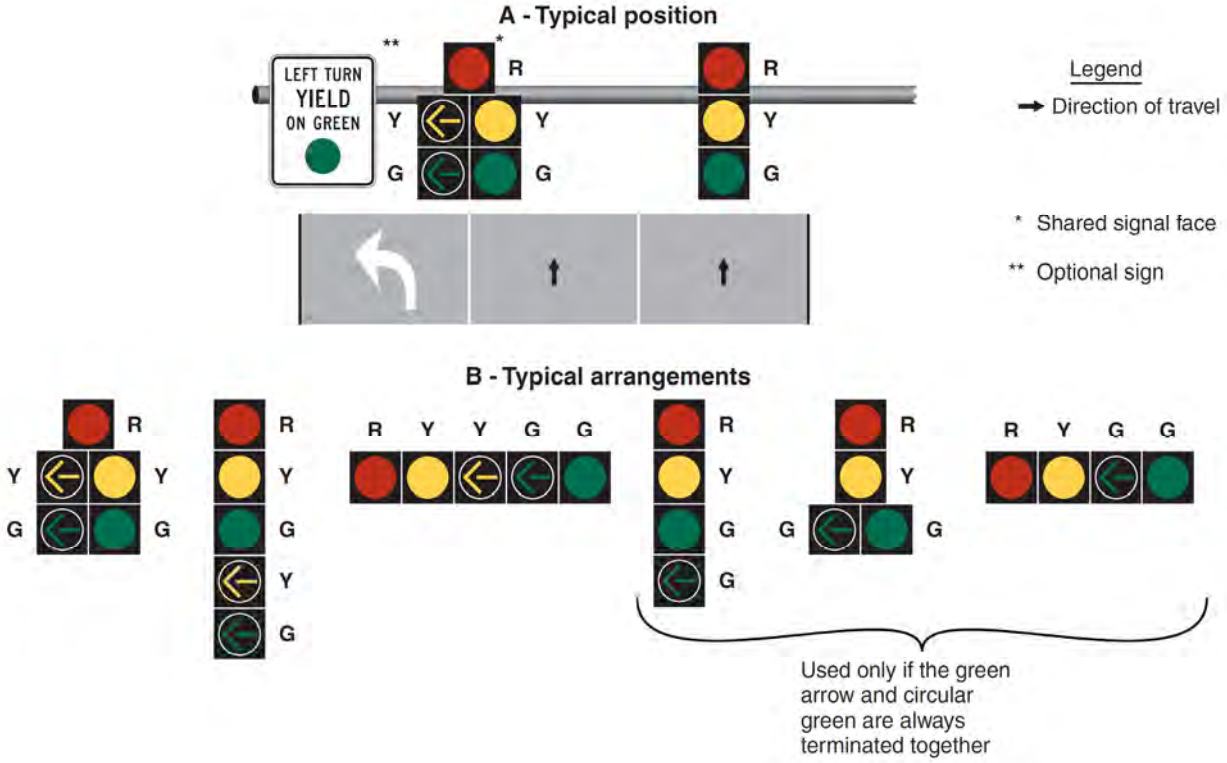


Figure 4D-12. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Protected/Permissive Mode and Protected Only Mode Left Turns

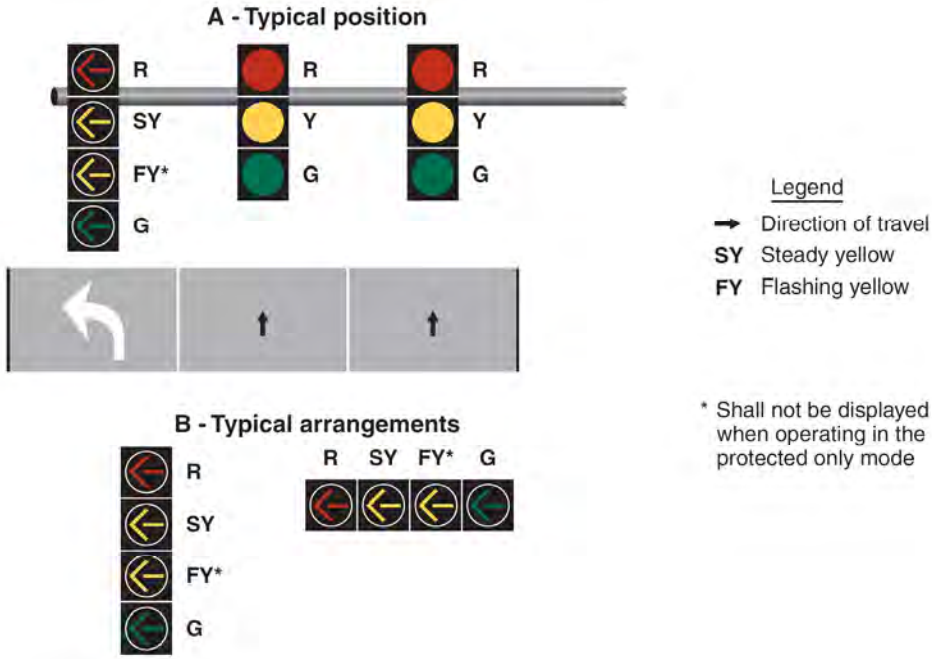


Figure 4D-13. Typical Positions and Arrangements of Shared Signal Faces for Permissive Only Mode Right Turns

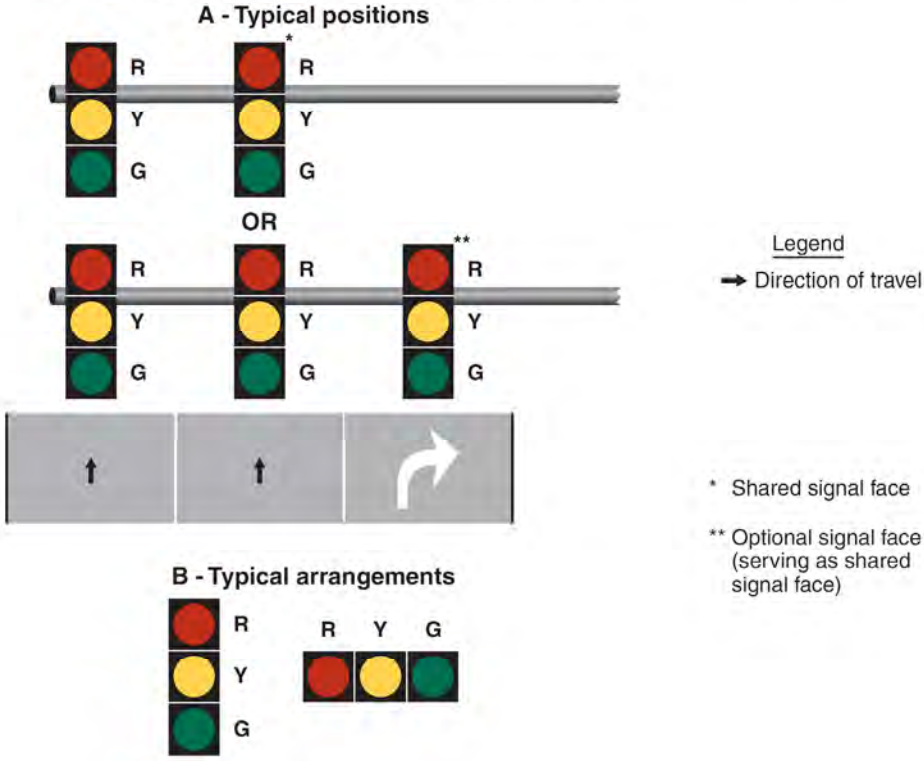


Figure 4D-14. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Permissive Only Mode Right Turns

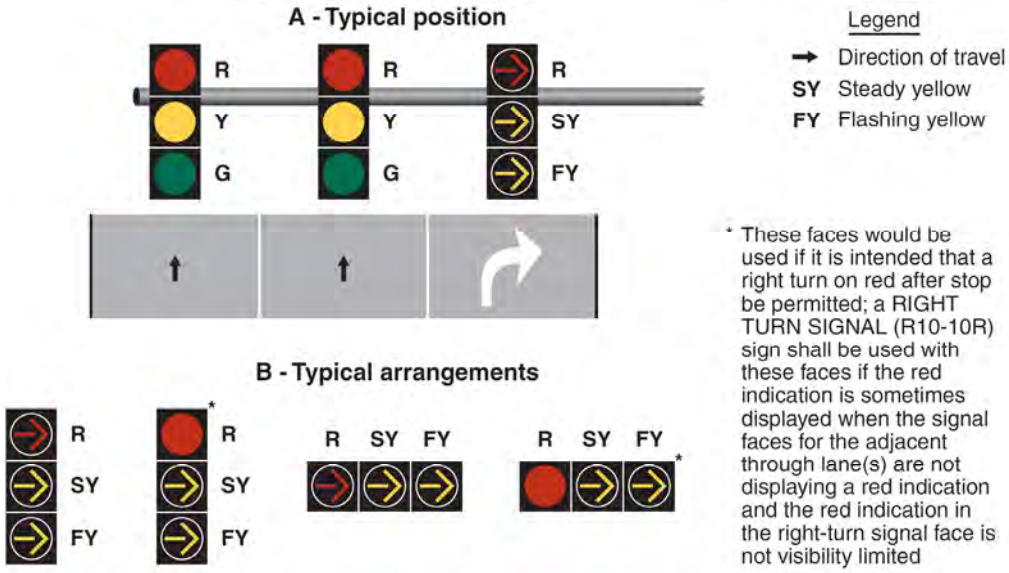
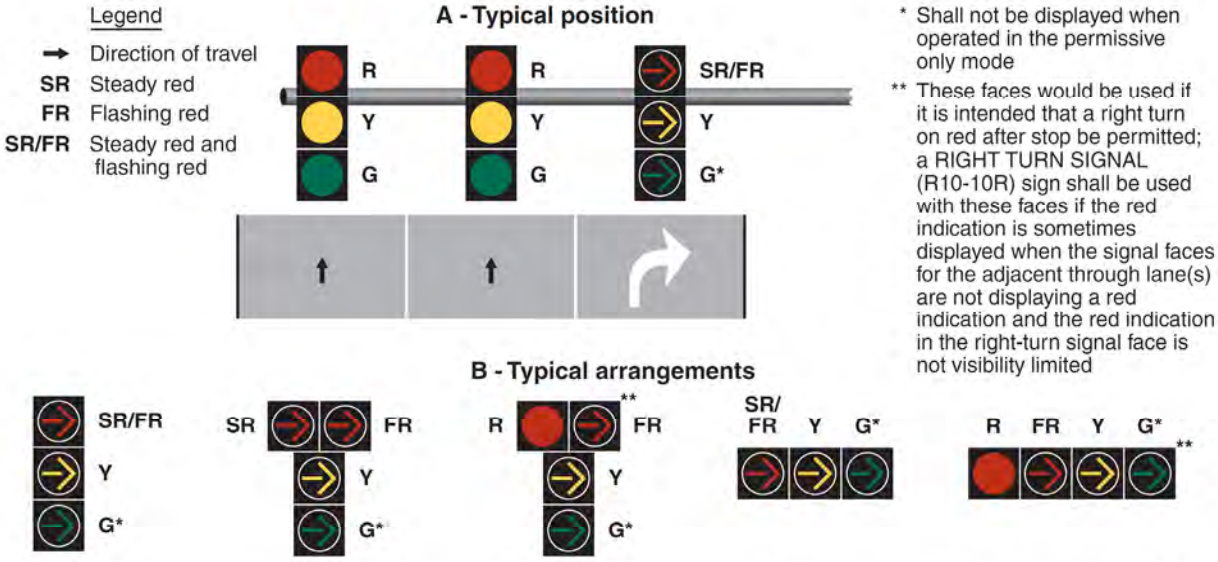
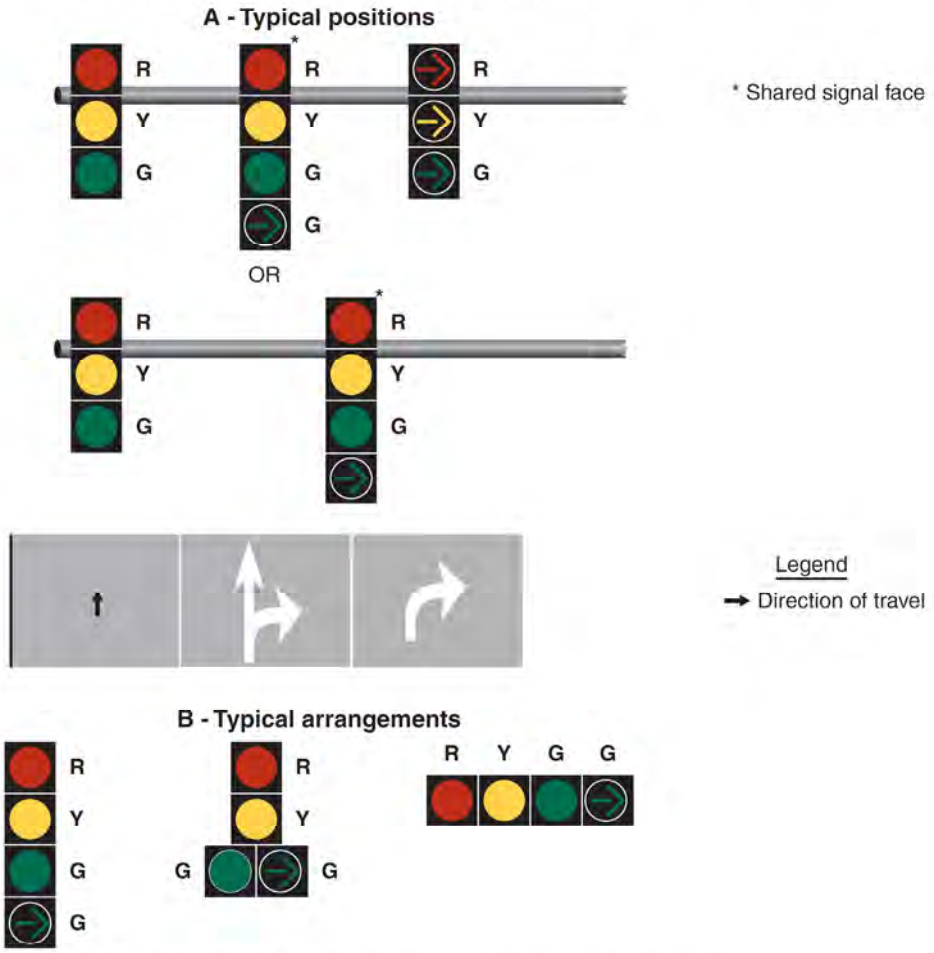


Figure 4D-15. Typical Position and Arrangements of Separate Signal Faces with Flashing Red Arrow for Permissive Only Mode and Protected/Permissive Mode Right Turns



Note: A flashing red arrow controlling a right-turn movement may be used only when an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive turn

Figure 4D-16. Typical Positions and Arrangements of Shared Signal Faces for Protected Only Mode Right Turns



Note: Shared signal faces shall only be used for a protected-only mode right turn if the circular green and green right-turn arrow indications always begin and terminate together

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

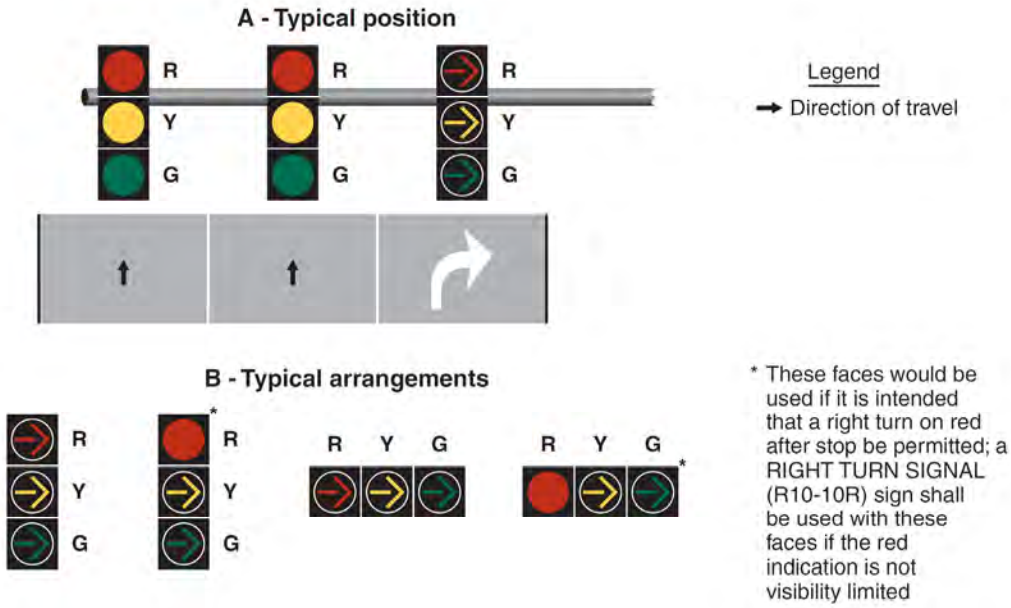


Figure 4D-18. Typical Positions and Arrangements of Shared Signal Faces for Protected/Permissive Mode Right Turns

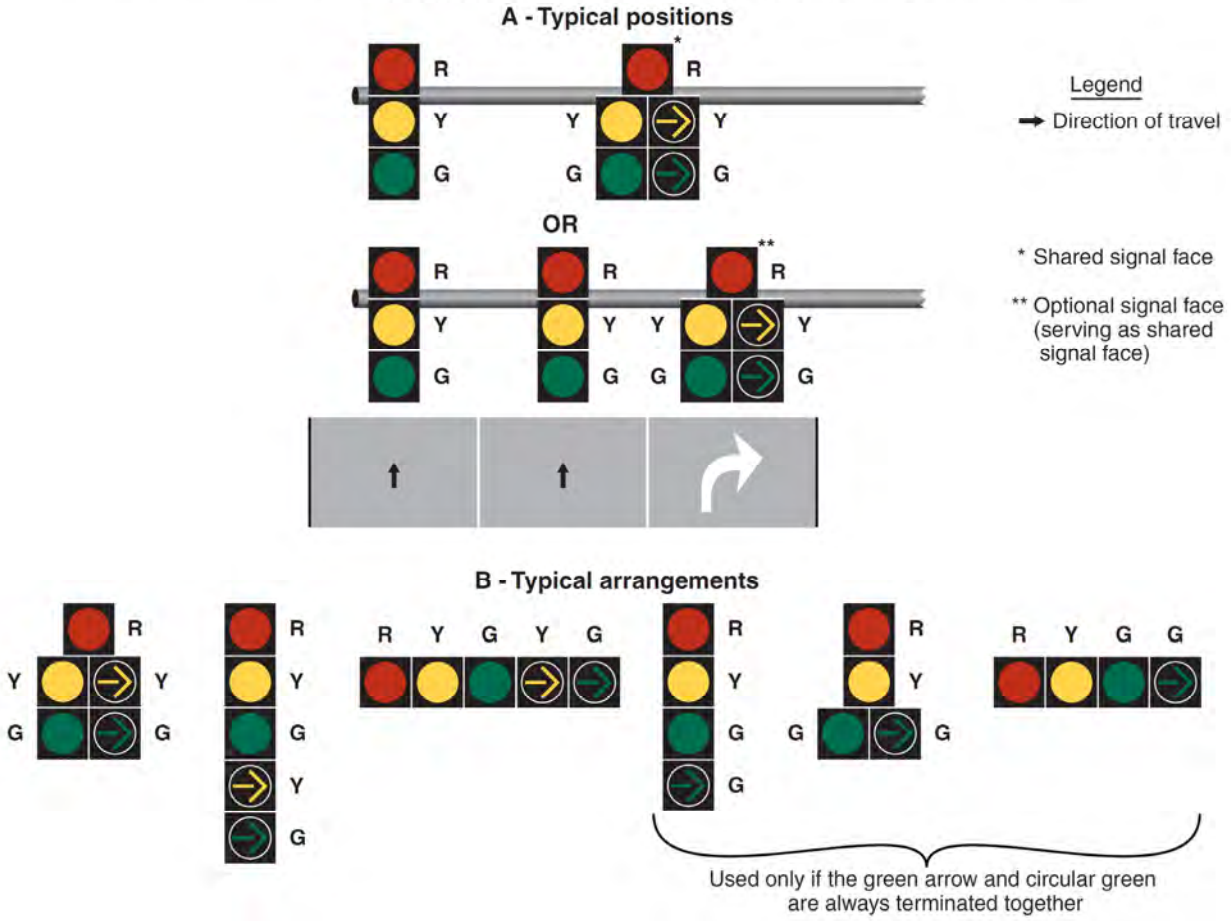


Figure 4D-19. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Protected/Permissive Mode and Protected Only Mode Right Turns

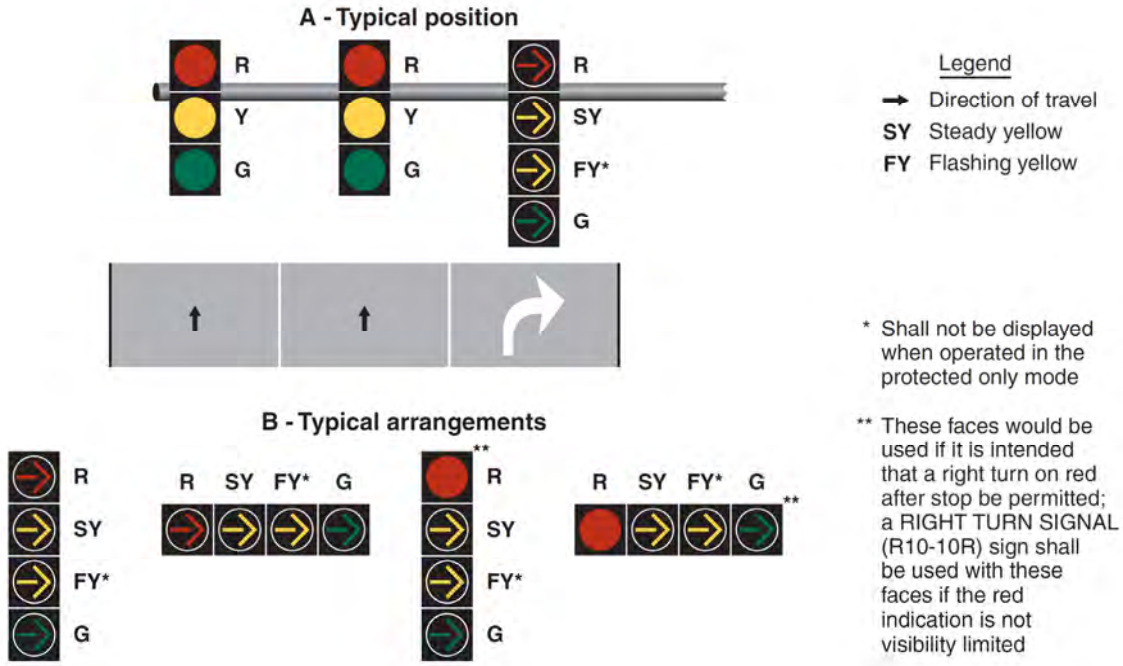
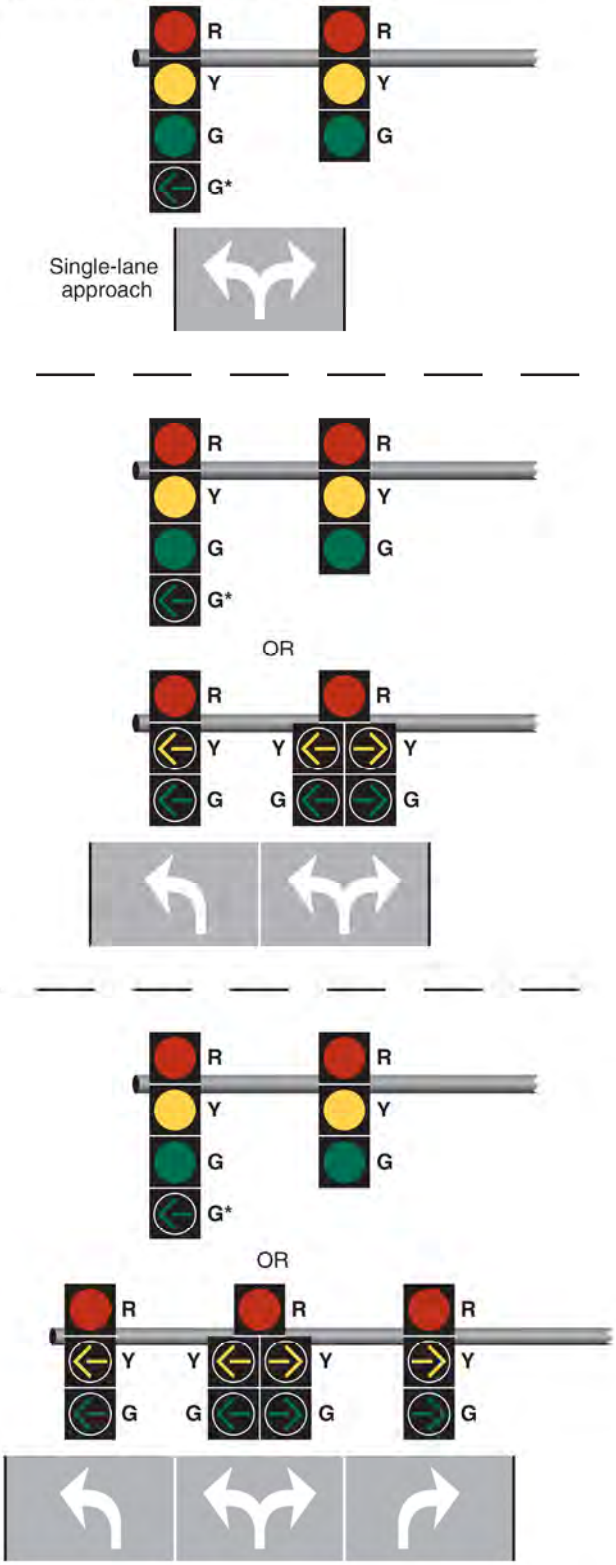


Figure 4D-20. Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 1 of 3)

A - No conflicting vehicular or pedestrian movements



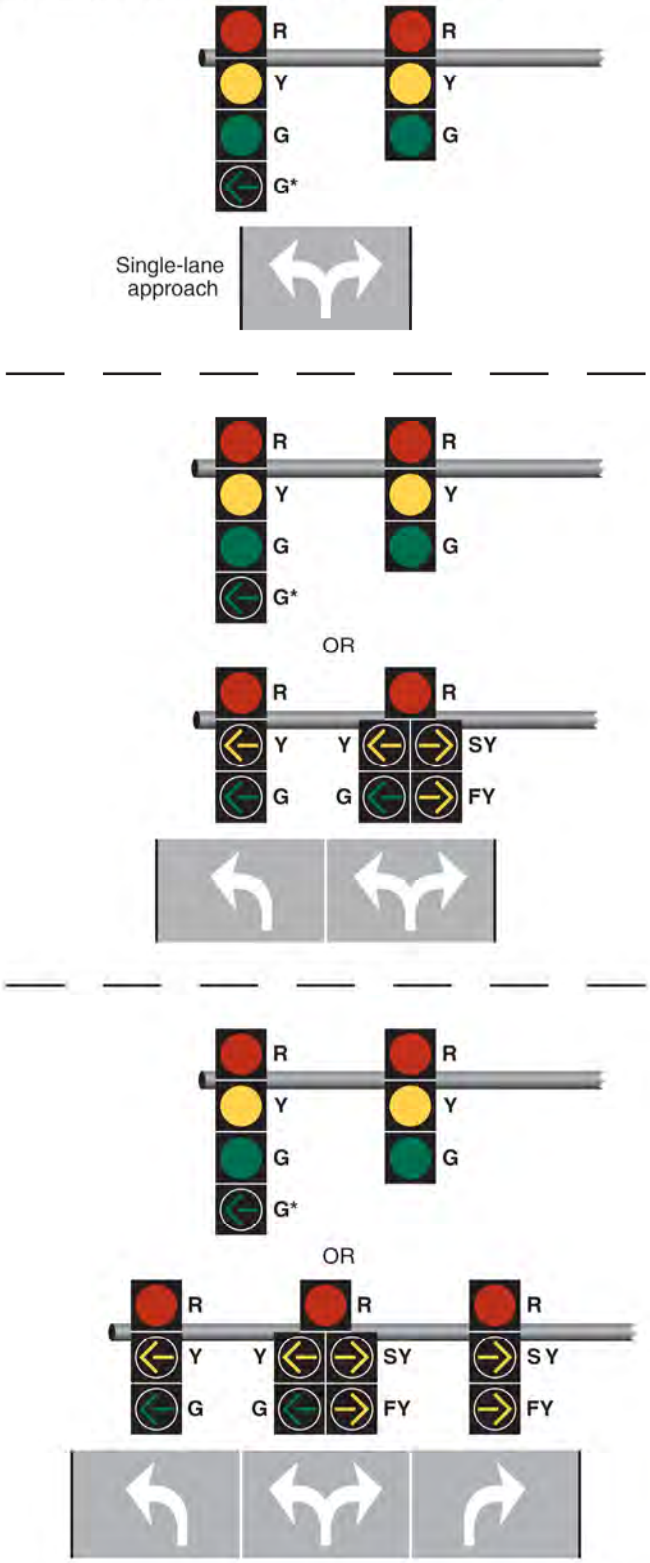
* Left-turn GREEN ARROW section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

Notes:

1. Horizontally-aligned signal faces may also be used.
2. Shared signal faces may also be 5 sections in a vertical straight line instead of a cluster.

Figure 4D-20. Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 2 of 3)

B - Pedestrian or vehicular conflict with one turn movement



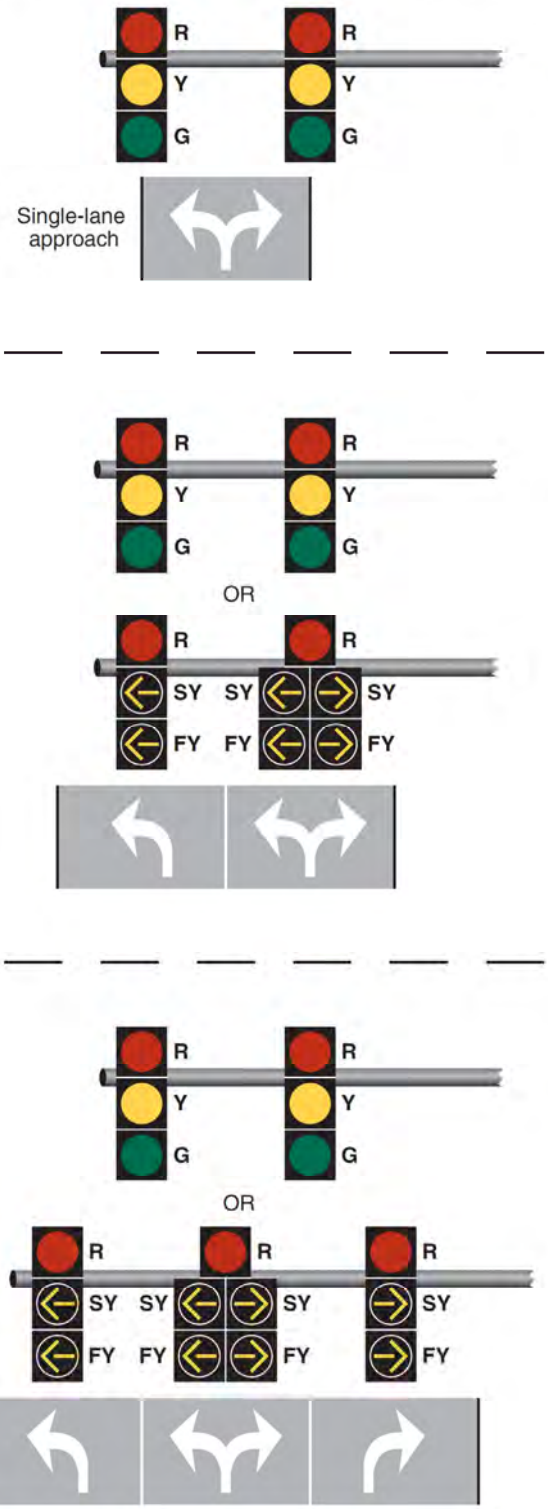
* Left-turn GREEN ARROW section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

Notes:

1. A conflict with the right-turn movement is illustrated.
2. Horizontally-aligned signal faces may also be used.
3. Shared signal faces may also be 5 sections in a vertical straight line instead of a cluster.

Figure 4D-20. Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 3 of 3)

C - Pedestrian or vehicular conflicts with both turn movements



Notes:

1. Horizontally-aligned signal faces may also be used.
2. Shared signal faces may also be 5 sections in a vertical straight line instead of a cluster.

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

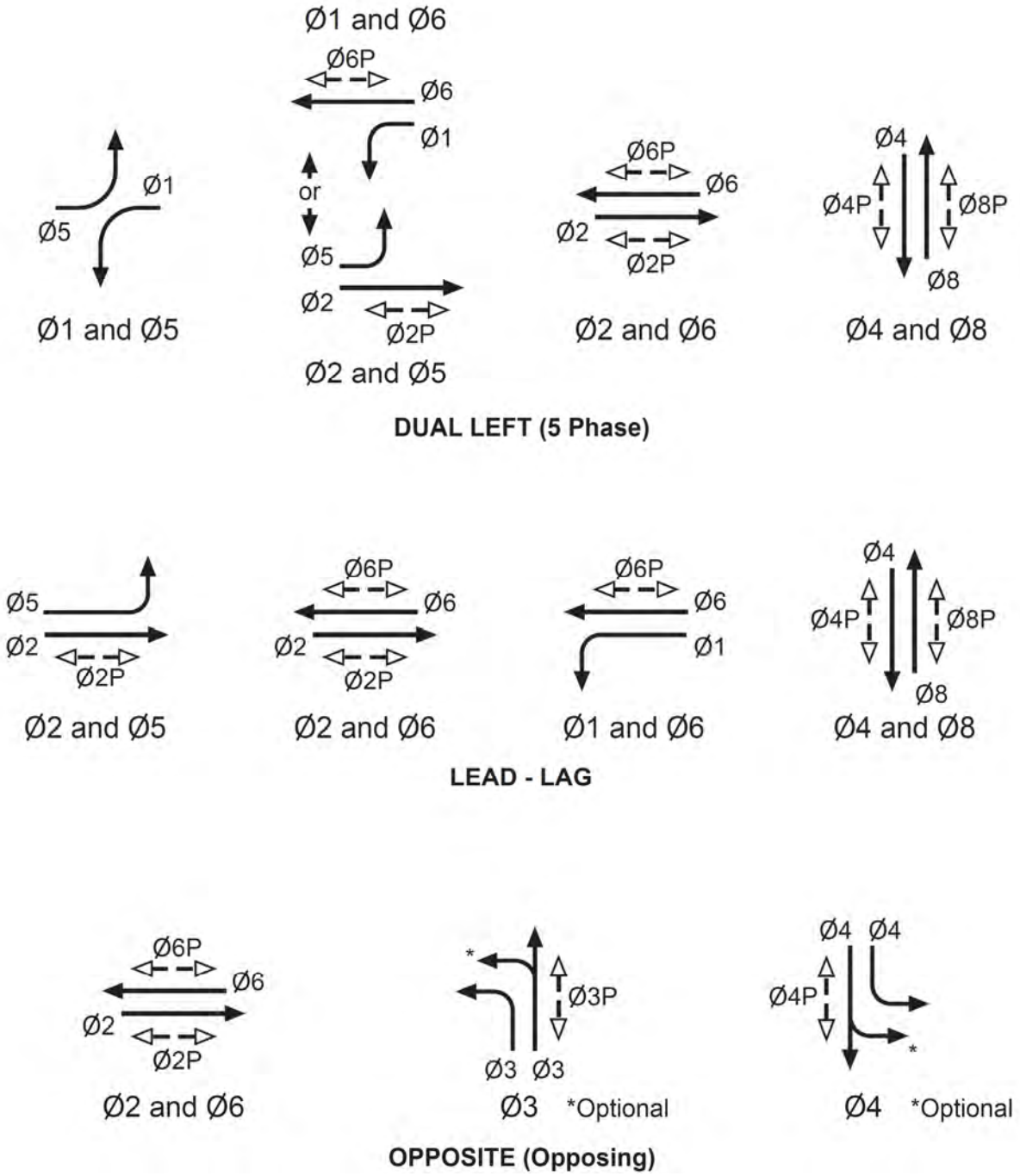
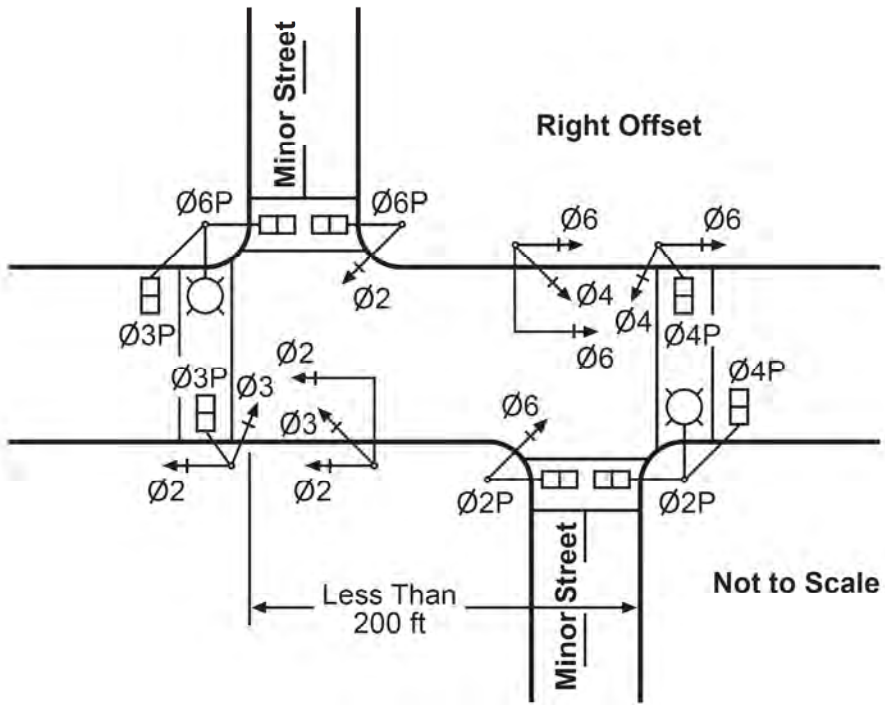
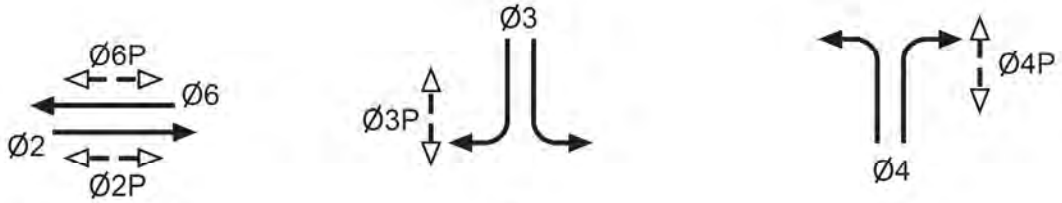


Figure 4D-102 (CA). Typical Signal Layout at Offset Intersections, Signalized and Marked as a Single Intersection (Sheet 1 of 4)



Phase Diagram



Ø2 and Ø6 Ø3 Ø4

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

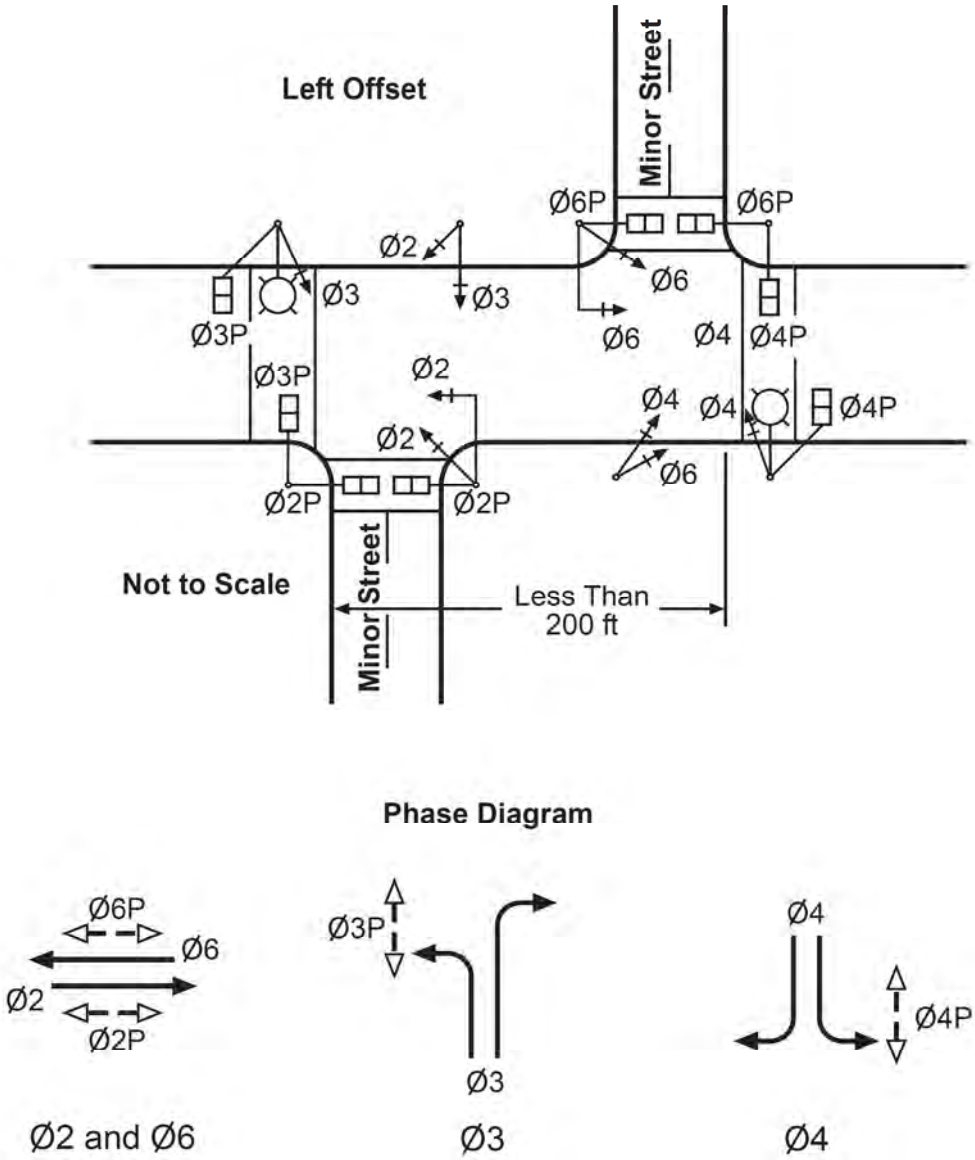


Figure 4D-102 (CA). Typical Signal Layout at Offset Intersections, Signalized and Marked as Separate Intersections (Sheet 3 of 4)

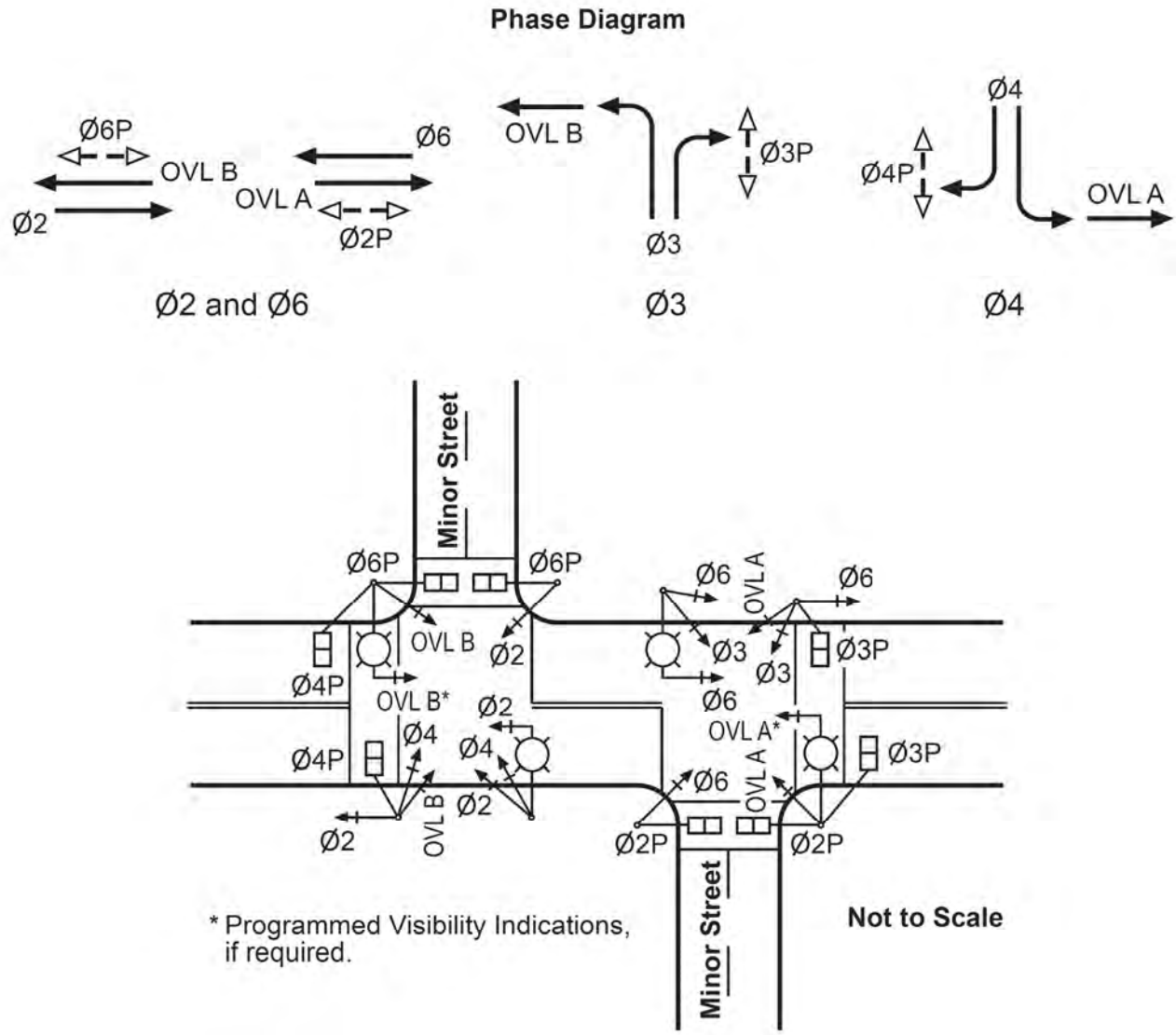


Figure 4D-102 (CA). Typical Signal Layout at Offset Intersections, Signalized and Marked as Separate Intersections (Sheet 4 of 4)

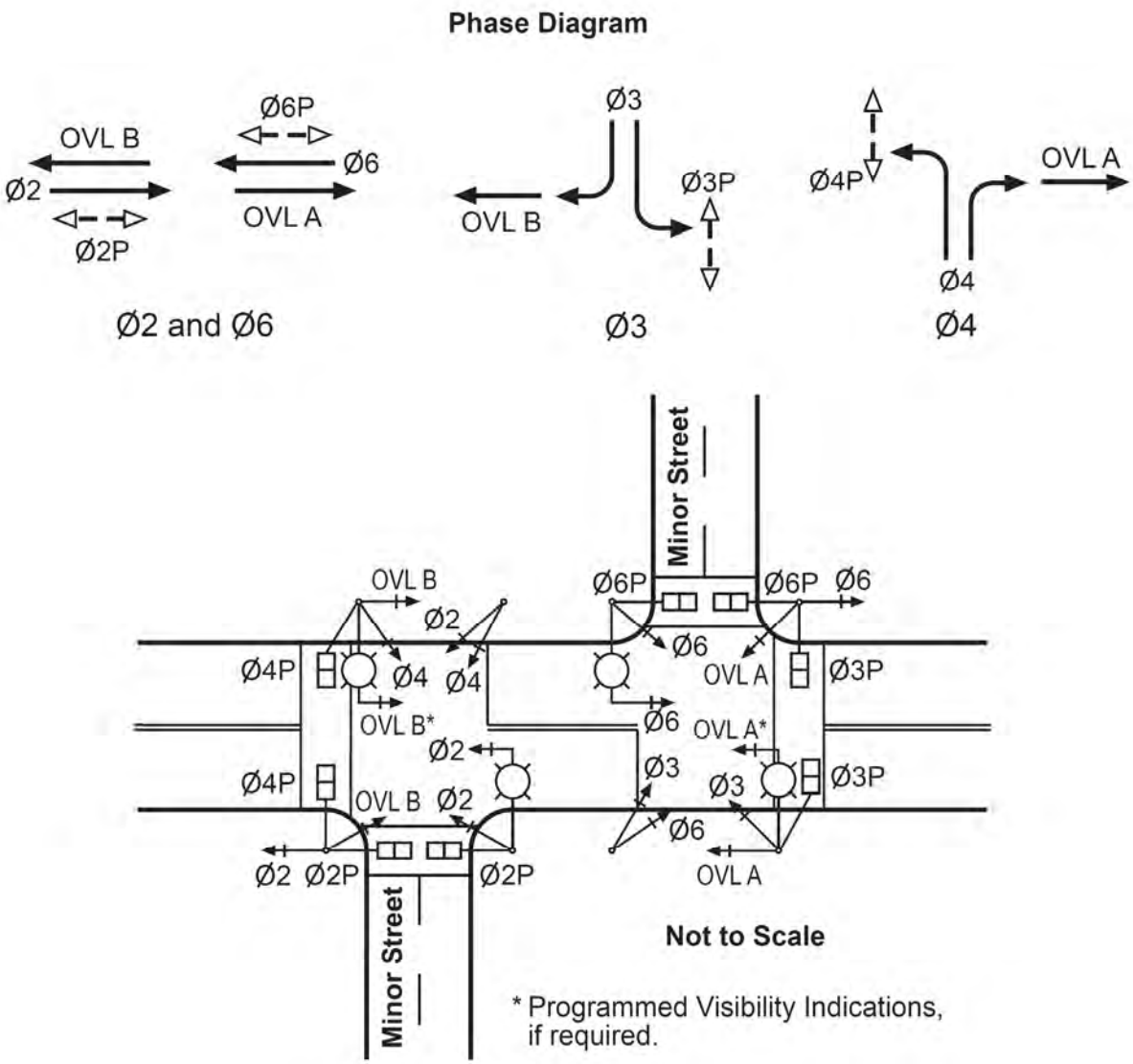


Figure 4D-103 (CA). Typical Signal Layout (Two Phase Operation)

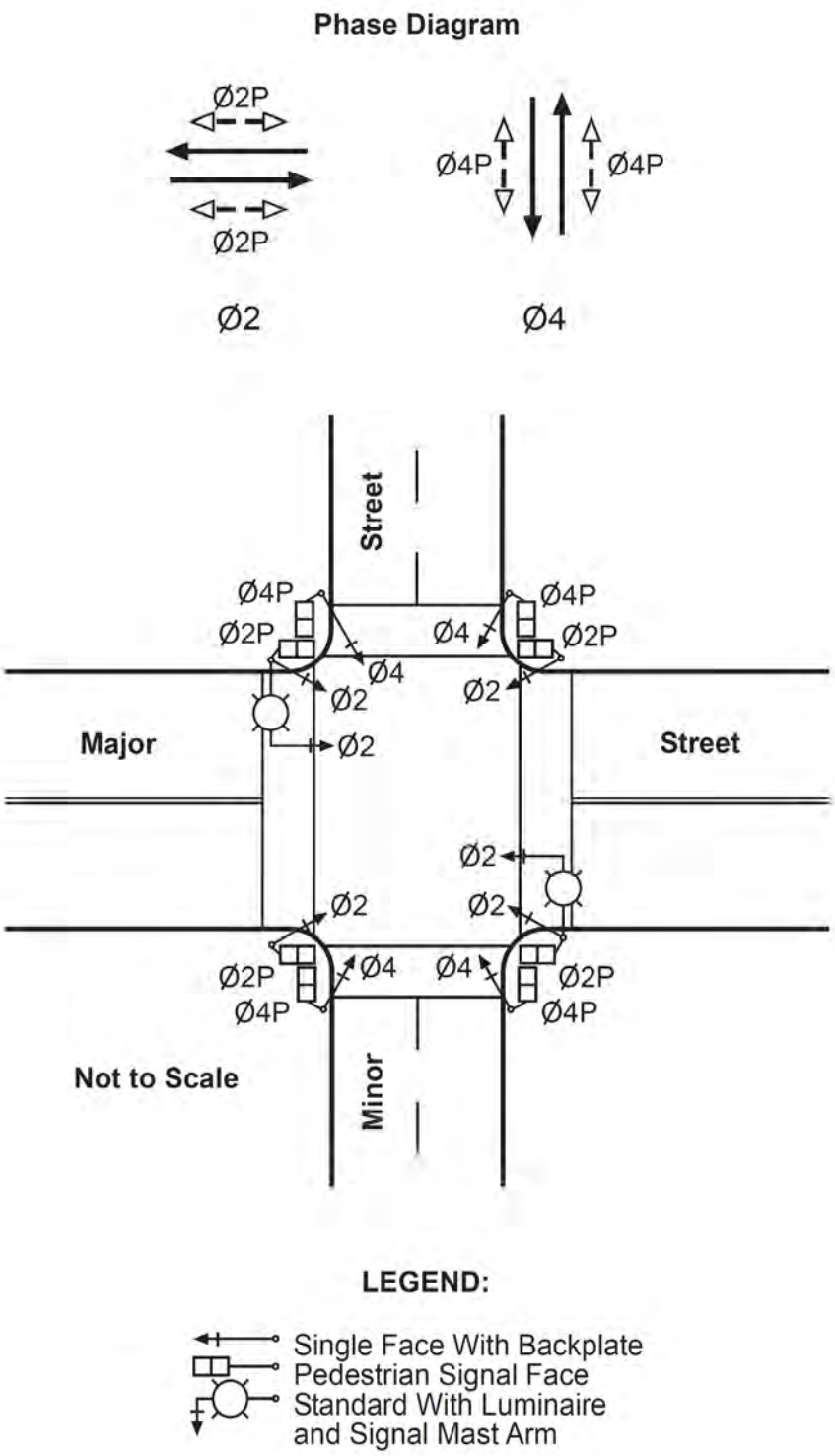
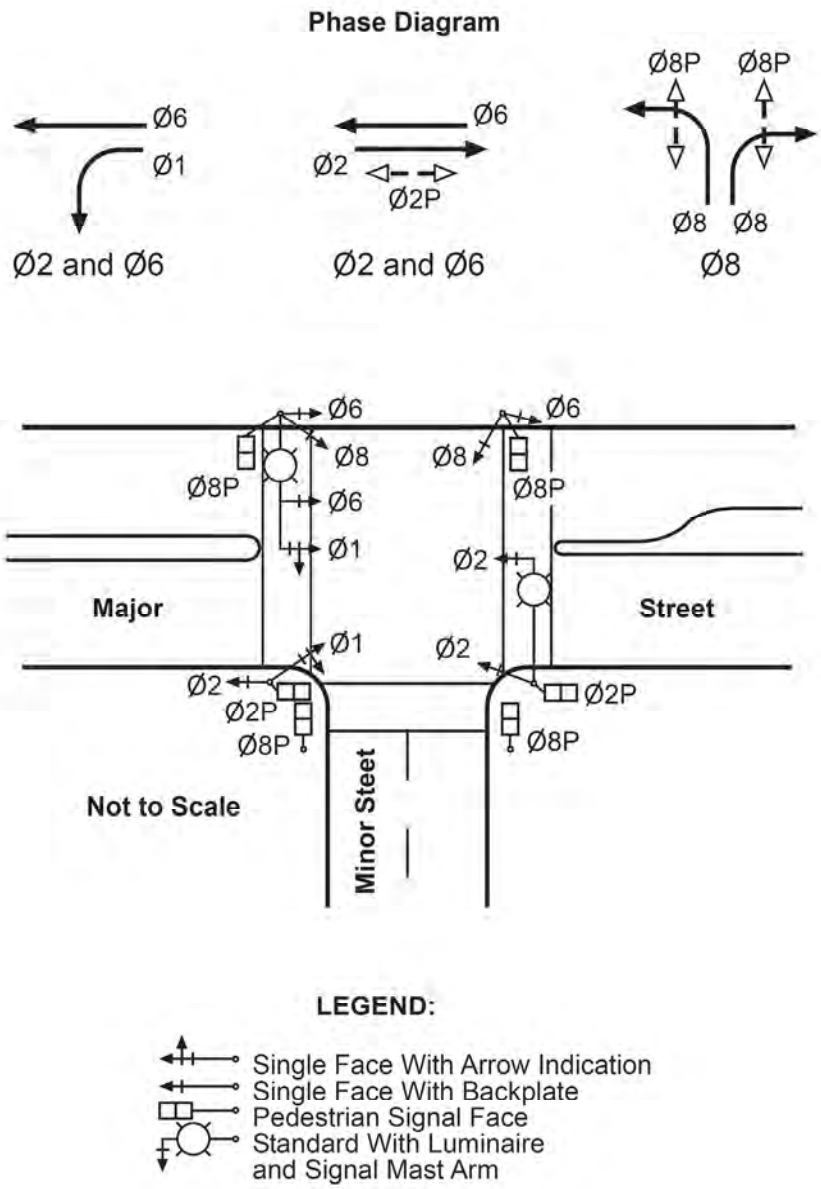


Figure 4D-104 (CA). Typical Signal Layout (Three Phase Operation)



LEGEND:

- Single Face With Arrow Indication
- Single Face With Backplate
- Pedestrian Signal Face
- Standard With Luminaire and Signal Mast Arm

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

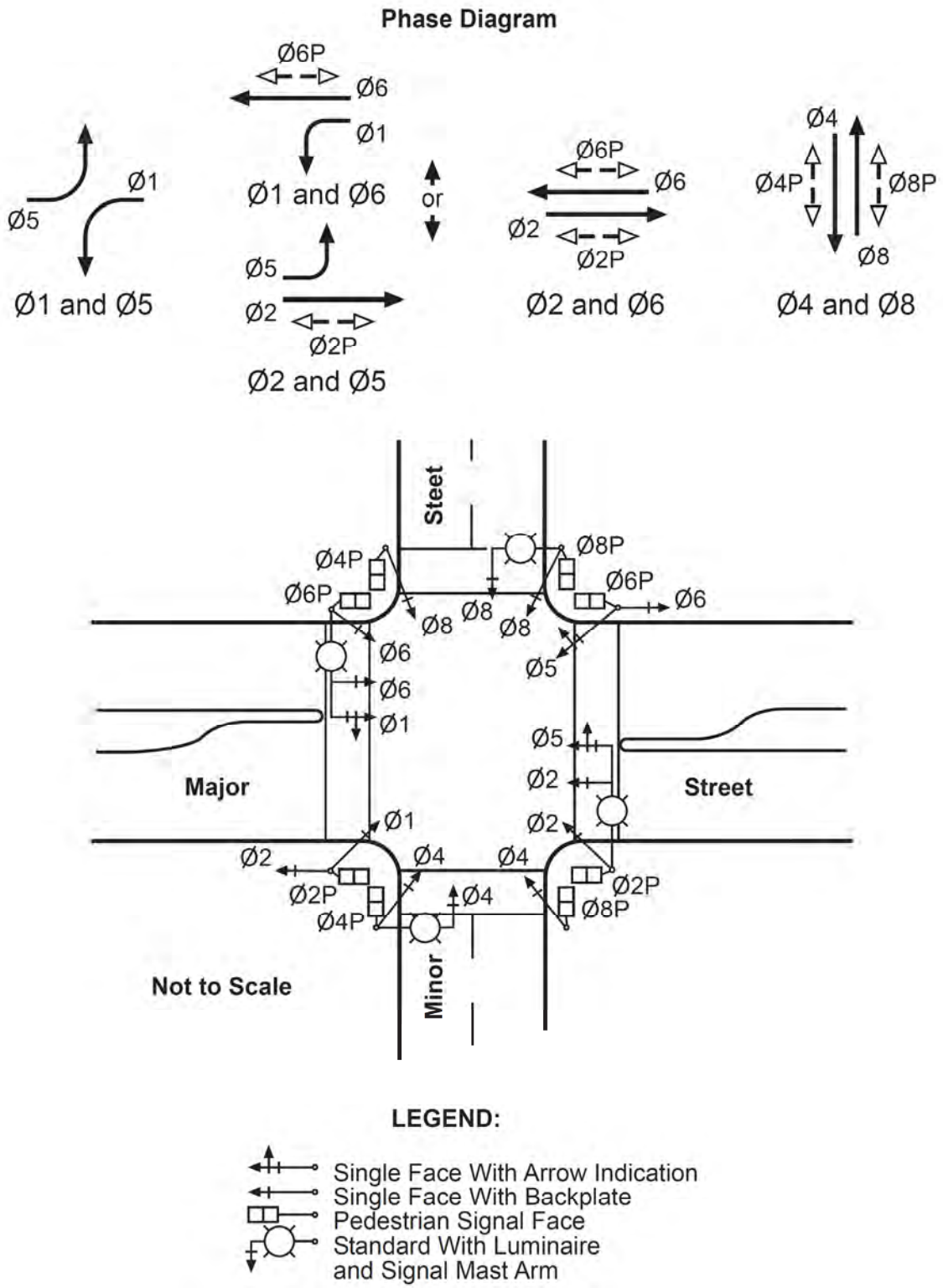


Figure 4D-106 (CA). Typical Signal Layout (Six Phase "Opposing" Operation)

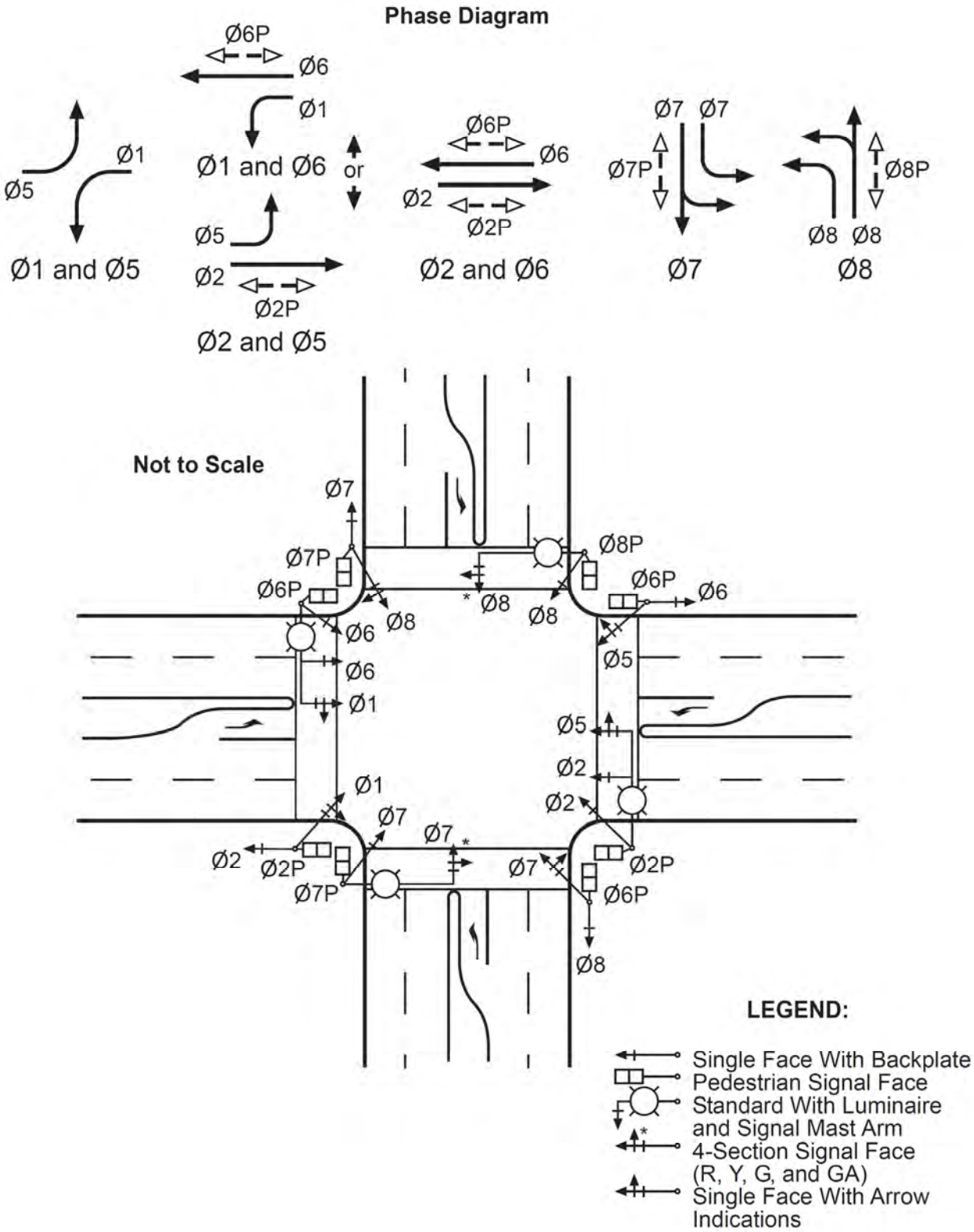


Figure 4D-107 (CA). Typical Signal Layout (Eight Phase "Quad Left" Operation)

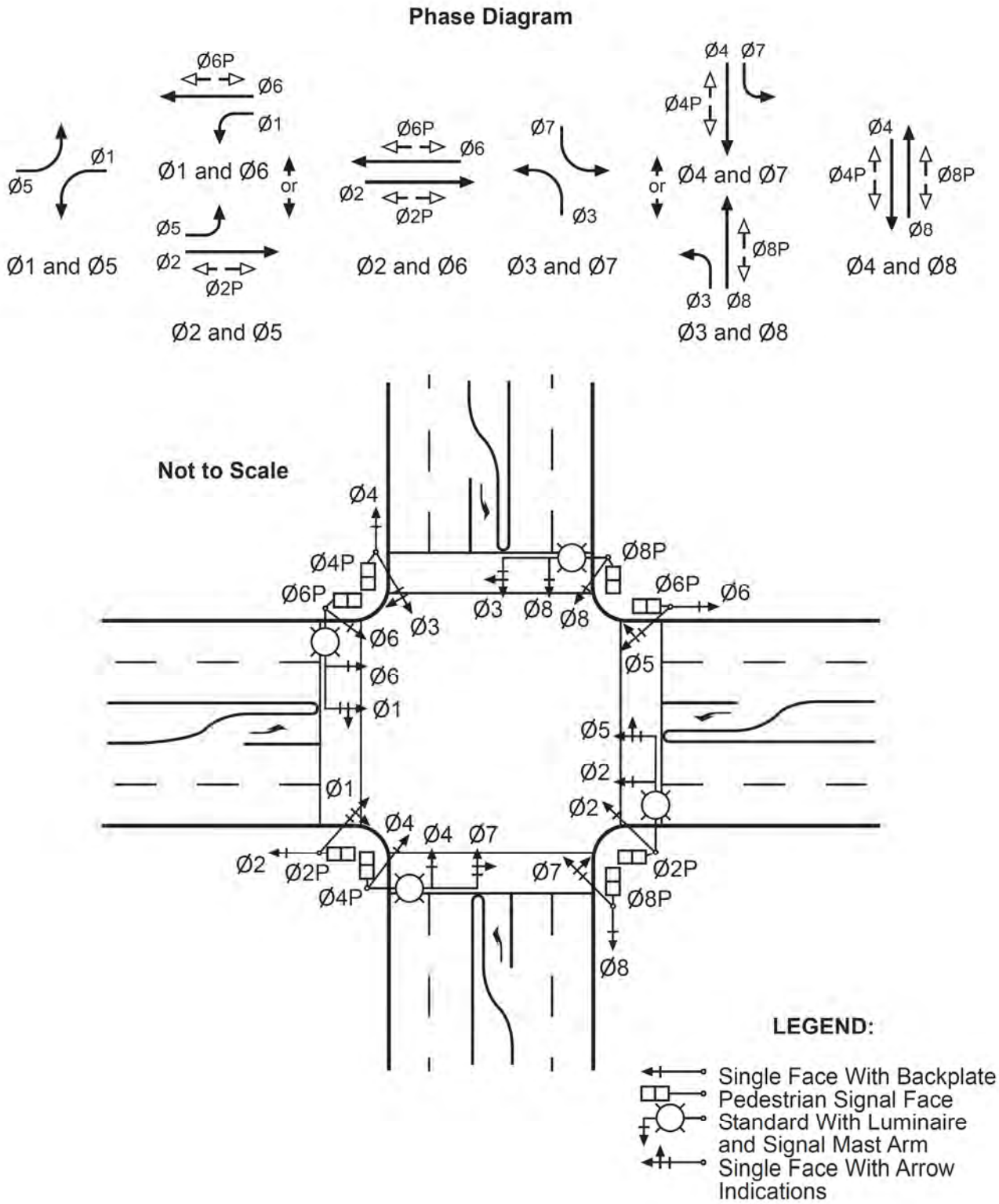


Figure 4D-108 (CA). Typical Traffic Signal Installation

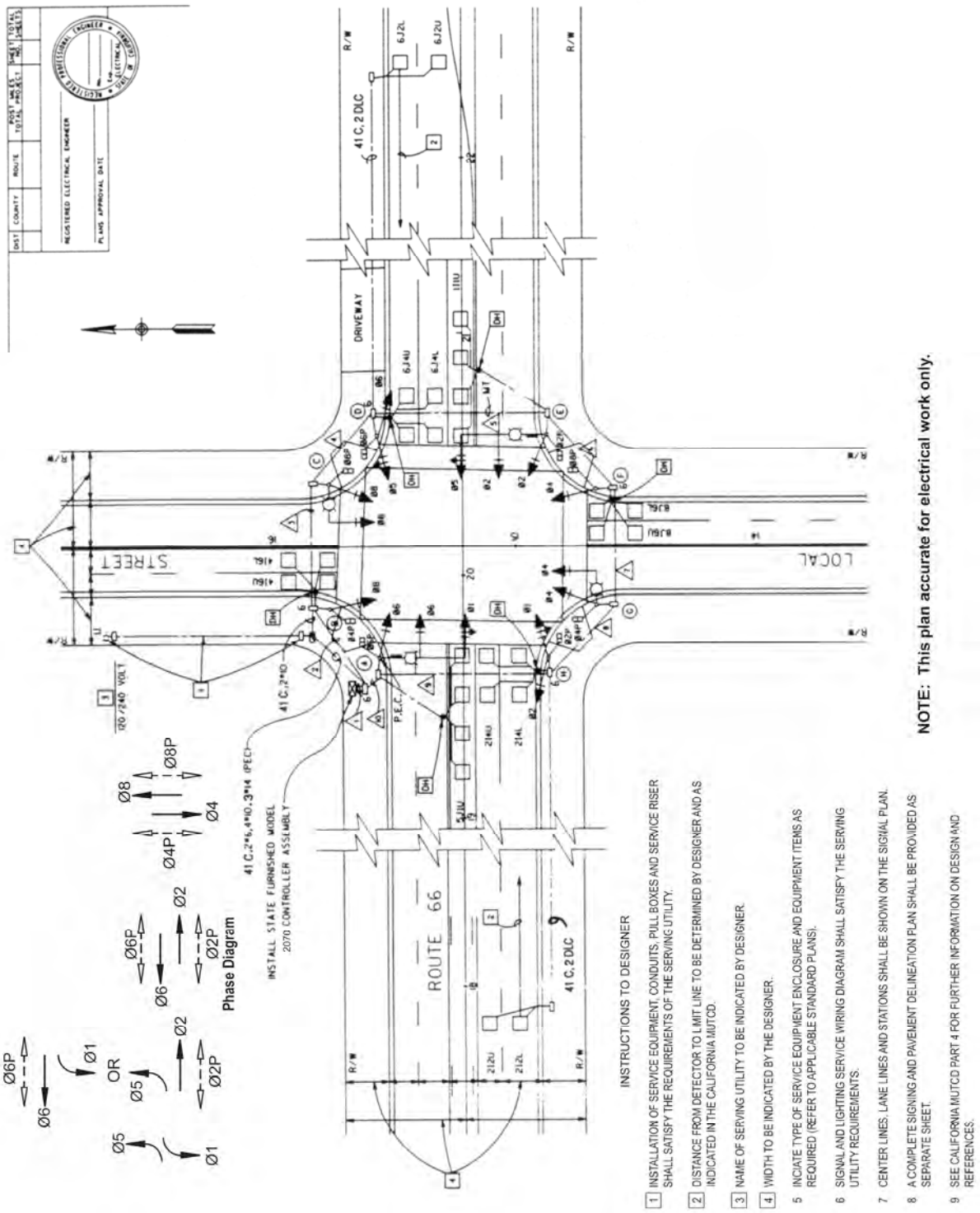
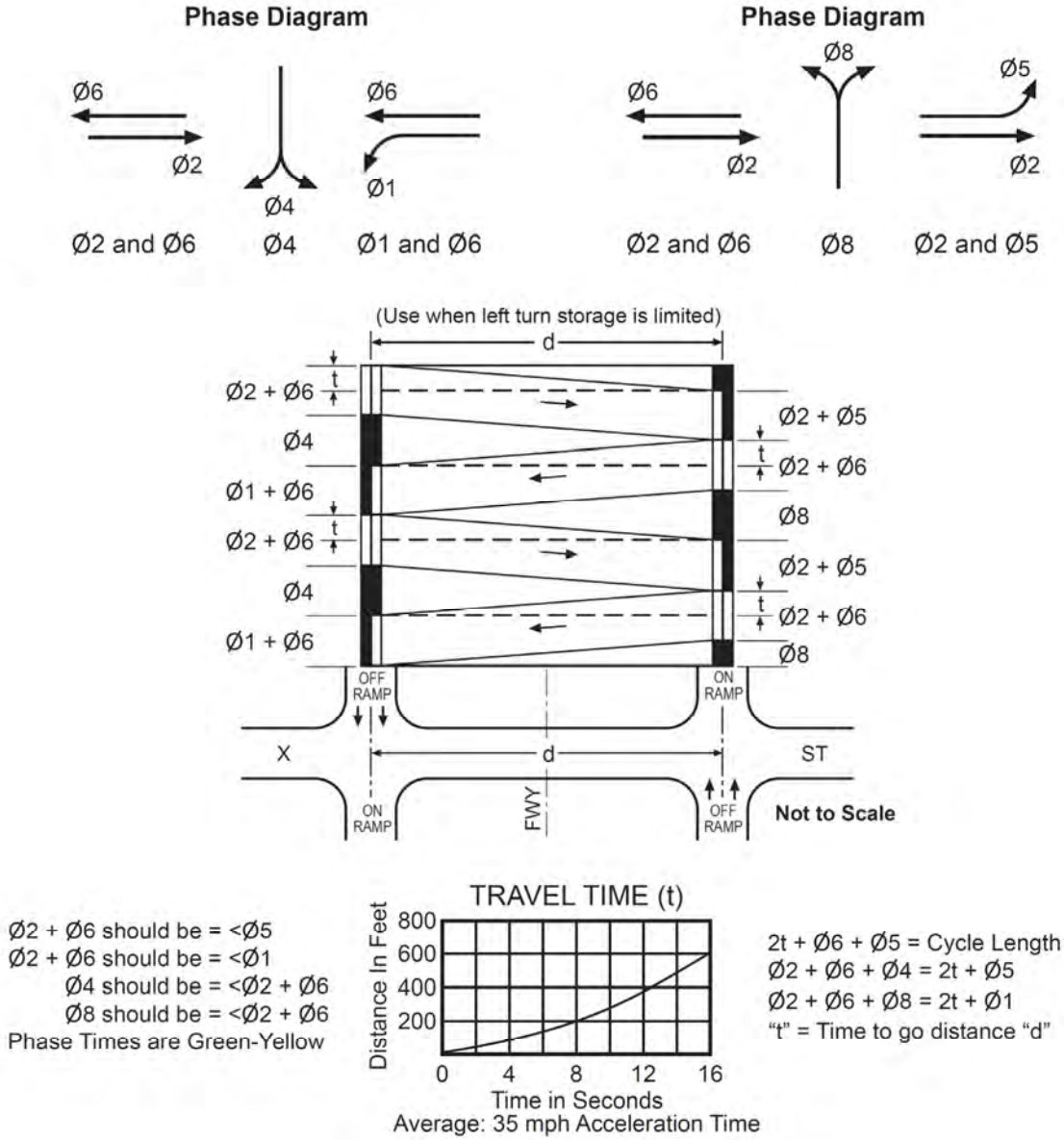
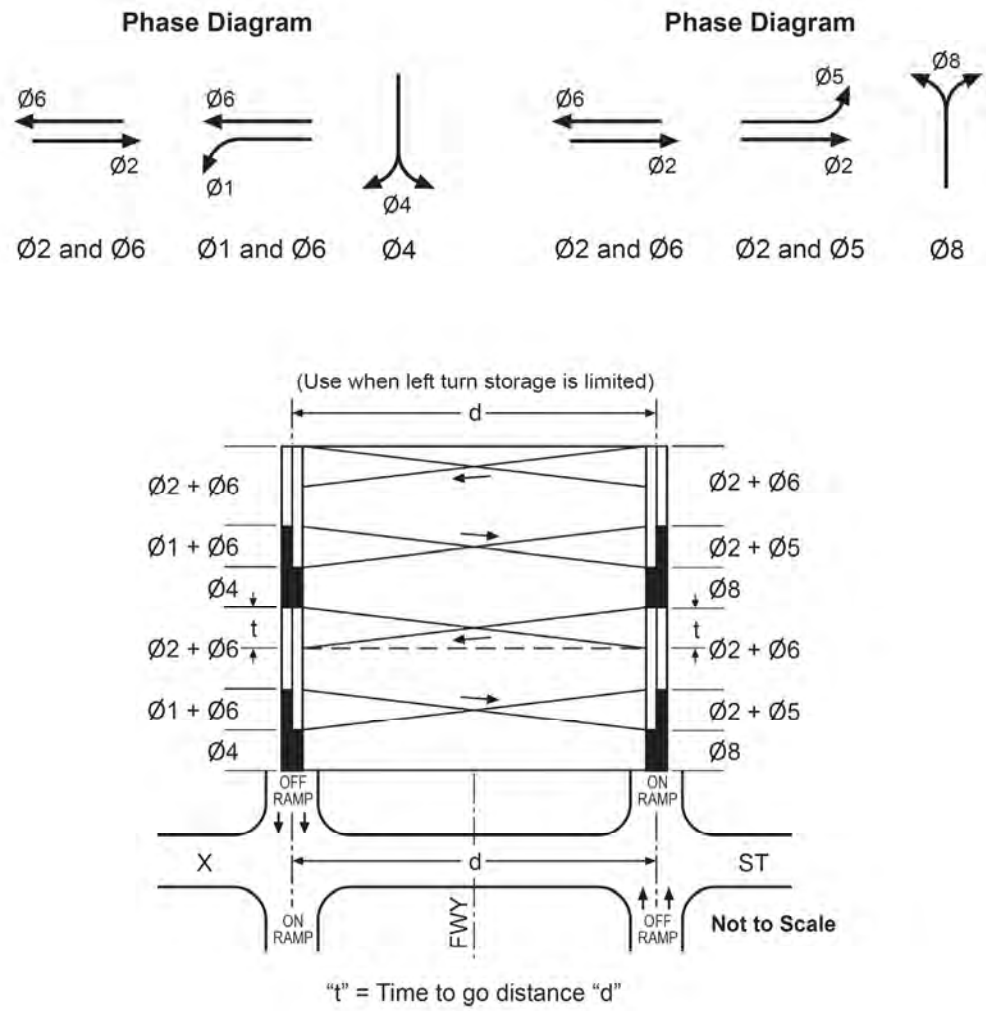


Figure 4D-109 (CA). Diamond Interchange Timing Chart (Heavy Left-Turn - 200 vphpl or More - Using Two Controllers)



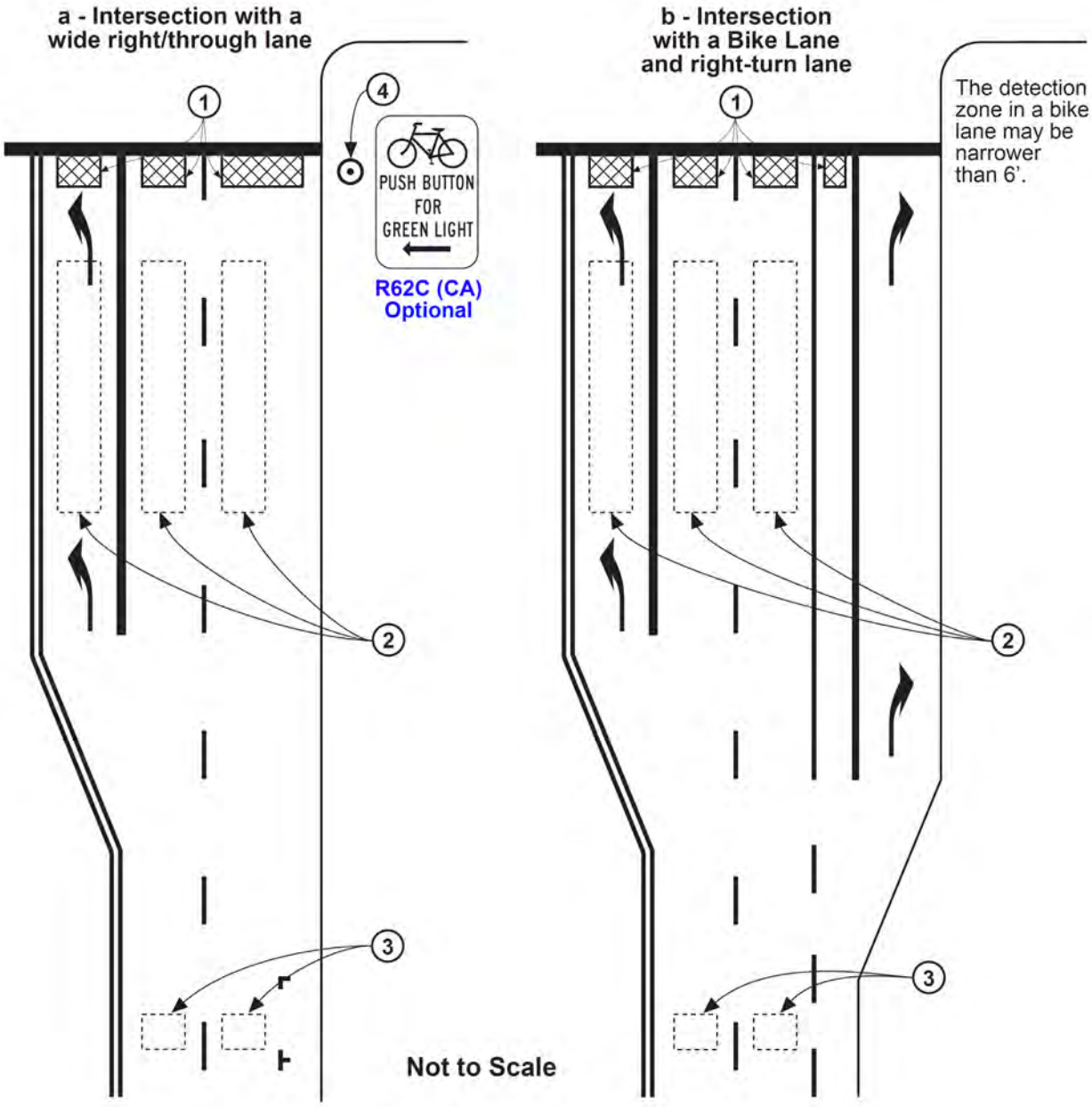
NOTE: These timing guidelines are ideal. Variations in timing may be necessary to provide proper splits to meet volume demands (See Table 4D-103 (CA)).

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



NOTES: 1. These timing guidelines are ideal. Variations in timing may be necessary to provide proper splits to meet volume demands (See Table 4D-103 (CA)).
2. The Green-Yellow interval for phases 1, 4, 5 or 8 should equal time "t".

Figure 4D-111 (CA). Examples of Detection Systems (Sheet 1 of 3)



NOTES:

1. Typical technology-neutral limit line detection locations. See Section 4D.105 (CA).
2. Typical presence detection locations. See Section 4D.103 (CA).
3. Typical advance detection locations.
4. A bicyclist pushbutton may be used to activate a traffic signal to supplement the required limit line detection. A pushbutton should be located so it is convenient to use by bicyclists. See Section 9B.11 for bicycle regulatory signs.

Figure 4D-111 (CA). Examples of Detection Systems (Sheet 2 of 3)

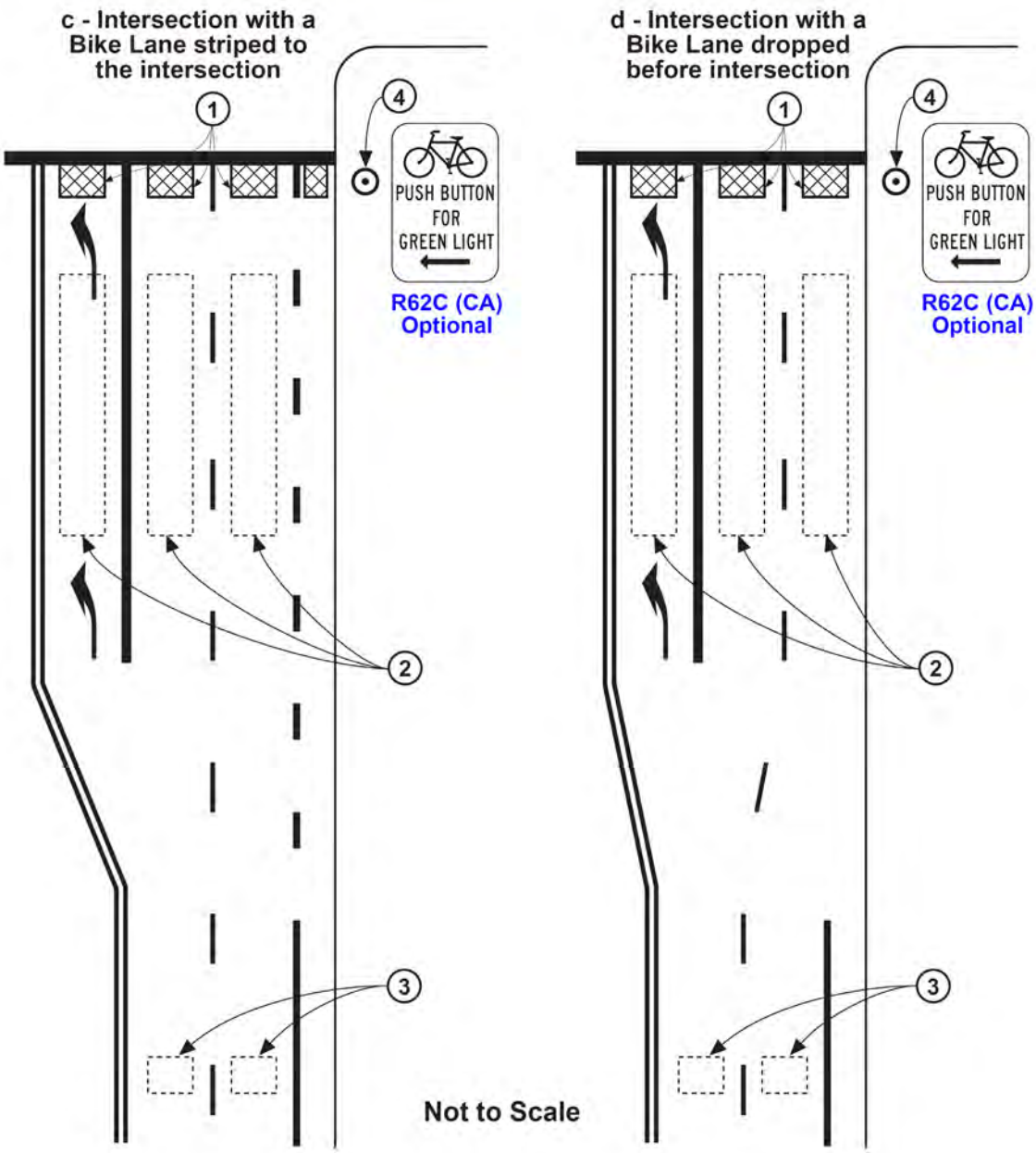


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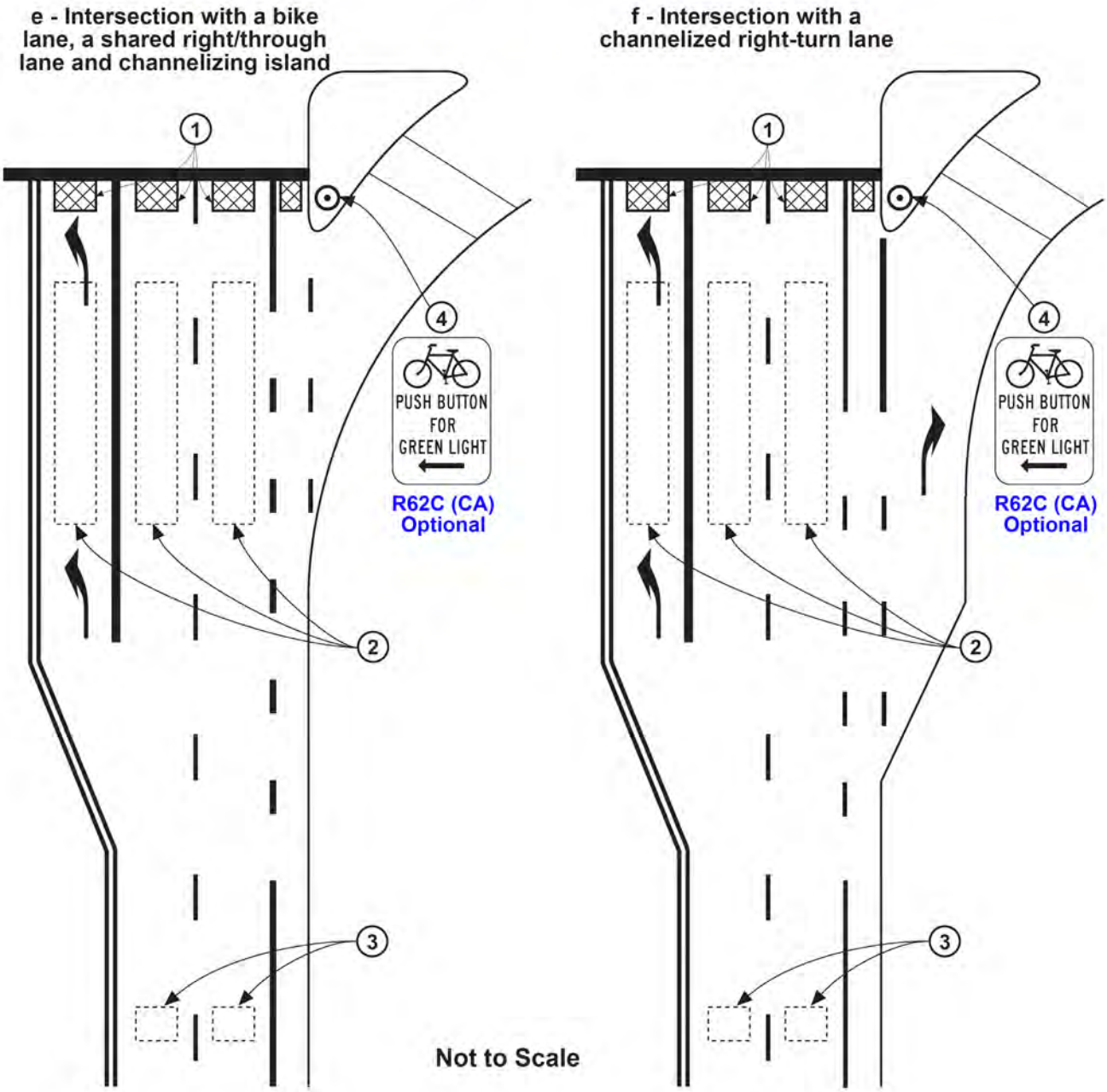
Figure 4D-111 (CA). Examples of Detection Systems (Sheet 3 of 3)



NOTES:

1. Typical technology-neutral limit line detection locations. See Section 4D.105 (CA).
2. Typical presence detection locations. See Section 4D.103 (CA).
3. Typical advance detection locations.
4. A bicyclist pushbutton may be used to activate a traffic signal to supplement the required limit line detection. A pushbutton should be located so it is convenient to use by bicyclists. See Section 9B.11 for bicycle regulatory signs.

Figure 4D-112 (CA). Example of Bicycle Signal Face

Table 4D-1. Recommended Minimum Number of Primary Signal Faces for Through Traffic on Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher

Number of Through Lanes on Approach	Total Number of Primary Through Signal Faces for Approach*	Minimum Number of Overhead-Mounted Primary Through Signal Faces for Approach
1	2	1
2	2	1
3	3	2**
4 or more	4 or more	3**

NOTES: * A minimum of two through signal faces is always required (See Section 4D.11). These recommended numbers of through signal faces may be exceeded. Also, see cone of vision requirements otherwise indicated in Section 4D.13.

** If practical, all of the recommended number of primary through signal faces should be located overhead.

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

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

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

Table 4D-101 (CA). Suggested Detector Setbacks From Limit Line

Deceleration Rate $d = 10\ ft/sec^2$

Reaction Time $t_R = 1.00\ sec$

Reaction Distance $= Vt_R$

Deceleration Distance $= {}^1/_2 dt^2$ or ${}^1/_2 Vt$ or $\frac{V^2}{2d}$

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

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

V = Deceleration Speed (ft/sec)

t_D **= Deceleration Time (sec)**

Note: 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	feet/s	Seconds	Feet	Seconds	Feet	Feet
25	36.68	3.67	66.93	4.67	103.90	105
30	44.00	4.40	96.82	5.40	140.80	140
35	51.35	5.13	131.80	6.13	183.10	185
40	58.69	5.87	172.10	6.87	230.80	230
45	66.04	6.60	217.80	7.60	283.90	285
50	73.36	7.33	268.90	8.33	342.30	345
55	80.71	8.06	325.40	9.06	406.10	405
60	88.00	8.80	387.30	9.80	475.30	475
65	95.37	9.53	454.50	10.53	549.90	550
70	102.7	10.27	526.60	11.27	629.30	630

Table 4D-102 (CA). Minimum Yellow Change Interval Timing

$$\text{Yellow Time} = \frac{\text{Detector Setback Distance}}{\text{Speed}}$$

$T = \frac{D}{V}$ = The minimum yellow change interval (sec)

V = Speed (ft/sec)

d = Deceleration Rate (10 ft/sec^2)

t_R = Reaction Time (1 sec)

Reaction Distance = Vt_R

Deceleration Distance = $^1/_2 dt^2$ or $^1/_2 Vt$ or $\frac{V^2}{2d}$

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

$$T = \frac{\frac{V^2}{2d} + Vt_R}{V}$$

$$\boxed{T = \frac{V}{2d} + t_R}$$

a - For Speed determined by 85th Percentile

SPEED (Determined by 85th Percentile Speed)*	MINIMUM YELLOW INTERVAL
mph	Seconds
25 or less	3.0
30	3.2
35	3.6
40	3.9
45	4.3
50	4.7
55	5.0
60	5.4
65	5.8

*See Section 4D.26 Standard under paragraph 14b

b - For Posted or Prima Facie Speed

POSTED SPEED or UNPOSTED PRIMA FACIE SPEED	MINIMUM YELLOW INTERVAL*	MINIMUM YELLOW INTERVAL*
mph	Seconds	Seconds
15	N/A	3.0
20	N/A	3.2
25	N/A	3.6
30	3.7	N/A
35	4.1	N/A
40	4.4	N/A
45	4.8	N/A
50	5.2	N/A
55	5.5	N/A
60 or higher	5.9	N/A

*Speed values for Table 4D-102b (CA) are inclusive of the 7 MPH added for speeds equal to 30 MPH or higher and 10 MPH for speeds equal to or lower than 25 MPH for determining the minimum values of the yellow intervals.

Table 4D-103 (CA). 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									
		Feet	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	25	0	2	70	60	50	45	40	35	30	25	20	15
2	7	50	88	4	145	120	100	90	80	70	60	50	40	30
3	9	75	176	6	215	180	150	135	120	110	90	70	60	45
4	11	100	264	8	290	240	205	180	160	145	120	95	80	60
5	13	125	352	10	360	360	255	225	200	180	150	120	100	75
6	15	150	440	12	430	420	310	270	240	215	180	145	120	90
7	17	175	528	14	505	480	360	315	280	250	210	170	140	105
8	19	200	616	16	575	540	410	360	320	290	240	190	160	120
9	21	225	704	18	650	600	460	405	360	320	270	215	180	135
10	23	250	792	20	720	660	510	450	400	360	300	240	200	150
11	25	275	880	22	790	720	560	495	440	400	330	265	220	165
12	27	300	968	24	865	780	610	540	480	430	360	290	240	180
13	29	325	1056	26	935	840	665	585	520	470	390	315	260	195
14	31	350	1144	28	1020	900	715	630	560	500	420	340	280	210
15	33	375	1232	30	1080	960	765	675	600	540	450	365	300	225
16	35	400	1320	32	1150	1020	815	720	640	580	480	385	320	240
17	37	425	1408	34	1225	1080	865	765	680	610	510	410	340	255
18	39	450	1496	36	1295	1140	920	810	720	650	540	430	360	270
19	41	475	1584	38		1200	970	855	760	680	570	455	380	285
20	43	500	1672	40		1260	1020	900	800	720	600	480	400	300
21	45	525	1760	42		1320	1070	945	840	760	630	505	420	315
22	47	550	1848	44		1380	1120	990	880	790	660	530	440	330
23	49	575	1936	46		1440	1175	1035	920	830	690	550	460	345
24	51	600	2024	48			1225	1080	960	860	720	575	480	360
25	53	625	2112	50			1275	1125	1000	900	750	600	500	375
26	55	650	2200	52			1325	1170	1040	930	780	625	520	390
27	57	675	2288	54			1375	1215	1080	960	810	650	540	405
28	59	700	2376	56			1430	1260	1120	990	840	670	560	420
29	61	725	2464	58				1305	1160	1020	870	700	580	435

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

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 (CA). 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 mph	Feet	Feet	MAST	POLE		Ø	ARROW		
A	24-4-100	35	12	MAT MAS	SV-1-T	SP-1-T	4	←	200W	Internally Illuminated Street Name Sign "Local Streets"
B	1A				TV-1-T	SP-1-T	6	→		
C	19-1-100	15	12	MAS	SV-1-T	SP-1-T	6	←	200W	
D	1A				TV-2-T	SP-1-T	8	→		
E	24-4-100	35	12	MAT MAS	SV-1-T	SP-1-T	8	←	200W	Internally Illuminated Street Name Sign "Local Streets"
F	1A				TV-1-T	SP-1-T	2	→		
G	19-1-100	15	12	MAS	SV-1-T	SP-1-T	2	←	200W	
H	1A				TV-2-T	SP-1-T	4	→		

Table 4D-106 (CA). 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 (2-3 in)	78C (3 in)	63C (2.5 in)	53C (2 in)	78C (3 in)	53C (2 in)	63C (2.5 in)	63C (2.5 in)	78C (3 in)	78C (3 in)

Table 4D-107 (CA). Available Conduit Area

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. Projects for existing conduit should be designed to the 35% fill limitation.

Table 4D-108 (CA). Conductor Size

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 (DLC)		0.064	
Signal Interconnect Cable (3-Pair)		0.091	
Signal Interconnect Cable (6-Pair)		0.181	

Table 4D-109 (CA). Signal Operations - Minimum Bicycle Timing

$G_{min} + Y + R_{clear} \geq 6$ sec + (w+6 ft)/14.7 ft/sec, where

G_{min} = Length of minimum green interval (sec)

Y = Length of yellow interval (sec)

R_{clear} = Length of red clearance interval (sec)

W = distance from limit line to far side of last conflicting lane (ft)

Distance from limit line to far side of last conflicting lane	Minimum phase length (minimum green plus yellow plus red clearance)
Feet	Seconds
40	9.1
50	9.8
60	10.5
70	11.2
80	11.9
90	12.5
100	13.2
110	13.9
120	14.6
130	15.3
140	15.9
150	16.6
160	17.3
170	18.0
180	18.7

CHAPTER 4E. PEDESTRIAN CONTROL FEATURES

Section 4E.01 Pedestrian Signal Heads

Support:

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

Guidance:

02 *Engineering judgment should determine the need for separate pedestrian signal heads (see Section 4D.03) and accessible pedestrian signals (see Section 4E.09).*

Support:

03 Chapter 4F contains information regarding the use of pedestrian hybrid beacons and Chapter 4N contains information regarding the use of In-Roadway Warning Lights at unsignalized marked crosswalks.

Standard:

04 **Signal design shall provide for or prohibit pedestrian movements.**

Section 4E.02 Meaning of Pedestrian Signal Head Indications

Standard:

01 **Pedestrian signal head indications shall have the following meanings:**

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

B. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed to the far side of the traveled way of the street or highway, unless otherwise directed by a traffic control device to proceed only to the median of a divided highway or only to some other island or pedestrian refuge area.

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

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

Section 4E.03 Application of Pedestrian Signal Heads

Standard:

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

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

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

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

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

Guidance:

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

A. If it is necessary to assist pedestrians in deciding when to begin crossing the roadway in the chosen direction or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;

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

C. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting a crossing provide insufficient guidance for them to decide when to begin crossing the roadway in the chosen direction, such as on one-way streets, at T-intersections, or at multi-phase signal operations.

Option:

03 Pedestrian signal heads may be used under other conditions based on engineering judgment.

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

Standard:

01 **All new pedestrian signal head indications shall be displayed within a rectangular background and shall consist of symbolized messages (see Figure 4E-1), except that existing pedestrian signal head indications with lettered or outline style symbol messages shall be permitted to be retained for the remainder of their useful service life. The symbol designs that are set forth in the "Standard Highway Signs and Markings" book (see Section 1A.11) shall be used. Each pedestrian signal head indication shall be independently displayed and emit a single color.**

02 **If a two-section pedestrian signal head is used, the UPRAISED HAND (symbolizing DONT WALK) signal section shall be mounted directly above the WALKING PERSON (symbolizing WALK) signal section. If a one-section pedestrian signal head is used, the symbols shall be either overlaid upon each other or arranged side-by-side with the UPRAISED HAND symbol to the left of the WALKING PERSON symbol, and a light source that can display each symbol independently shall be used.**

03 **The WALKING PERSON (symbolizing WALK) signal indication shall be white, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.**

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

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

06 **For pedestrian signal head indications, the symbols shall be at least 6 inches high.**

07 **The light source of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be flashed continuously at a rate of not less than 50 or more than 60 times per minute. The displayed period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total flash cycle.**

Guidance:

08 *Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 10 feet from the end of the controlled crosswalk during both day and night.*

09 *For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the pedestrian signal head indications, the symbols should be at least 9 inches high.*

10 *If the pedestrian signal indication is so bright that it causes excessive glare in nighttime conditions, some form of automatic dimming should be used to reduce the brilliance of the signal indication.*

Option:

11 An animated eyes symbol may be added to a pedestrian signal head in order to prompt pedestrians to look for vehicles in the intersection during the time that the WALKING PERSON (symbolizing WALK) signal indication is displayed.

Standard:

12 **If used, the animated eyes symbol shall consist of an outline of a pair of white steadily-illuminated eyes with white eyeballs that scan from side to side at a rate of approximately once per second. The animated eyes symbol shall be at least 12 inches wide with each eye having a width of at least 5 inches and a height of at least 2.5 inches. The animated eyes symbol shall be illuminated at the start of the walk interval and shall terminate at the end of the walk interval.**

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

Standard:

01 **Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 7 feet or more than 10 feet above sidewalk level, and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk.**

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

Section 4E.06 Pedestrian Intervals and Signal Phases

Standard:

01 **At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal indications shall not be displayed.**

02 **When the pedestrian signal heads associated with a crosswalk are displaying either a steady WALKING PERSON (symbolizing WALK) or a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication, a steady or a flashing red signal indication shall be shown to any conflicting vehicular movement that is approaching the intersection or midblock location perpendicular or nearly perpendicular to the crosswalk.**

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

04 **A pedestrian change interval consisting of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication except as provided in Section 4D.27. Following the pedestrian change interval, a buffer interval consisting of a steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed for at least 3 seconds prior to the release of any conflicting vehicular movement. The sum of the time of the pedestrian change interval and the buffer interval shall not be less than the calculated pedestrian clearance time (see Paragraphs 7 through 16). The buffer interval shall not begin later than the beginning of the red clearance interval, if used.**

Option:

05 During the yellow change interval, the UPRAISED HAND (symbolizing DON'T WALK) signal indication may be displayed as either a flashing indication, a steady indication, or a flashing indication for an initial portion of the yellow change interval and a steady indication for the remainder of the interval.

Support:

06 Figure 4E-2 illustrates the pedestrian intervals and their possible relationships with associated vehicular signal phase intervals.

Guidance:

07 *Except as provided in Paragraph 8, the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.*

Option:

08 A walking speed of up to 4 feet per second may be used to evaluate the sufficiency of the pedestrian clearance time at locations where an extended pushbutton press function has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time. Passive pedestrian detection

may also be used to automatically adjust the pedestrian clearance time based on the pedestrian's actual walking speed or actual clearance of the crosswalk.

09 The additional time provided by an extended pushbutton press to satisfy pedestrian clearance time needs may be added to either the walk interval or the pedestrian change interval.

Guidance:

10 *Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time.*

10a *Where older or disabled pedestrians routinely use the crosswalk, a walking speed of 2.8 feet per second should be considered in determining the pedestrian clearance time.*

11 *Except as provided in Paragraph 12, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.*

Option:

12 If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.

Support:

13 The walk interval is intended for pedestrians to start their crossing. The pedestrian clearance time is intended to allow pedestrians who started crossing during the walk interval to complete their crossing. Longer walk intervals are often used when the duration of the vehicular green phase associated with the pedestrian crossing is long enough to allow it.

Guidance:

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

Option:

15 On a street with a median of sufficient width for pedestrians to wait, a pedestrian clearance time that allows the pedestrian to cross only from the curb or shoulder to the median may be provided.

Standard:

16 **Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, median-mounted pedestrian signals (with pedestrian detectors if actuated operation is used) shall be provided (see Sections 4E.08 and 4E.09) and signing such as the R10-3d sign (see Section 2B.52) shall be provided to notify pedestrians to cross only to the median to await the next WALKING PERSON (symbolizing WALK) signal indication.**

Guidance:

17 *Where median-mounted pedestrian signals and detectors are provided, the use of accessible pedestrian signals (see Sections 4E.09 through 4E.13) should be considered.*

Option:

18 During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in Section 4D.27.

19 At intersections with high pedestrian volumes and high conflicting turning vehicle volumes, a brief leading pedestrian interval, during which an advance WALKING PERSON (symbolizing WALK) indication is displayed for the crosswalk while red indications continue to be displayed to parallel through and/or turning traffic, may be used to reduce conflicts between pedestrians and turning vehicles.

Guidance:

20 *If a leading pedestrian interval is used, the use of accessible pedestrian signals (see Sections 4E.09 through 4E.13) should be considered.*

Support:

21 If a leading pedestrian interval is used without accessible features, pedestrians who are visually impaired can be expected to begin crossing at the onset of the vehicular movement when drivers are not expecting them to begin crossing.

Guidance:

22 *If a leading pedestrian interval is used, it should be at least 3 seconds in duration and should be timed to allow pedestrians to cross at least one lane of traffic or, in the case of a large corner radius, to travel far enough for pedestrians to establish their position ahead of the turning traffic before the turning traffic is released.* 23 *If a leading pedestrian interval is used, consideration should be given to prohibiting turns across the crosswalk during the leading pedestrian interval.*

Support:

24 At intersections with pedestrian volumes that are so high that drivers have difficulty finding an opportunity to turn across the crosswalk, the duration of the green interval for a parallel concurrent vehicular movement is sometimes intentionally set to extend beyond the pedestrian clearance time to provide turning drivers additional green time to make their turns while the pedestrian signal head is displaying a steady UPRAISED HAND (symbolizing DONT WALK) signal indication after pedestrians have had time to complete their crossings.

Section 4E.07 Countdown Pedestrian Signals

Standard:

01 **All pedestrian signal heads used at crosswalks where the pedestrian change interval is more than 7 seconds shall include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.**

Option:

02 Pedestrian signal heads used at crosswalks where the pedestrian change interval is 7 seconds or less may include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.

Standard:

03 **Where countdown pedestrian signals are used, the countdown shall always be displayed simultaneously with the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication displayed for that crosswalk.**

04 **Countdown pedestrian signals shall consist of Portland orange numbers that are at least 6 inches in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DONT WALK) pedestrian signal head indication (see Figure 4E-1).**

05 **The display of the number of remaining seconds shall begin only at the beginning of the pedestrian change interval (flashing UPRAISED HAND). After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.**

06 **The countdown pedestrian signal shall display the number of seconds remaining until the termination of the pedestrian change interval (flashing UPRAISED HAND). Countdown displays shall not be used during the walk interval or during the red clearance interval of a concurrent vehicular phase.**

Guidance:

07 *If used with a pedestrian signal head that does not have a concurrent vehicular phase, the pedestrian change interval (flashing UPRAISED HAND) should be set to be approximately 4 seconds less than the required pedestrian clearance time (see Section 4E.06) and an additional clearance interval (during which a steady UPRAISED HAND is displayed) should be provided prior to the start of the conflicting vehicular phase.*

08 *For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the countdown pedestrian signal display, the numbers should be at least 9 inches in height.*

09 *Because some technology includes the countdown pedestrian signal logic in a separate timing device that is independent of the timing in the traffic signal controller, care should be exercised by the engineer when timing changes are made to pedestrian change intervals.*

10 *If the pedestrian change interval is interrupted or shortened as a part of a transition into a preemption sequence (see Section 4E.06), the countdown pedestrian signal display should be discontinued and go dark immediately upon activation of the preemption transition.*

Section 4E.08 Pedestrian Detectors

Option:

01 Pedestrian detectors may be pushbuttons or passive detection devices.

Support:

02 Passive detection devices register the presence of a pedestrian in a position indicative of a desire to cross, without requiring the pedestrian to push a button. Some passive detection devices are capable of tracking the progress of a pedestrian as the pedestrian crosses the roadway for the purpose of extending or shortening the duration of certain pedestrian timing intervals.

03 The provisions in this Section place pedestrian pushbuttons within easy reach of pedestrians who are intending to cross each crosswalk and make it obvious which pushbutton is associated with each crosswalk. These provisions also position pushbutton poles in optimal locations for installation of accessible pedestrian signals (see Sections 4E.09 through 4E.13). Information regarding reach ranges can be found in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).

Guidance:

04 *If pedestrian pushbuttons are used, they should be capable of easy activation and conveniently located near each end of the crosswalks. Except as provided in Paragraphs 5 and 6, pedestrian pushbuttons should be located to meet all of the following criteria (see Figure 4E-3):*

A. Unobstructed and adjacent to a level all-weather surface to provide access from a wheelchair;
B. Where there is an all-weather surface, a wheelchair accessible route from the pushbutton to the ramp;
C. Between the edge of the crosswalk line (extended) farthest from the center of the intersection and the side of a curb ramp (if present), but not greater than 5 feet from said crosswalk line;
D. Between 1.5 and 6 feet from the edge of the curb, shoulder, or pavement;
E. With the face of the pushbutton parallel to the crosswalk to be used; and
F. At a mounting height of approximately 3.5 feet, but no more than 4 feet, above the sidewalk.

05 *Where there are physical constraints that make it impractical to place the pedestrian pushbutton adjacent to a level all-weather surface, the surface should be as level as feasible.*

06 *Where there are physical constraints that make it impractical to place the pedestrian pushbutton between 1.5 and 6 feet from the edge of the curb, shoulder, or pavement, it should not be farther than 10 feet from the edge of curb, shoulder, or pavement.*

07 *Except as provided in Paragraph 8, where two pedestrian pushbuttons are provided on the same corner of a signalized location, the pushbuttons should be separated by a distance of at least 10 feet.*

Option:

08 Where there are physical constraints on a particular corner that make it impractical to provide the 10-foot separation between the two pedestrian pushbuttons, the pushbuttons may be placed closer together or on the same pole.

Support:

09 Figure 4E-4 shows typical pedestrian pushbutton locations for a variety of situations.

Standard:

10 **Signs (see Section 2B.52) shall be mounted adjacent to or integral with pedestrian pushbuttons, explaining their purpose and use.**

Option:

11 At certain locations, a supplemental sign in a more visible location may be used to call attention to the pedestrian pushbutton.

Standard:

12 **The positioning of pedestrian pushbuttons and the legends on the pedestrian pushbutton signs shall clearly indicate which crosswalk signal is actuated by each pedestrian pushbutton.**

13 **If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and the signals are pedestrian actuated, an additional pedestrian detector shall be provided in the median.**

Guidance:

14 *The use of additional pedestrian detectors on islands or medians where a pedestrian might become stranded should be considered.*

15 *If used, special purpose pushbuttons (to be operated only by authorized persons) should include a housing capable of being locked to prevent access by the general public and do not need an instructional sign.*

Standard:

16 **If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, the pilot light shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed.**

17 **If a pilot light is used at an accessible pedestrian signal location (see Sections 4E.09 through 4E.13), each actuation shall be accompanied by the speech message "wait."**

Option:

18 At signalized locations with a demonstrated need and subject to equipment capabilities, pedestrians with special needs may be provided with additional crossing time by means of an extended pushbutton press.

Standard:

19 **If additional crossing time is provided by means of an extended pushbutton press, a PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) plaque (see Figure 2B-26) shall be mounted adjacent to or integral with the pedestrian pushbutton.**

Section 4E.09 Accessible Pedestrian Signals and Detectors – General

Support:

01 Accessible pedestrian signals and detectors provide information in non-visual formats (such as audible tones, speech messages, and/or vibrating surfaces).

02 The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move, which often corresponds to the onset of the green interval. The existing environment is often not sufficient to provide the information that pedestrians who have visual disabilities need to cross a roadway at a signalized location.

Guidance:

03 *If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross the roadway, an engineering study should be conducted that considers the needs of pedestrians in general, as well as the information needs of pedestrians with visual disabilities. The engineering study should consider the following factors:*

A. Potential demand for accessible pedestrian signals;
B. A request for accessible pedestrian signals;
C. Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;
D. The complexity of traffic signal phasing (such as split phases, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases); and
E. The complexity of intersection geometry.

Support:

04 The factors that make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red (which masks the beginning of the through phase), continuous right-turn movements, complex signal operations, traffic circles, and wide streets. Furthermore, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.

05 Local organizations, providing support services to pedestrians who have visual and/or hearing disabilities, can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board (www.access-board.gov) provides technical

assistance for making pedestrian signal information available to persons with visual disabilities (see Page i for the address for the U.S. Access Board).

Standard:

06 **When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.**

07 **Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.**

Option:

08 Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.

09 At locations with pretimed traffic control signals or non-actuated approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

Support:

10 Accessible pedestrian signals are typically integrated into the pedestrian detector (pushbutton), so the audible tones and/or messages come from the pushbutton housing. They have a pushbutton locator tone and tactile arrow, and can include audible beaconing and other special features.

Option:

11 The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print. Tactile maps of crosswalks may also be provided.

Support:

12 Specifications regarding the use of Braille or raised print for traffic control devices can be found in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).

Standard:

13 **At accessible pedestrian signal locations where pedestrian pushbuttons are used, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.**

Standard:

14 **The tone of the walk signal shall not be similar to the push button locator tones.**

15 **The cost of installing and maintaining Accessible Pedestrian Signals shall be shared with the local agency in the same manner as a traffic signal. See Section 4B.104(CA).**

Option:

16 New signalized intersections and planned upgrades to signalized intersections that are equipped with pedestrian crosswalks as well as the following characteristics may be considered for accessible pedestrian signals when the need and viability are confirmed by an engineering study:

A. Intersections near blind centers and senior centers
B. Transit terminals
C. T-type intersections
D. Wide intersections
E. Intersections with unusual geometry
F. Skewed intersections
G. Mid-block crosswalks
H. Intersections with exclusive phasing
I. Intersections with leading pedestrian intervals
J. Intersections with frequent side street calls, and;
K. Intersections with high turning volumes

Option:

17 The installation of Accessible Pedestrian Signals may be considered when an engineering study and evaluation have been conducted and the following minimum conditions have been met:

A. The proposed intersection crosswalk must be signalized.
B. The audible devices should be retrofittable to the existing traffic signal hardware.
C. The signalized intersection should be equipped with pedestrian push buttons.
D. The selected crosswalk must be suitable for the installation of audible signals, in terms of surrounding land use and traffic patterns.

E. There must be a demonstrated need for the audible signals in the form of a request from an individual or group that would use the audible signal.
F. The individual or group requesting the device should agree to train the visually impaired users of the audible signals.

Section 4E.10 Accessible Pedestrian Signals and Detectors – Location

Support:

01 Accessible pedestrian signals that are located as close as possible to pedestrians waiting to cross the street provide the clearest and least ambiguous indication of which pedestrian crossing is served by a device.

Guidance:

02 *Pushbuttons for accessible pedestrian signals should be located in accordance with the provisions of Section 4E.08 and should be located as close as possible to the crosswalk line furthest from the center of the intersection and as close as possible to the curb ramp.*

Standard:

03 **If two accessible pedestrian pushbuttons are placed less than 10 feet apart or on the same pole, each accessible pedestrian pushbutton shall be provided with the following features (see Sections 4E.11 through 4E.13):**

A. A pushbutton locator tone,
B. A tactile arrow,
C. A speech walk message for the WALKING PERSON (symbolizing WALK) indication, and
D. A speech pushbutton information message.

04 **If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector shall be provided in the median.**

Section 4E.11 Accessible Pedestrian Signals and Detectors – Walk Indications

Support:

01 Technology that provides different sounds for each non-concurrent signal phase has frequently been found to provide ambiguous information. Research indicates that a rapid tick tone for each crossing coming from accessible pedestrian signal devices on separated poles located close to each crosswalk provides unambiguous information to pedestrians who are blind or visually impaired. Vibrotactile indications provide information to pedestrians who are blind and deaf and are also used by pedestrians who are blind or who have low vision to confirm the walk signal in noisy situations.

Standard:

02 **Accessible pedestrian signals shall have both audible and vibrotactile walk indications.**

03 **Vibrotactile walk indications shall be provided by a tactile arrow on the pushbutton (see Section 4E.12) that vibrates during the walk interval.**

04 **Accessible pedestrian signals shall have an audible walk indication during the walk interval only. The audible walk indication shall be audible from the beginning of the associated crosswalk.**

05 **The accessible walk indication shall have the same duration as the pedestrian walk signal except when the pedestrian signal rests in walk.**

Guidance:

06 *If the pedestrian signal rests in walk, the accessible walk indication should be limited to the first 7 seconds of the walk interval. The accessible walk indication should be recalled by a button press during the walk interval provided that the crossing time remaining is greater than the pedestrian change interval.*

Standard:

07 **Where two accessible pedestrian signals are separated by a distance of at least 10 feet, the audible walk indication shall be a percussive tone. Where two accessible pedestrian signals on one corner are not separated by a distance of at least 10 feet, the audible walk indication shall be a speech walk message.**

08 **Audible tone walk indications shall repeat at eight to ten ticks per second. Audible tones used as walk indications shall consist of multiple frequencies with a dominant component at 880 Hz.**

Guidance:

09 *The volume of audible walk indications and pushbutton locator tones (see Section 4E.12) should be set to be a maximum of 5 dBA louder than ambient sound, except when audible beaconing is provided in response to an extended pushbutton press.*

Standard:

10 **Automatic volume adjustment in response to ambient traffic sound level shall be provided up to a maximum volume of 100 dBA.**

Guidance:

11 *The sound level of audible walk indications and pushbutton locator tones should be adjusted to be low enough to avoid misleading pedestrians who have visual disabilities when the following conditions exist:*

A. *Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.*
B. *Where multi-leg approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone.*
C. *At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street.*

Option:

12 An alert tone, which is a very brief burst of high-frequency sound at the beginning of the audible walk indication that rapidly decays to the frequency of the walk tone, may be used to alert pedestrians to the beginning of the walk interval.

Support:

13 An alert tone can be particularly useful if the walk tone is not easily audible in some traffic conditions.

14 Speech walk messages communicate to pedestrians which street has the walk interval. Speech messages might be either directly audible or transmitted, requiring a personal receiver to hear the message. To be a useful system, the words and their meaning need to be correctly understood by all users in the context of the street environment where they are used. Because of this, tones are the preferred means of providing audible walk indications except where two accessible pedestrian signals on one corner are not separated by a distance of at least 10 feet.

15 If speech walk messages are used, pedestrians have to know the names of the streets that they are crossing in order for the speech walk messages to be unambiguous. In getting directions to travel to a new location, pedestrians with visual disabilities do not always get the name of each street to be crossed. Therefore, it is desirable to give users of accessible pedestrian signals the name of the street controlled by the pushbutton. This can be done by means of a speech pushbutton information message (see Section ~~4D.13~~ 4E.13) during the flashing or steady UPRAISED HAND intervals, or by raised print and Braille labels on the pushbutton housing.

16 By combining the information from the pushbutton message or Braille label, the tactile arrow aligned in the direction of travel on the relevant crosswalk, and the speech walk message, pedestrians with visual disabilities are able to correctly respond to speech walk messages even if there are two pushbuttons on the same pole.

Standard:

17 **If speech walk messages are used to communicate the walk interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies. Speech walk messages shall be used only at intersections where it is technically infeasible to install two accessible pedestrian signals at one corner separated by a distance of at least 10 feet.**

18 **Speech walk messages that are used at intersections having pedestrian phasing that is concurrent with vehicular phasing shall be patterned after the model: "Broadway. Walk sign is on to cross Broadway."**

19 **Speech walk messages that are used at intersections having exclusive pedestrian phasing shall be patterned after the model: "Walk sign is on for all crossings."**

20 **Speech walk messages shall not contain any additional information, except they shall include designations such as "Street" or "Avenue" where this information is necessary to avoid ambiguity at a particular location.**

Guidance:

21 *Speech walk messages should not state or imply a command to the pedestrian, such as "Cross Broadway now." Speech walk messages should not tell pedestrians that it is "safe to cross," because it is always the pedestrian's responsibility to check actual traffic conditions.*

Standard:

22 **A speech walk message is not required at times when the walk interval is not timing, but, if provided:**

A. It shall begin with the term "wait."

B. It need not be repeated for the entire time that the walk interval is not timing.

23 **If a pilot light (see Section 4E.08) is used at an accessible pedestrian signal location, each actuation shall be accompanied by the speech message "wait."**

Option:

24 Accessible pedestrian signals that provide speech walk messages may provide similar messages in languages other than English, if needed, except for the terms "walk sign" and "wait."

Standard:

25 **Following the audible walk indication, accessible pedestrian signals shall revert to the pushbutton locator tone (see Section 4E.12) during the pedestrian change interval.**

Section 4E.12 Accessible Pedestrian Signals and Detectors – Tactile Arrows and Locator Tones

Standard:

01 **To enable pedestrians who have visual disabilities to distinguish and locate the appropriate pushbutton at an accessible pedestrian signal location, pushbuttons shall clearly indicate by means of tactile arrows which crosswalk signal is actuated by each pushbutton. Tactile arrows shall be located on the pushbutton, have high visual contrast (light on dark or dark on light), and shall be aligned parallel to the direction of travel on the associated crosswalk.**

02 **An accessible pedestrian pushbutton shall incorporate a locator tone.**

Support:

03 A pushbutton locator tone is a repeating sound that informs approaching pedestrians that a pushbutton to actuate pedestrian timing or receive additional information exists, and that enables pedestrians with visual disabilities to locate the pushbutton.

Standard:

04 **Pushbutton locator tones shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.**

05 **Pushbutton locator tones shall be deactivated when the traffic control signal is operating in a flashing mode. This requirement shall not apply to traffic control signals or pedestrian hybrid beacons that are activated from a flashing or dark mode to a stop-and-go mode by pedestrian actuations.**

06 **Pushbutton locator tones shall be intensity responsive to ambient sound, and be audible 6 to 12 feet from the pushbutton, or to the building line, whichever is less.**

Support:

07 Section 4E.11 contains additional provisions regarding the volume and sound level of pushbutton locator tones.

Section 4E.13 Accessible Pedestrian Signals and Detectors – Extended Pushbutton Press Features

Option:

01 Pedestrians may be provided with additional features such as increased crossing time, audible beaconing, or a speech pushbutton information message as a result of an extended pushbutton press.

Standard:

02 **If an extended pushbutton press is used to provide any additional feature(s), a pushbutton press of less than one second shall actuate only the pedestrian timing and any associated accessible walk indication, and a pushbutton press of one second or more shall actuate the pedestrian timing, any associated accessible walk indication, and any additional feature(s).**

03 **If additional crossing time is provided by means of an extended pushbutton press, a PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) plaque (see Figure 2B-26) shall be mounted adjacent to or integral with the pedestrian pushbutton.**

Support:

04 Audible beaconing is the use of an audible signal in such a way that pedestrians with visual disabilities can home in on the signal that is located on the far end of the crosswalk as they cross the street.

05 Not all crosswalks at an intersection need audible beaconing; audible beaconing can actually cause confusion if used at all crosswalks at some intersections. Audible beaconing is not appropriate at locations with channelized turns or split phasing, because of the possibility of confusion.

Guidance:

06 *Audible beaconing should only be considered following an engineering study at:*

A. Crosswalks longer than 70 feet, unless they are divided by a median that has another accessible pedestrian signal with a locator tone;

B. Crosswalks that are skewed;

C. Intersections with irregular geometry, such as more than four legs;

D. Crosswalks where audible beaconing is requested by an individual with visual disabilities; or

E. Other locations where a study indicates audible beaconing would be beneficial.

Option:

07 Audible beaconing may be provided in several ways, any of which are initiated by an extended pushbutton press.

Standard:

08 **If audible beaconing is used, the volume of the pushbutton locator tone during the pedestrian change interval of the called pedestrian phase shall be increased and operated in one of the following ways:**

A. The louder audible walk indication and louder locator tone comes from the far end of the crosswalk, as pedestrians cross the street,

B. The louder locator tone comes from both ends of the crosswalk, or

C. The louder locator tone comes from an additional speaker that is aimed at the center of the crosswalk and that is mounted on a pedestrian signal head.

Option:

09 Speech pushbutton information messages may provide intersection identification, as well as information about unusual intersection signalization and geometry, such as notification regarding exclusive pedestrian phasing, leading pedestrian intervals, split phasing, diagonal crosswalks, and medians or islands.

Standard:

10 **If speech pushbutton information messages are made available by actuating the accessible pedestrian signal detector, they shall only be actuated when the walk interval is not timing. They shall begin with the term "Wait," followed by intersection identification information modeled after: "Wait to cross Broadway at Grand." If information on intersection signalization or geometry is also given, it shall follow the intersection identification information.**

Guidance:

11 *Speech pushbutton information messages should not be used to provide landmark information or to inform pedestrians with visual disabilities about detours or temporary traffic control situations.*

Support:

12 Additional information on the structure and wording of speech pushbutton information messages is included in ITE's "Electronic Toolbox for Making Intersections More Accessible for Pedestrians Who Are Blind or Visually Impaired," which is available at ITE's website (see Page i).

Figure 4E-1. Typical Pedestrian Signal Indications

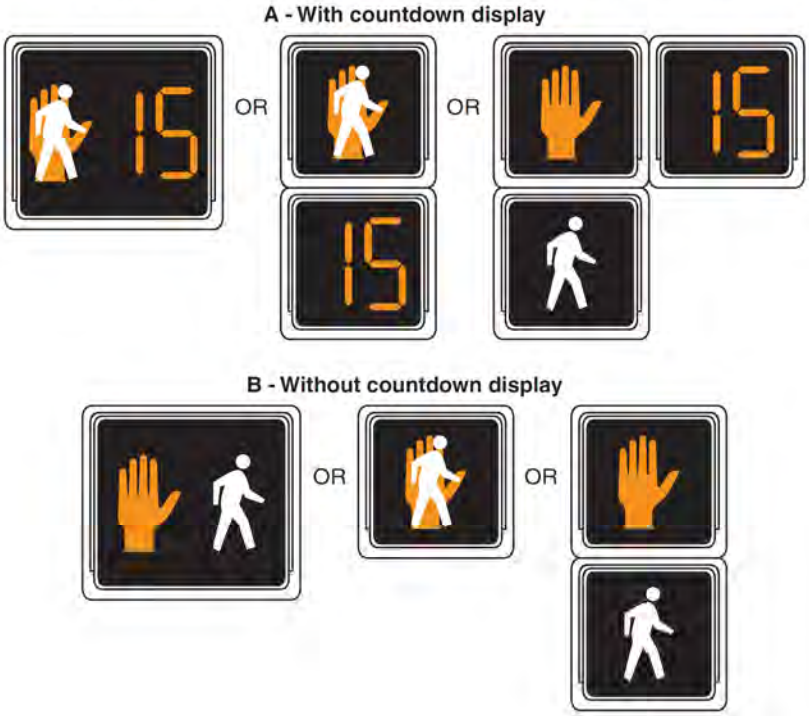
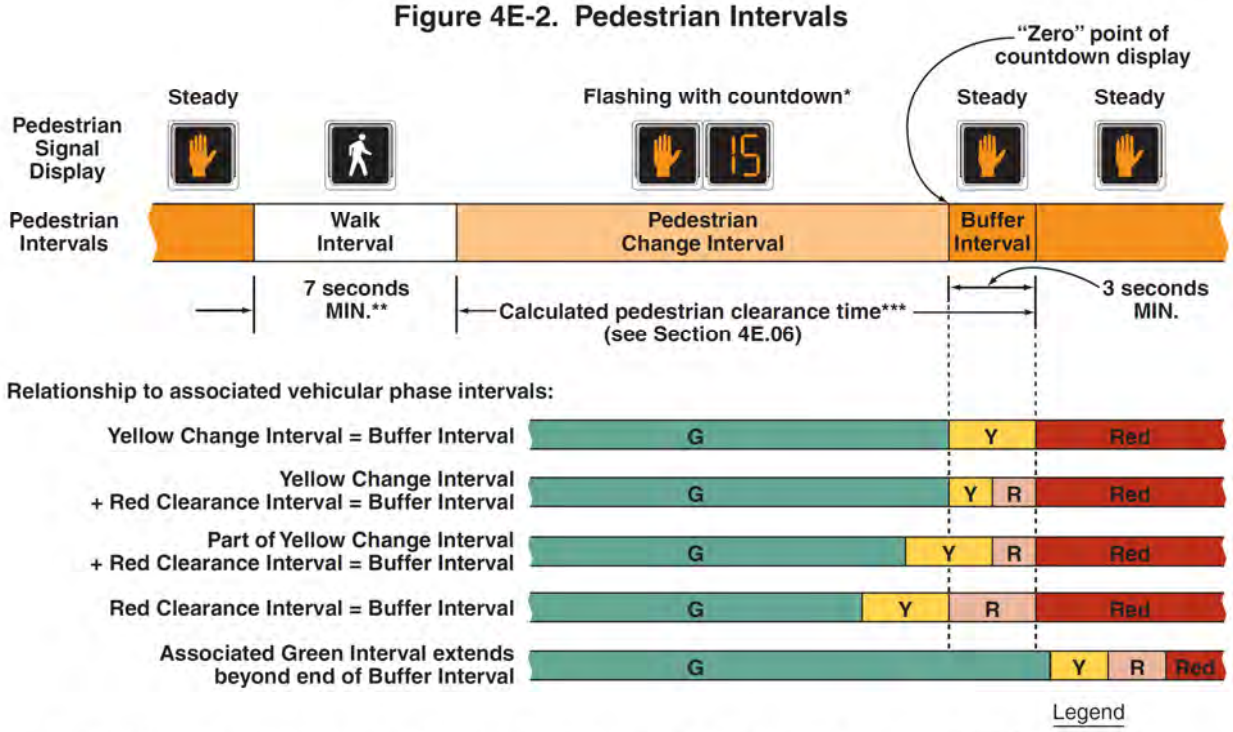


Figure 4E-2. Pedestrian Intervals



* The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.

** The Walk Interval may be reduced under some conditions (see Section 4E.06).

*** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.

Legend

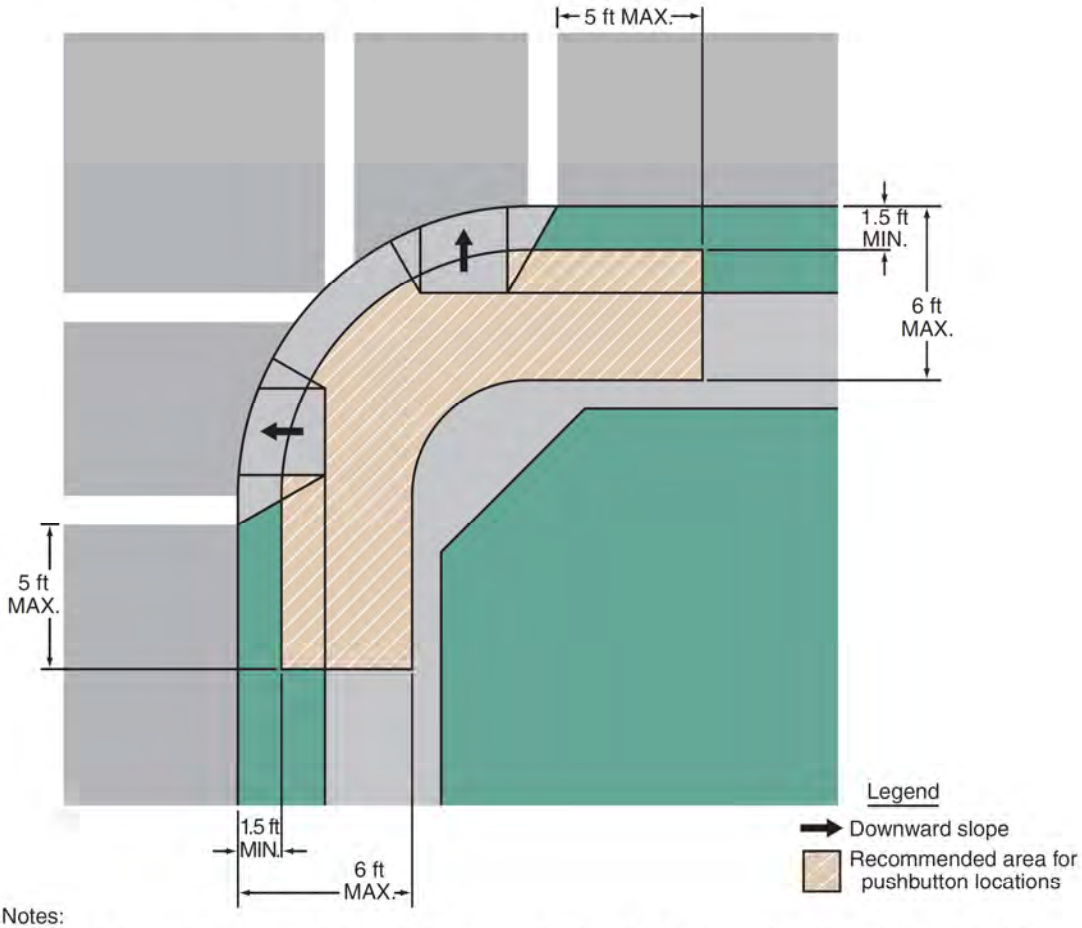
G = Green Interval

Y = Yellow Change Interval (of at least 3 seconds)

R = Red Clearance Interval

Red = Red because conflicting traffic has been released

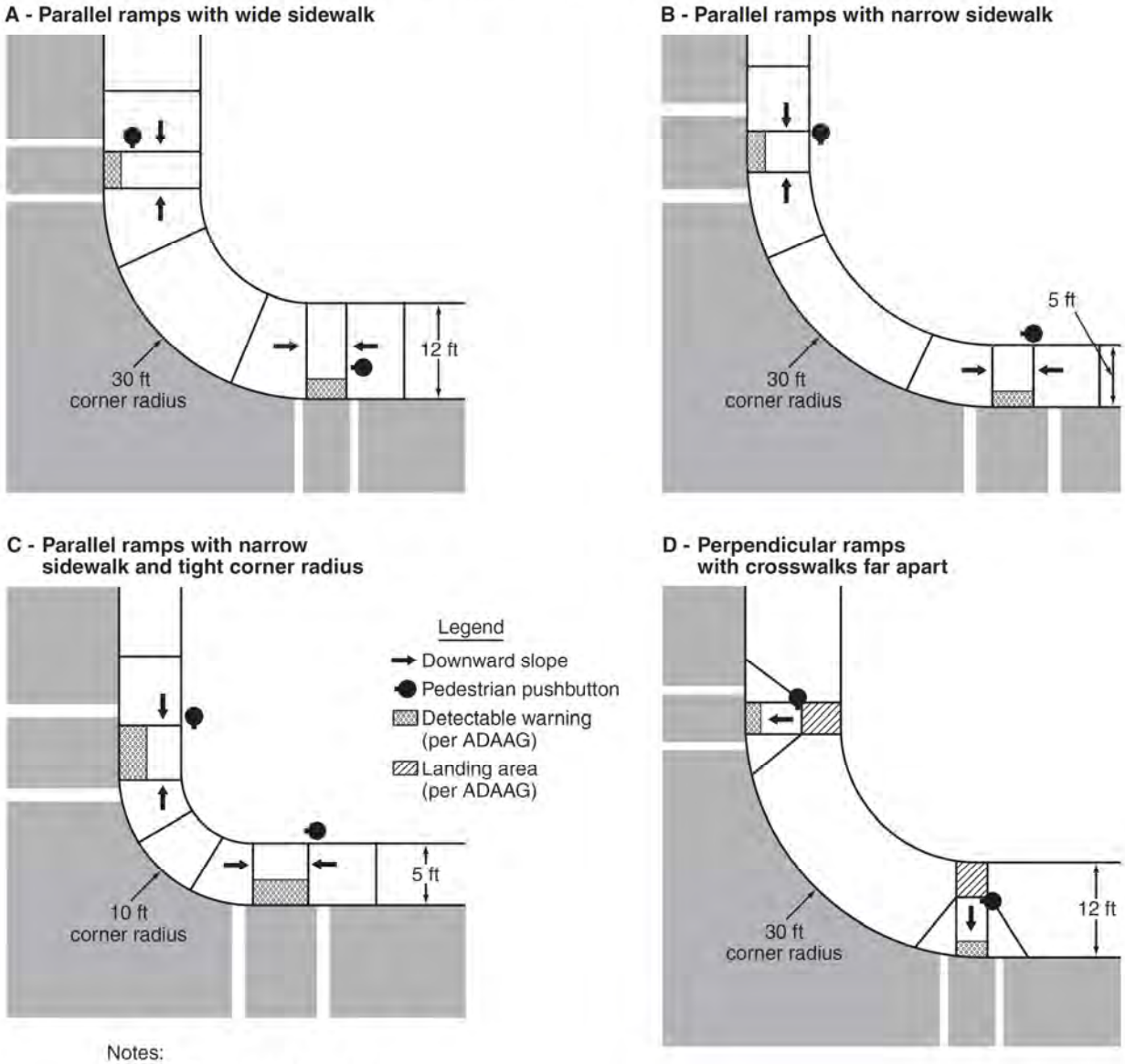
Figure 4E-3. Pushbutton Location Area



Notes:

1. Where there are constraints that make it impractical to place the pedestrian pushbutton between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement, it should not be further than 10 feet from the edge of curb, shoulder, or pavement.
2. Two pedestrian pushbuttons on a corner should be separated by 10 feet.
3. This figure is not drawn to scale.
4. Figure 4E-4 shows typical pushbutton locations.

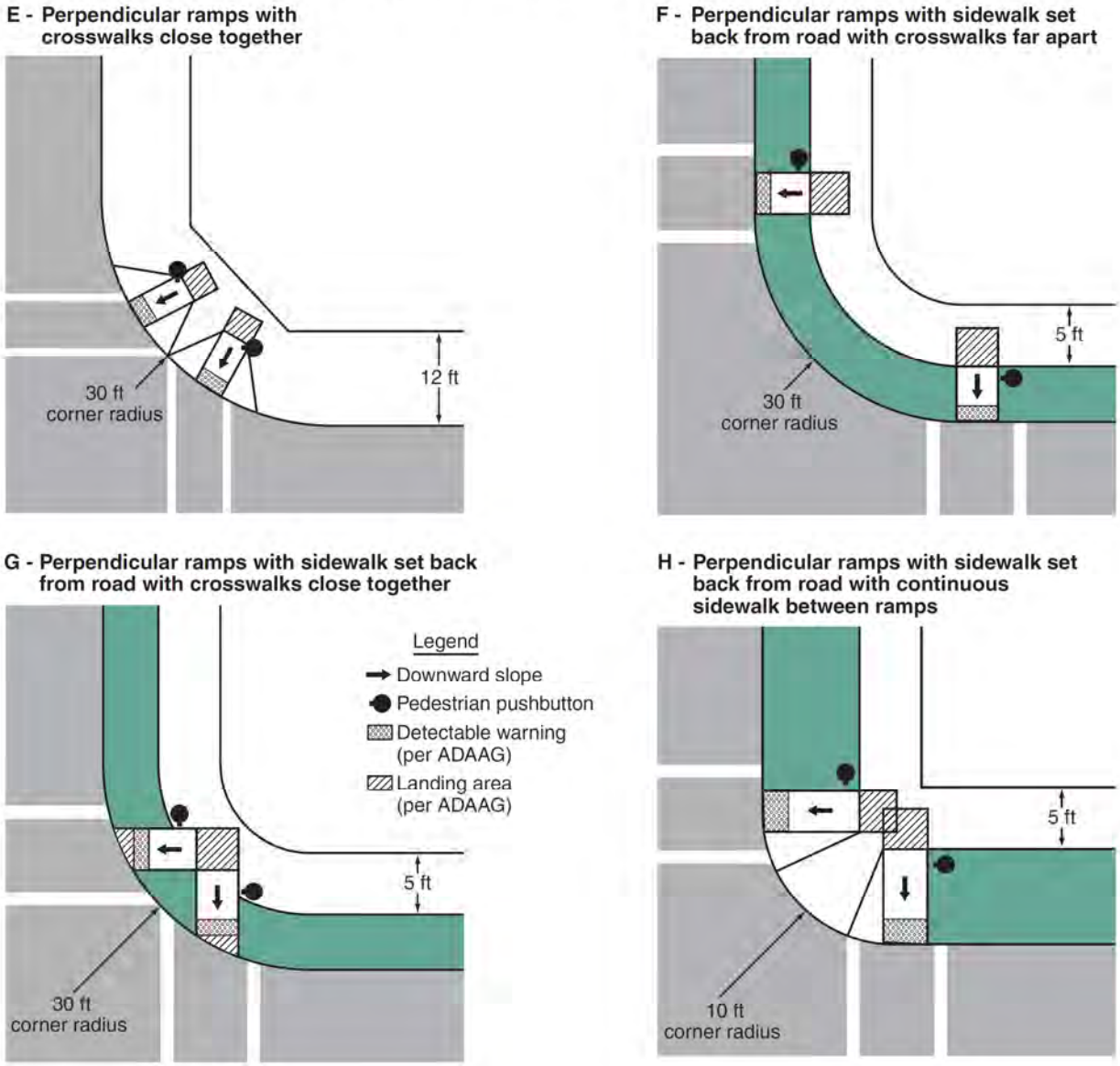
Figure 4E-4. Typical Pushbutton Locations (Sheet 1 of 2)



Notes:

1. This figure is not drawn to scale.
2. These drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

Figure 4E-4. Typical Pushbutton Locations (Sheet 2 of 2)



Notes:

1. This figure is not drawn to scale.
2. Tese drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

CHAPTER 4F. PEDESTRIAN HYBRID BEACONS

Section 4F.01 Application of Pedestrian Hybrid Beacons

Support:

01 A pedestrian hybrid beacon is a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk.

01a A conventional traffic control signal operation with a standard signal face displaying green, yellow and red (steady and/or flashing red) indications, at a mid-block crosswalk is an alternative to the pedestrian hybrid beacon.

Option:

02 A pedestrian hybrid beacon may be considered for installation to facilitate pedestrian crossings at a location that does not meet traffic signal warrants (see Chapter 4C), or at a location that meets traffic signal warrants under Sections 4C.05 and/or 4C.06 but a decision is made to not install a traffic control signal.

Standard:

03 **If used, pedestrian hybrid beacons shall be used in conjunction with signs and pavement markings to warn and control traffic at locations where pedestrians enter or cross a street or highway. A pedestrian hybrid beacon shall only be installed at a marked crosswalk.**

Guidance:

04 *If one of the signal warrants of Chapter 4C is met and a traffic control signal is justified by an engineering study, and if a decision is made to install a traffic control signal, it should be installed based upon the provisions of Chapters 4D and 4E.*

05 *If a traffic control signal is not justified under the signal warrants of Chapter 4C and if gaps in traffic are not adequate to permit pedestrians to cross, or if the speed for vehicles approaching on the major street is too high to permit pedestrians to cross, or if pedestrian delay is excessive, the need for a pedestrian hybrid beacon should be considered on the basis of an engineering study that considers major-street volumes, speeds, widths, and gaps in conjunction with pedestrian volumes, walking speeds, and delay.*

06 *For a major street where the posted or statutory speed limit or the 85th-percentile speed is 35 mph or less, the need for a pedestrian hybrid beacon should be considered if the engineering study finds that the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding total of all pedestrians crossing the major street for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4F-1 for the length of the crosswalk.*

07 *For a major street where the posted or statutory speed limit or the 85th-percentile speed exceeds 35 mph, the need for a pedestrian hybrid beacon should be considered if the engineering study finds that the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding total of all pedestrians crossing the major street for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4F-2 for the length of the crosswalk.*

08 *For crosswalks that have lengths other than the four that are specifically shown in Figures 4F-1 and 4F-2, the values should be interpolated between the curves.*

Section 4F.02 Design of Pedestrian Hybrid Beacons

Standard:

01 **Except as otherwise provided in this Section, a pedestrian hybrid beacon shall meet the provisions of Chapters 4D and 4E.**

02 **A pedestrian hybrid beacon face shall consist of three signal sections, with a CIRCULAR YELLOW signal indication centered below two horizontally aligned CIRCULAR RED signal indications (see Figure 4F-3).**

03 **When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then:**

A. At least two pedestrian hybrid beacon faces shall be installed for each approach of the major street,

B. A stop line shall be installed for each approach to the crosswalk,

C. A pedestrian signal head conforming to the provisions set forth in Chapter 4E shall be installed at each end of the marked crosswalk, and

D. The pedestrian hybrid beacon shall be pedestrian actuated.

Guidance:

04 *When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then:*

A. *The pedestrian hybrid beacon should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs,*

B. *Parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the marked crosswalk, or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance,*

C. *The installation should include suitable standard signs and pavement markings, and*

D. *If installed within a signal system, the pedestrian hybrid beacon should be coordinated.*

05 *On approaches having posted or statutory speed limits or 85th-percentile speeds in excess of 35 mph and on approaches having traffic or operating conditions that would tend to obscure visibility of roadside hybrid beacon face locations, both of the minimum of two pedestrian hybrid beacon faces should be installed over the roadway.*

06 *On multi-lane approaches having a posted or statutory speed limits or 85th-percentile speeds of 35 mph or less, either a pedestrian hybrid beacon face should be installed on each side of the approach (if a median of sufficient width exists) or at least one of the pedestrian hybrid beacon faces should be installed over the roadway.*

07 *A pedestrian hybrid beacon should comply with the signal face location provisions described in Sections 4D.11 through 4D.16.*

Standard:

08 **A CROSSWALK STOP ON RED (symbolic circular red) (R10-23) sign (see Section 2B.53) shall be mounted adjacent to a pedestrian hybrid beacon face on each major street approach. If an overhead pedestrian hybrid beacon face is provided, the sign shall be mounted adjacent to the overhead signal face.**

Option:

09 A Pedestrian (W11-2) warning sign (see Section 2C.50) with an AHEAD (W16-9P) supplemental plaque may be placed in advance of a pedestrian hybrid beacon. A warning beacon may be installed to supplement the W11-2 sign.

Guidance:

10 *If a warning beacon supplements a W11-2 sign in advance of a pedestrian hybrid beacon, it should be programmed to flash only when the pedestrian hybrid beacon is not in the dark mode.*

Standard:

11 **If a warning beacon is installed to supplement the W11-2 sign, the design and location of the warning beacon shall comply with the provisions of Sections 4L.01 and 4L.03.**

Section 4F.03 Operation of Pedestrian Hybrid Beacons

Standard:

01 **Pedestrian hybrid beacon indications shall be dark (not illuminated) during periods between actuations.**

02 **Upon actuation by a pedestrian, a pedestrian hybrid beacon face shall display a flashing CIRCULAR yellow signal indication, followed by a steady CIRCULAR yellow signal indication, followed by both steady CIRCULAR RED signal indications during the pedestrian walk interval, followed by alternating flashing CIRCULAR RED signal indications during the pedestrian ~~clearance~~ change interval (see Figure 4F-3). Upon termination of the pedestrian clearance interval, the pedestrian hybrid beacon faces shall revert to a dark (not illuminated) condition.**

03 **Except as provided in Paragraph 4, the pedestrian signal heads shall continue to display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are either dark or displaying flashing or steady CIRCULAR yellow signal indications. The pedestrian signal heads shall display a WALKING PERSON (symbolizing WALK) signal indication when the pedestrian hybrid beacon faces are displaying steady CIRCULAR RED signal indications. The pedestrian signal heads shall display a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are displaying alternating flashing CIRCULAR RED signal indications. Upon termination of the pedestrian clearance interval, the pedestrian signal heads shall revert to a steady UPRAISED HAND (symbolizing DONT WALK) signal indication.**

Option:

04 Where the pedestrian hybrid beacon is installed adjacent to a roundabout to facilitate crossings by pedestrians with visual disabilities and an engineering study determines that pedestrians without visual disabilities can be allowed to cross the roadway without actuating the pedestrian hybrid beacon, the pedestrian signal heads may be dark (not illuminated) when the pedestrian hybrid beacon faces are dark.

Guidance:

05 *The duration of the flashing yellow interval should be determined by engineering judgment.*

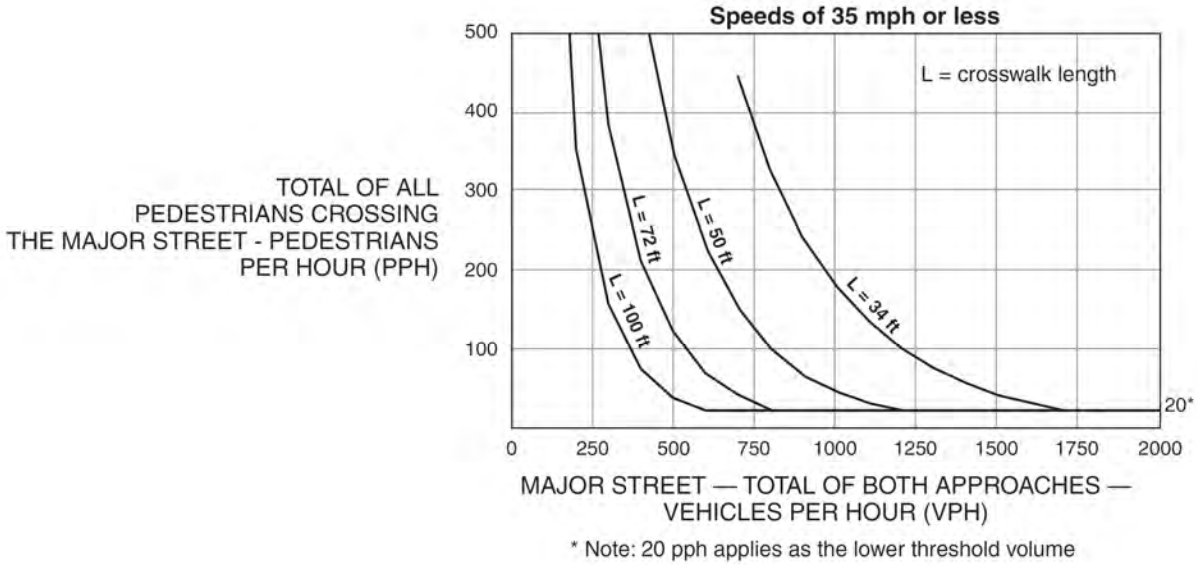
Standard:

06 **The duration of the steady yellow change interval shall be determined using engineering practices.**

Guidance:

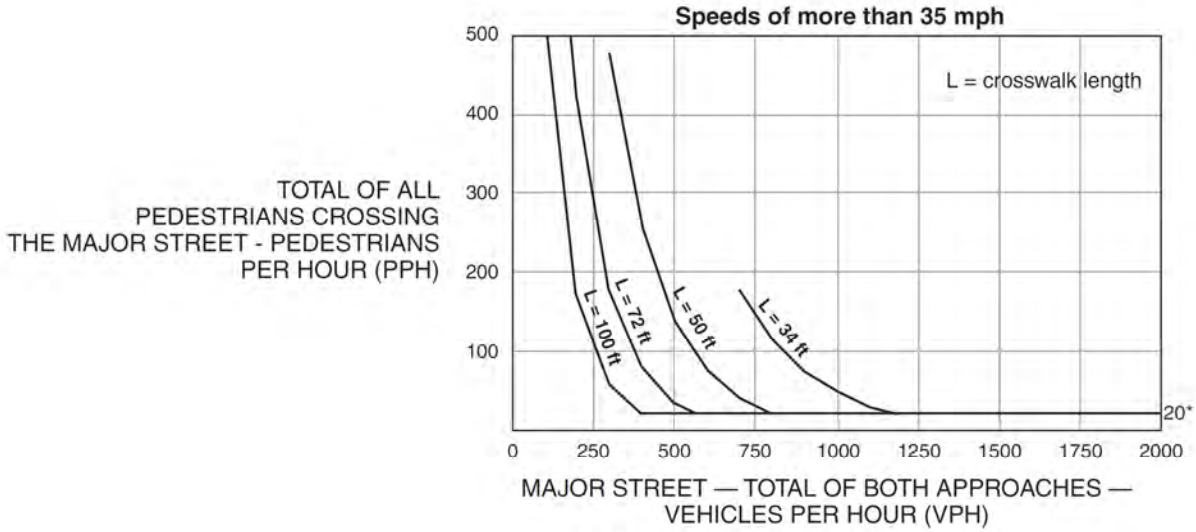
07 *The steady yellow interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds (see Section 4D.26). The longer intervals should be reserved for use on approaches with higher speeds.*

Figure 4F-1. Guidelines for the Installation of Pedestrian Hybrid Beacons on Low-Speed Roadways



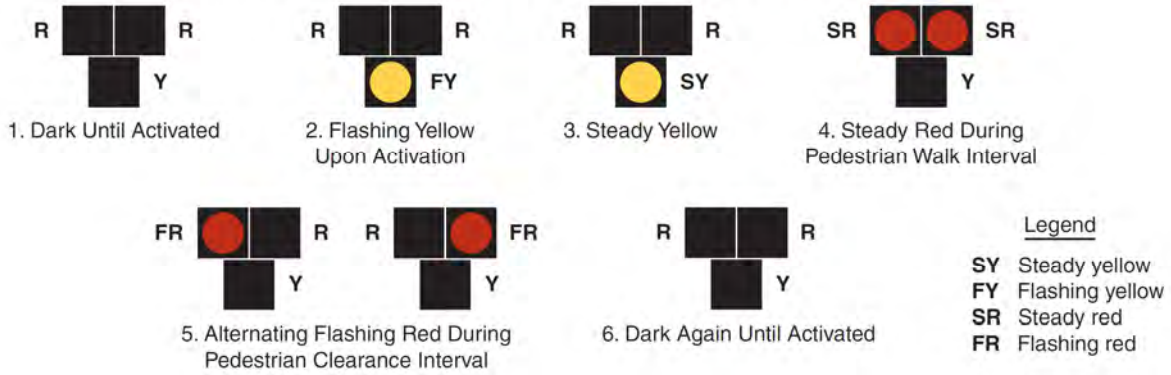
* Note: 20 pph applies as the lower threshold volume

Figure 4F-2. Guidelines for the Installation of Pedestrian Hybrid Beacons on High-Speed Roadways



* Note: 20 pph applies as the lower threshold volume

Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon



CHAPTER 4G. TRAFFIC CONTROL SIGNALS AND HYBRID BEACONS FOR EMERGENCY-VEHICLE ACCESS

Section 4G.01 Application of Emergency-Vehicle Traffic Control Signals and Hybrid Beacons

Support:

01 An emergency-vehicle traffic control signal is a special traffic control signal that assigns the right-of-way to an authorized emergency vehicle.

Option:

02 An emergency-vehicle traffic control signal may be installed at a location that does not meet other traffic signal warrants such as at an intersection or other location to permit direct access from a building housing the emergency vehicle.

03 An emergency-vehicle hybrid beacon may be installed instead of an emergency-vehicle traffic control signal under conditions described in Section 4G.04.

Guidance:

04 *If a traffic control signal is not justified under the signal warrants of Chapter 4C and if gaps in traffic are not adequate to permit the timely entrance of emergency vehicles, or the stopping sight distance for vehicles approaching on the major street is insufficient for emergency vehicles, installing an emergency-vehicle traffic control signal should be considered. If one of the signal warrants of Chapter 4C is met and a traffic control signal is justified by an engineering study, and if a decision is made to install a traffic control signal, it should be installed based upon the provisions of Chapter 4D.*

05 *The sight distance determination should be based on the location of the visibility obstruction for the critical approach lane for each street or drive and the posted or statutory speed limit or 85th-percentile speed on the major street, whichever is higher.*

Section 4G.02 Design of Emergency-Vehicle Traffic Control Signals

Standard:

01 **Except as otherwise provided in this Section, an emergency-vehicle traffic control signal shall meet the requirements of this Manual.**

02 **An Emergency Vehicle (W11-8) sign (see Section 2C.49) with an EMERGENCY SIGNAL AHEAD (W11-12P) supplemental plaque shall be placed in advance of all emergency-vehicle traffic control signals. If a warning beacon is installed to supplement the W11-8 sign, the design and location of the beacon shall comply with the Standards of Sections 4L.01 and 4L.03.**

Guidance:

03 *At least one of the two required signal faces for each approach on the major street should be located over the roadway.*

04 *The following size signal indications should be used for emergency-vehicle traffic control signals: 12-inch diameter for steady red and steady yellow circular signal indications and any arrow indications, and 8-inch diameter for green or flashing yellow circular signal indications.*

Standard:

05 **An EMERGENCY SIGNAL (R10-13) sign shall be mounted adjacent to a signal face on each major street approach (see Section 2B.53). If an overhead signal face is provided, the EMERGENCY SIGNAL sign shall be mounted adjacent to the overhead signal face.**

Option:

06 An approach that only serves emergency vehicles may be provided with only one signal face consisting of one or more signal sections.

07 Besides using an 8-inch diameter signal indication, other appropriate means to reduce the flashing yellow light output may be used.

Section 4G.03 Operation of Emergency-Vehicle Traffic Control Signals

Standard:

01 **Right-of-way for emergency vehicles at signalized locations operating in the steady (stop-and-go) mode shall be obtained as provided in Section 4D.27.**

02 **As a minimum, the signal indications, sequence, and manner of operation of an emergency-vehicle traffic control signal installed at a midblock location shall be as follows:**

A. The signal indication, between emergency-vehicle actuations, shall be either green or flashing yellow. If the flashing yellow signal indication is used instead of the green signal indication, it shall be displayed in the normal position of the green signal indication, while the steady red and steady yellow signal indications shall be displayed in their normal positions.

B. When an emergency-vehicle actuation occurs, a steady yellow change interval followed by a steady red interval shall be displayed to traffic on the major street.

C. A yellow change interval is not required following the green interval for the emergency-vehicle driveway.

03 **Emergency-vehicle traffic control signals located at intersections shall either be operated in the flashing mode between emergency-vehicle actuations (see Sections 4D.28 and 4D.30) or be full-actuated or semi-actuated to accommodate normal vehicular and pedestrian traffic on the streets.**

04 **Warning beacons, if used with an emergency-vehicle traffic control signal, shall be flashed only:**

A. For an appropriate time in advance of and during the steady yellow change interval for the major street; and

B. During the steady red interval for the major street.

Guidance:

05 *The duration of the steady red interval for traffic on the major street should be determined by on-site test-run time studies, but should not exceed 1.5 times the time required for the emergency vehicle to clear the path of conflicting vehicles.*

Option:

06 An emergency-vehicle traffic control signal sequence may be initiated manually from a local control point such as a fire station or law enforcement headquarters or from an emergency vehicle equipped for remote operation of the signal.

Section 4G.04 Emergency-Vehicle Hybrid Beacons

Standard:

01 **Emergency-vehicle hybrid beacons shall be used only in conjunction with signs to warn and control traffic at an unsignalized location where emergency vehicles enter or cross a street or highway. Emergency-vehicle hybrid beacons shall be actuated only by authorized emergency or maintenance personnel.**

Guidance:

02 *Emergency-vehicle hybrid beacons should only be used when all of the following criteria are satisfied:*

A. The conditions justifying an emergency-vehicle traffic control signal (see Section 4G.01) are met; and

B. An engineering study, considering the road width, approach speeds, and other pertinent factors, determines that emergency-vehicle hybrid beacons can be designed and located in compliance with the requirements contained in this Section and in Section 4L.01, such that they effectively warn and control traffic at the location; and

C. The location is not at or within 100 feet from an intersection or driveway where the side road or driveway is controlled by a STOP or YIELD sign.

Standard:

03 **Except as otherwise provided in this Section, an emergency-vehicle hybrid beacon shall meet the requirements of this Manual.**

04 **An emergency-vehicle hybrid beacon face shall consist of three signal sections, with a CIRCULAR YELLOW signal indication centered below two horizontally aligned CIRCULAR RED signal indications (see Figure 4G-1).**

05 **Emergency-vehicle hybrid beacons shall be placed in a dark mode (no indications displayed) during periods between actuations.**

06 **Upon actuation by authorized emergency personnel, the emergency-vehicle hybrid beacon faces shall each display a flashing yellow signal indication, followed by a steady yellow change interval, prior to displaying two CIRCULAR RED signal indications in an alternating flashing array for a duration of time adequate for egress of the emergency vehicles. The alternating flashing red signal indications shall only be displayed when it is required that drivers on the major street stop and then proceed subject to the rules applicable after making a stop at a STOP sign. Upon termination of the flashing red signal indications, the emergency-vehicle hybrid beacons shall revert to a dark mode (no indications displayed) condition.**

Guidance:

07 *The duration of the flashing yellow interval should be determined by engineering judgment.*

Standard:

08 **The duration of the steady yellow change interval shall be determined using engineering practices.**

Guidance:

09 *The steady yellow change interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds (see Section 4D.26). The longer intervals should be reserved for use on approaches with higher speeds.*

Option:

10 A steady red clearance interval may be used after the steady yellow change interval.

11 Emergency-vehicle hybrid beacons may be equipped with a light or other display visible to the operator of the egressing emergency vehicle to provide confirmation that the beacons are operating.

12 Emergency-vehicle hybrid beacons may be supplemented with an advance warning sign, which may also be supplemented with a Warning Beacon (see Section 4L.03).

Guidance:

13 *If a Warning Beacon is used to supplement the advance warning sign, it should be programmed to flash only when the emergency-vehicle hybrid beacon is not in the dark mode.*

Standard:

14 **At least two emergency-vehicle hybrid beacon faces shall be installed for each approach of the major street and a stop line shall be installed for each approach of the major street.**

Guidance:

15 *On approaches having posted or statutory speed limits or 85th-percentile speeds in excess of 40 mph, and on approaches having traffic or operating conditions that would tend to obscure visibility of roadside beacon faces, both of the minimum of two emergency-vehicle hybrid beacon faces should be installed over the roadway.*

16 *On multi-lane approaches having posted or statutory speed limits or 85th-percentile speeds of 40 mph or less, either an emergency-vehicle hybrid beacon face should be installed on each side of the approach (if a median of sufficient width exists) or at least one of the emergency-vehicle hybrid beacon faces should be installed over the roadway.*

17 *An emergency-vehicle hybrid beacon should comply with the signal face location provisions described in Sections 4D.11 through 4D.16.*

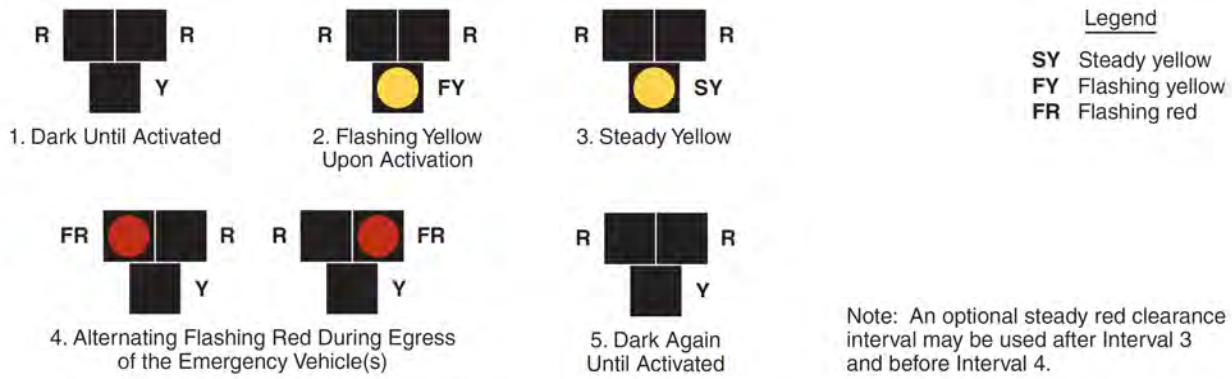
Standard:

18 **Stop lines and EMERGENCY SIGNAL—STOP WHEN FLASHING RED (R10-14 or R10-14a) signs (see ~~Section 2B.53~~ Figure 2B-27) shall be used with emergency-vehicle hybrid beacons.**

Option:

19 If needed for extra emphasis, a STOP HERE ON FLASHING RED (R10-14b) sign (see Section 2B.53) may be installed with an emergency-vehicle hybrid beacon.

Figure 4G-1. Sequence for an Emergency-Vehicle Hybrid Beacon



CHAPTER 4H. TRAFFIC CONTROL SIGNALS FOR ONE-LANE, TWO-WAY FACILITIES

Section 4H.01 Application of Traffic Control Signals for One-Lane, Two-Way Facilities

Support:

01 A traffic control signal at a narrow bridge, tunnel, or roadway section is a special signal that assigns the right-of-way for vehicles passing over a bridge or through a tunnel or roadway section that is not of sufficient width for two opposing vehicles to pass.

02 Temporary traffic control signals (see Sections 4D.32 and 6F.84) are the most frequent application of one-lane, two-way facilities.

Guidance:

03 *Sight distance across or through the one-lane, two-way facility should be considered as well as the approach speed and sight distance approaching the facility when determining whether traffic control signals should be installed.*

Option:

04 At a narrow bridge, tunnel, or roadway section where a traffic control signal is not justified under the conditions of Chapter 4C, a traffic control signal may be used if gaps in opposing traffic do not permit the flow of traffic through the one-lane section of roadway.

Section 4H.02 Design of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

01 **The provisions of Chapter 4D shall apply to traffic control signals for one-lane, two-way facilities, except that:**

A. Durations of red clearance intervals shall be adequate to clear the one-lane section of conflicting vehicles.

B. Adequate means, such as interconnection, shall be provided to prevent conflicting signal indications, such as green and green, at opposite ends of the section.

Section 4H.03 Operation of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

01 **Traffic control signals at one-lane, two-way facilities shall operate in a manner consistent with traffic requirements.**

02 **When in the flashing mode, the signal indications shall flash red.**

Guidance:

03 *Adequate time should be provided to allow traffic to clear the narrow facility before opposing traffic is allowed to move. Engineering judgment should be used to determine the proper timing for the signal.*

CHAPTER 4I. TRAFFIC CONTROL SIGNALS FOR FREEWAY ENTRANCE RAMPS

Section 4I.01 Application of Freeway Entrance Ramp Control Signals

Support:

01 Ramp control signals are traffic control signals that control the flow of traffic entering the freeway facility. ~~This is often referred to as "ramp metering."~~

02 Freeway entrance ramp control signals are sometimes used if controlling traffic entering the freeway could reduce the total expected delay to traffic in the freeway corridor, including freeway ramps and local streets.

Guidance:

03 *The installation of ramp control signals should be preceded by an engineering study of the physical and traffic conditions on the highway facilities likely to be affected. The study should include the ramps and ramp connections and the surface streets that would be affected by the ramp control, as well as the freeway section concerned.*

Support:

04 Information on conditions that might justify freeway entrance ramp control signals, factors to be evaluated in traffic engineering studies for ramp control signals, design of ramp control signals, and operation of ramp control signals can be found in the FHWA's "Ramp Management and Control Handbook" (see Section 1A.11).

Section 4I.02 Design of Freeway Entrance Ramp Control Signals

Standard:

01 **Ramp control signals shall meet all of the standard design specifications for traffic control signals, except as otherwise provided in this Section.**

02 **The signal face for freeway entrance ramp control signals shall be ~~either a two-section signal face containing red and green signal indications or~~ a three-section signal face containing red, yellow, and green signal indications.**

03 **If only one lane is present on an entrance ramp or if more than one lane is present on an entrance ramp and the ramp control signals are operated such that green signal indications are always displayed simultaneously to all of the lanes on the ramp, then a minimum of two signal faces per ramp shall face entering traffic. The minimum number of upper signal heads per ramp shall not be less than the total number of lanes at the limit line for viewing by approaching motorists. For side-mounted signals, the same number of lower signal heads shall also be provided for viewing by stopped motorists at the limit line.**

04 **~~If more than one lane is present on an entrance ramp and the ramp control signals are operated such that green signal indications are not always displayed simultaneously to all of the lanes on the ramp, then one signal face shall be provided over the approximate center of each separately-controlled lane.~~**

04a **If multiple lanes are present on an entrance ramp and the ramp control faces are operated such that green signal indications are not always displayed simultaneously to all of the lanes on the ramp, then the following shall apply:**

A. If there are two separately-controlled lanes, a minimum of two signal faces shall be provided for each of the two lanes, with both mounted overhead, both mounted at the side of the roadway on a single pole (see Paragraphs 9 and 10 below), or a combination thereof.

B. If there are three or more separately-controlled lanes, one signal face shall be provided over the approximate center of each separately-controlled lane.

Guidance:

05 *Additional side-mounted signal faces should be considered for ramps with ~~two or more separately-controlled lanes~~ overhead mounted upper signal faces.*

Standard:

06 **Ramp control signals shall be located and designed to minimize their viewing by mainline freeway traffic.**

Option:

07 Ramp control signals may be placed in the dark mode (no indications displayed) when not in use.

08 Ramp control signals may be used to control some, but not all, lanes on a ramp, such as when non-metered HOV ~~bypass~~ lanes are provided on a ramp.

Standard:

09 **The required signal faces, if located at the side of the ramp roadway, one for each lane ~~may~~ shall be mounted such that the height above the pavement grade at the center of the ramp roadway to the bottom of the signal housing of the lowest signal face is between 4.5 and 6 feet.**

Option:

10 For entrance ramps with only one controlled lane, the two required signal faces may both be mounted at the side of the roadway on a single pole, with one face at the normal mounting height and one face mounted lower as provided in Paragraph 9, as a specific exception to the normal 8-foot minimum lateral separation of signal faces required by Section 4D.13.

Guidance:

11 *Regulatory signs with legends appropriate to the control, such as ~~XX Vehicle (S) Per Green or XX VEHICLE(S) PER GREEN Each Lane~~ 1 CAR (2 CARS) PER GREEN (R89(CA)) or 1 CAR (2 CARS) PER GREEN EACH LANE (R89-1(CA)) or 1 CAR (2 CARS) PER GREEN THIS LANE (R89-2(CA)) (see Section 2B.56), should be installed adjacent to the ramp control signal faces. When ramp control signals are installed on a freeway-to-freeway ramp, special consideration should be given to assuring adequate visibility of the ramp control signals, and multiple advance warning signs with flashing warning beacons should be installed to warn road users of the metered operation.*

Support:

12 Refer to Section 2G.102(CA) for regulatory signs for HOV lanes at metered ramps.

Section 4I.03 Operation of Freeway Entrance Ramp Control Signals

Guidance:

01 *Operational strategies for ramp control signals, such as periods of operation, metering rates and algorithms, and queue management, should be determined by the operating agency prior to the installation of the ramp control signals and should be closely monitored and adjusted as needed thereafter.*

02 *When the ramp control signals are in operation ~~operated only during certain periods of the day~~, a RAMP METERED WHEN FLASHING (W3-8) sign (see Section 2C.37) or an internally illuminated "METER ON" indication, or an internally illuminated "METER ON" indication, or an extinguishable "PREPARE TO STOP" message sign should be installed in advance of the ramp control signal near the entrance to the ramp, or on the arterial on the approach to the ramp, to alert road users to the presence and operation of ramp meters.*

Standard:

03 **The RAMP METERED WHEN FLASHING sign shall be supplemented with a warning beacon (see Section 4L.03) that flashes when the ramp control signal is in operation.**

CHAPTER 4J. TRAFFIC CONTROL FOR MOVABLE BRIDGES

Section 4J.01 Application of Traffic Control for Movable Bridges

Support:

01 Traffic control signals for movable bridges are a special type of highway traffic signal installed at movable bridges to notify road users to stop because of a road closure rather than alternately giving the right-of-way to conflicting traffic movements. The signals are operated in coordination with the opening and closing of the movable bridge, and with the operation of movable bridge warning and resistance gates, or other devices and features used to warn, control, and stop traffic.

02 Movable bridge warning gates installed at movable bridges decrease the likelihood of vehicles and pedestrians passing the stop line and entering an area where potential hazards exist because of bridge operations.

03 A movable bridge resistance gate is sometimes used at movable bridges and located downstream of the movable bridge warning gate. A movable bridge resistance gate provides a physical deterrent to road users when placed in the appropriate position. The movable bridge resistance gates are considered a design feature and not a traffic control device; requirements for them are contained in AASHTO's "Standard Specifications for Movable Highway Bridges" (see Page i for AASHTO's address).

Standard:

04 **Traffic control at movable bridges shall include both signals and gates, except in the following cases:**

A. Neither is required if other traffic control devices or measures considered appropriate are used under either of the following conditions:
   1. On low-volume roads (roads of less than 400 vehicles average daily traffic), or
   2. At manually operated bridges if electric power is not available.

B. Only signals are required in urban areas if intersecting streets or driveways make gates ineffective.

C. Only movable bridge warning gates are required if a traffic control signal that is controlled as part of the bridge operations exists within 500 feet of the movable bridge resistance gates and no intervening traffic entrances exist.

Section 4J.02 Design and Location of Movable Bridge Signals and Gates

Standard:

01 **The signal faces and mountings of movable bridge signals shall comply with the provisions of Chapter 4D except as provided in this Section.**

02 **Signal faces with 12-inch diameter signal indications shall be used for all new movable bridge signals.**

Option:

03 Existing signal faces with 8-inch diameter lenses may be retained for the remainder of their useful service life.

Standard:

04 **Since movable bridge operations cover a variable range of time periods between openings, the signal faces shall be one of the following types:**

A. Three-section signal faces with red, yellow, and green signal indications; or

B. Two one-section signal faces with red signal indications in a vertical array separated by a STOP HERE ON RED (R10-6) sign (see Section 2B.53).

05 **Regardless of which signal type is selected, at least two signal faces shall be provided for each approach to the movable span and a stop line (see Section 3B.16) shall be installed to indicate the point behind which vehicles are required to stop.**

Guidance:

06 *If movable bridge operation is frequent, the use of three-section signal faces should be considered.*

07 *Insofar as practical, the height and lateral placement of signal faces should comply with the requirements for other traffic control signals in accordance with Chapter 4D. They should be located no more than 50 feet in advance of the movable bridge warning gate.*

Option:

08 Movable bridge signals may be supplemented with audible warning devices to provide additional warning to drivers and pedestrians.

Standard:

09 **A DRAW BRIDGE (W3-6) sign (see Section 2C.39) shall be used in advance of movable bridge signals and gates to give warning to road users, except in urban conditions where such signing would not be practical.**

10 **If physical conditions prevent a road user from having a continuous view of at least two signal indications for the distance specified in Table 4D-2, an auxiliary device (either a supplemental signal face or the mandatory DRAW BRIDGE (W3-6) sign to which has been added a warning beacon that is interconnected with the movable bridge controller unit) shall be provided in advance of movable bridge signals and gates.**

Option:

11 The DRAW BRIDGE (W3-6) sign may be supplemented by a Warning Beacon (see Section 4L.03).

Standard:

12 **If two sets of gates (both a warning and a resistance gate) are used for a single direction, highway traffic signals shall not be required to accompany the resistance gate nearest the span opening.**

13 **Movable bridge warning gates, if used, shall be at least standard railroad size, striped with 16-inch alternate vertical, fully reflectorized red and white stripes. Flashing red lights in accordance with the Standards for those on railroad gates (see Section 8C.04) shall be included on the gate arm and they shall only be operated if the gate is closed or in the process of being opened or closed. In the horizontal position, the top of the gate shall be approximately 4 feet above the pavement.**

Guidance:

14 *Movable bridge warning gates should be of lightweight construction. In its normal upright position, the gate arm should provide adequate lateral clearance.*

Option:

15 The movable bridge resistance gates may be delineated, if practical, in a manner similar to the movable bridge warning gate.

Standard:

16 **Movable bridge warning gates, if used, shall extend at least across the full width of the approach lanes if movable bridge resistance gates are used. On divided highways in which the roadways are separated by a barrier median, movable bridge warning gates, if used, shall extend across all roadway lanes approaching the span openings.**

Guidance:

17 *If movable bridge resistance gates are not used on undivided highways, movable bridge warning gates, if used, should extend across the full width of the roadway.*

Option:

18 A single full-width gate or two half-width gates may be used.

Support:

19 The locations of movable bridge signals and gates are determined by the location of the movable bridge resistance gate (if used) rather than by the location of the movable spans. The movable bridge resistance gates for high-speed highways are preferably located 50 feet or more from the span opening except for bascule and lift bridges, where they are often attached to, or are a part of, the structure.

Standard:

20 **Except where physical conditions make it impractical, movable bridge warning gates shall be located 100 feet or more from the movable bridge resistance gates or, if movable bridge resistance gates are not used, 100 feet or more from the movable span.**

Guidance:

21 *On bridges or causeways that cross a long reach of water and that might be hit by large marine vessels, within the limits of practicality, traffic should not be halted on a section of the bridge or causeway that is subject to impact.*

22 *In cases where it is not practical to halt traffic on a span that is not subject to impact, traffic should be halted at least one span from the opening. If traffic is halted by signals and gates more than 330 feet from the movable bridge warning gates (or from the span opening if movable bridge warning gates are not used), a second set of gates should be installed approximately 100 feet from the gate or span opening.*

23 *If the movable bridge is close to a grade crossing and traffic might possibly be stopped on the crossing as a result of the bridge opening, a traffic control device should notify the road users to not stop on the railroad tracks.*

Section 4J.03 Operation of Movable Bridge Signals and Gates

Standard:

01 **Traffic control devices at movable bridges shall be coordinated with the movable spans, so that the signals, gates, and movable spans are controlled by the bridge tender through an interlocked control.**

02 **If the three-section type of signal face is used, the green signal indication shall be displayed at all times between bridge openings, except that if the bridge is not expected to open during continuous periods in excess of 5 hours, a flashing yellow signal indication shall be permitted to be used. The signal shall display a steady red signal indication when traffic is required to stop. The duration of the yellow change interval between the display of the green and steady red signal indications, or flashing yellow and steady red signal indications, shall be determined using engineering practices (see Section 4D.26).**

03 **If the vertical array of red signal indications is the type of signal face selected, the red signal indications shall flash alternately only when traffic is required to stop.**

Guidance:

04 *The yellow change interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds. The longer intervals should be reserved for use on approaches with higher speeds.*

05 *Traffic control signals on adjacent streets and highways should be interconnected with the drawbridge control if indicated by engineering judgment. When such interconnection is provided, the traffic control signals at adjacent intersections should be preempted by the operation of the movable bridge in the manner described in Section 4D.27.*

CHAPTER 4K. HIGHWAY TRAFFIC SIGNALS AT TOLL PLAZAS

Section 4K.01 Traffic Signals at Toll Plazas

Standard:

01 **Traffic control signals or devices that closely resemble traffic control signals that use red or green circular indications shall not be used at toll plazas to indicate the open or closed status of the toll plaza lanes.**

Guidance:

02 *Traffic control signals or devices that closely resemble traffic control signals that use red or green circular indications should not be used for new or reconstructed installations at toll plazas to indicate the success or failure of electronic toll payments or to alternately direct drivers making cash toll payments to stop and then proceed.*

Section 4K.02 Lane-Use Control Signals at or Near Toll Plazas

Standard:

01 **Lane-use control signals used at toll plazas shall comply with the provisions of Chapter 4M except as otherwise provided in this Section.**

02 **At toll plazas with multiple lanes where one or more lanes is sometimes closed to traffic, a lane-use control signal shall be installed above the center of each toll plaza lane to indicate the open or closed status of the controlled lane.**

Option:

03 The bottom of the signal housing of a lane-use control signal above a toll plaza lane having a canopy may be mounted lower than 15 feet above the pavement, but not lower than the vertical clearance of the canopy structure.

04 Lane-use control signals may also be used to indicate the open or closed status of an Open-Road ETC lane as a supplement to other devices used for the temporary closure of a lane (see Part 6).

Section 4K.03 Warning Beacons at Toll Plazas

Standard:

01 **Warning Beacons used at toll plazas shall comply with the provisions of Chapter 4L except as otherwise provided in this Section.**

Guidance:

02 *Warning Beacons, if used with a toll plaza canopy sign (see Section 2F.16) to assist drivers of such vehicles in locating the dedicated ETC Account-Only lane(s), should be installed in a manner such that the beacons are distinctly separate from the lane-use control signals (see Section 4M.01) for the toll plaza lane.*

Option:

03 Warning Beacons that are mounted on toll plaza islands, behind impact attenuators in front of toll plaza islands, and/or on toll booth pylons (ramparts) to identify them as objects in the roadway may be mounted at a height that is appropriate for viewing in a toll plaza context, even if that height is lower than the normal minimum of 8 feet above the pavement.

CHAPTER 4L. FLASHING BEACONS

Section 4L.01 General Design and Operation of Flashing Beacons

Support:

01 A Flashing Beacon is a highway traffic signal with one or more signal sections that operates in a flashing mode. It can provide traffic control when used as an intersection control beacon (see Section 4L.02) or it can provide warning when used in other applications (see Sections 4L.03, 4L.04, and 4L.05).

Standard:

02 **Flashing Beacon units and their mountings shall comply with the provisions of Chapter 4D, except as otherwise provided in this Chapter.**

03 **Beacons shall be flashed at a rate of not less than 50 or more than 60 times per minute. The illuminated period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total cycle.**

04 **A beacon shall not be included within the border of a sign except for SCHOOL SPEED LIMIT sign beacons (see Sections 4L.04 and 7B.15).**

Guidance:

05 *If used to supplement a warning or regulatory sign, the edge of the beacon signal housing should normally be located no closer than 12 inches outside of the nearest edge of the sign.*

Option:

06 An automatic dimming device may be used to reduce the brilliance of flashing yellow signal indications during night operation.

Support:

07 Typical applications for flashing beacons include the following:

A. Signal Ahead
B. Stop Signs
C. Speed Limit Signs
D. Other Warning and Regulatory Signs
E. Schools
F. Fire Stations
G. Intersection Control
H. Freeway Bus Stops
I. At Intersections where a more visible warning is desired.

08 Typical uses include:

A. Obstructions in or immediately adjacent to the roadway.
B. Supplemental to advance warning signs.
C. At mid-block crosswalks.
D. At intersections where a warning is appropriate.

Option:

09 Only warning, regulatory or construction signs may be supplemented by flashing beacons.

Standard:

10 The cost of installing a Warning or Regulatory Sign Flashing Beacon on a State highway shall be at 100% State expense.

Section 4L.02 Intersection Control Beacon

Standard:

01 **An Intersection Control Beacon shall consist of one or more signal faces directed toward each approach to an intersection. Each signal face shall consist of one or more signal sections of a standard traffic signal face, with flashing CIRCULAR YELLOW or CIRCULAR RED signal indications in each signal face. They shall be installed and used only at an intersection to control two or more directions of travel.**

02 **Application of Intersection Control Beacon signal indications shall be limited to the following:**

A. Yellow on one route (normally the major street) and red for the remaining approaches for existing installations**, and**

B. Red for all approaches at new installations **(if the warrant described in Section 2B.07 for a multi-way stop is satisfied).**

03 **Flashing yellow signal indications shall not face conflicting vehicular approaches.**

04 **A STOP sign shall be used on approaches to which a flashing red signal indication is displayed on an Intersection Control Beacon (see Section 2B.04).**

05 **If two horizontally aligned red signal indications are used on an approach for an Intersection Control Beacon, they shall be flashed simultaneously to avoid being confused with grade crossing flashing-light signals. If two vertically aligned red signal indications are used on an approach for an Intersection Control Beacon, they shall be flashed alternately.**

Guidance:

06 *An Intersection Control Beacon should not be mounted on a pedestal in the roadway unless the pedestal is within the confines of a traffic or pedestrian island.*

Option:

07 Supplemental signal indications may be used on one or more approaches in order to provide adequate visibility to approaching road users.

08 Intersection Control Beacons may be used at intersections where traffic or physical conditions do not justify conventional traffic control signals but crash rates indicate the possibility of a special need.

09 An Intersection Control Beacon is generally located over the center of an intersection; however, it may be used at other suitable locations.

Standard:

10 New installations of overhead intersection control flashing beacon shall consist of red indications for each approach.

11 The cost of installing an Intersection Control Beacon and intersection lighting shall be shared with the local agency in the same manner as a traffic signal.

Option:

12 Yellow flashing beacons may be used with Signal Ahead (W3-3) signs in advance of:

A. An isolated traffic signal on either a conventional highway or on an expressway in a rural area.

B. The first traffic signal approaching an urban area.

C. Any traffic signal with limited approach visibility, or where approach speeds exceed 50 mph.

13 On divided highways where the median is 8 feet wide, or greater, the installation may consist of:

A. Two Type 1 standards, each with a Signal Ahead (W3-3) sign and a 12-inch signal face, with one standard located in the median and the other off of the right shoulder; or

B. A Type 9 cantilever flashing beacon installation with a Signal Ahead (W3-3) sign and two 12-inch signal faces as shown in Caltrans' Standard Plans. See Section 1A.11 for information regarding this publication.

14 The above installation designs may result in noncompliance with Caltrans' Highway Design Manual mandatory standards for horizontal clearance and shoulder width, and the advisory design standard for clear recovery zones. If such nonstandard features cannot be avoided, the designer must obtain approval in accordance with Topic 82 of Caltrans' Highway Design Manual and the current instructions pertaining to exceptions from mandatory and advisory design standards. See Section 1A.11 for information regarding this publication.

15 On undivided highways or on highways where the median is less than 8 feet wide, the installation may consist of a single standard located off of the right shoulder or Type 9 cantilever flashing beacon installation as described for use on divided highways, or it may be a Type 15-FBS flashing beacon installation.

Support:

16 The cost of installing a Signal Ahead Flashing Beacon is normally included in the traffic signal project and the cost shared with the local agency.

Section 4L.03 Warning Beacon

Support:

01 Typical applications of Warning Beacons include the following:

A. At obstructions in or immediately adjacent to the roadway;

B. As supplemental emphasis to warning signs;

C. As emphasis for midblock crosswalks;

D. As supplemental emphasis to regulatory signs, except STOP, DO NOT ENTER, WRONG WAY, and SPEED LIMIT signs; and

E. In conjunction with a regulatory or warning sign that includes the phrase WHEN FLASHING in its legend to indicate that the regulation is in effect or that the condition is present only at certain times.

Standard:

02 **A Warning Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR YELLOW signal indication in each signal section.**

03 **A Warning Beacon shall be used only to supplement an appropriate warning or regulatory sign or marker.**

04 **Warning Beacons, if used at intersections, shall not face conflicting vehicular approaches.**

05 **If a Warning Beacon is suspended over the roadway, the clearance above the pavement shall be a minimum of 15 feet and a maximum of 19 feet.**

Guidance:

06 *The condition or regulation justifying Warning Beacons should largely govern their location with respect to the roadway.*

07 *If an obstruction is in or adjacent to the roadway, illumination of the lower portion or the beginning of the obstruction or a sign on or in front of the obstruction, in addition to the beacon, should be considered.*

08 *Warning Beacons should be operated only during those periods or times when the condition or regulation exists.*

Option:

09 Warning Beacons that are actuated by pedestrians, bicyclists, or other road users may be used as appropriate to provide additional warning to vehicles approaching a crossing or other location.

10 If Warning Beacons have more than one signal section, they may be flashed either alternately or simultaneously.

11 A flashing yellow beacon interconnected with a traffic signal controller assembly may be used with a traffic signal warning sign (see Section 2C.36).

Section 4L.04 Speed Limit Sign Beacon

Standard:

01 **A Speed Limit Sign Beacon shall be used only to supplement a Speed Limit sign.**

02 **A Speed Limit Sign Beacon shall consist of one or more signal sections of a standard traffic control signal face, with a flashing CIRCULAR YELLOW signal indication in each signal section. The signal indications shall have a nominal diameter of not less than 8 inches. If two signal indications are used, they shall be vertically aligned, except that they shall be permitted to be horizontally aligned if the Speed Limit (R2-1) sign is longer horizontally than vertically. If two signal indications are used, they shall be alternately flashed.**

Option:

03 A Speed Limit Sign Beacon may be used with a fixed or variable Speed Limit sign. If applicable, a flashing Speed Limit Sign Beacon (with an appropriate accompanying sign) may be used to indicate that the displayed speed limit is in effect.

04 ~~A Speed Limit Sign Beacon may be included within the border of a School Speed Limit (S5-1) sign (see Section 7B.15).~~

Guidance:

05 *When a Speed Limit Sign Flashing Beacon is installed at the request of a local agency, or installed by the local agency under an encroachment permit the costs of installing and maintaining the beacon should be at 100% local agency expense.*

Section 4L.05 Stop Beacon

Standard:

01 **A Stop Beacon shall be used only to supplement a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.**

02 **A Stop Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR RED signal indication in each signal section. If two horizontally aligned signal indications are used for a Stop Beacon, they shall be flashed simultaneously to avoid being confused with grade crossing flashing-light signals. If two vertically aligned signal indications are used for a Stop Beacon, they shall be flashed alternately.**

03 **The bottom of the signal housing of a Stop Beacon shall be not less than 12 inches or more than 24 inches above the top of a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.**

Support:

04 A Stop Sign Flashing Beacon consists of one or two signal sections with a flashing circular red indication in each section.

Standard:

05 The bottom of the housing of a Stop Sign Flashing Beacon shall not be less than 12 inches nor more than 24 inches above the top of the stop sign.

06 The cost of installing a Stop Sign Beacon shall be shared with the local agency in the same manner as a traffic signal.

Section 4L.101(CA) Flashing Beacons at School Crosswalks

Option:

01 Flashing beacons at school crosswalks may be installed on State highways in accordance with CVC Sections 21372 and 21373.

02 Flashing yellow beacons may be installed to supplement standard school signing and markings for the purpose of providing advanced warning during specified times of operation when justified.

03 A flashing yellow beacon may be justified when ALL of the following conditions are fulfilled:

A. The uncontrolled school crossing is on the "Suggested Route to School"; and
B. At least 40 school pedestrians use the crossing during each of any two hours (not necessarily consecutive) of a normal school day; and
C. The crossing is at least 600 feet from the nearest alternate crossing controlled by traffic signals, stop signs or crossing guards; and
D. The vehicular volume through the crossing exceeds 200 vehicles per hour in urban areas or 140 vehicles per hour in rural areas during the same hour the students are going to and from school during normal school hours; and
E. The critical approach speeds exceeds 35 mph or the approach visibility is less than the stopping sight distance.

Standard:

04 If school authorities are to operate flashing yellow beacon, an inter-agency agreement shall be executed to assure designations of a responsible adult to operate the beacon controls and to provide accessibility for necessary equipment maintenance.

05 Where traffic signals and/or flashing beacons are justified only by the School Area Traffic Signal Warrant on a State highway, the installation shall be at 100% State expense. When any other warrant is met also, the cost is shared in the usual manner.

Support:

06 Figure 4L-101(CA) shows the worksheet for flashing beacon at school crossings.

Section 4L.102(CA) Flashing Beacons for Fire Stations

Option:

01 Flashing beacons at fire station driveways or at intersections immediately adjacent to a fire station may be installed on State highways.

Standard:

02 The flashing beacon shall be used only to supplement an appropriate warning or regulatory sign. The flashing beacon shall be actuated from an non-illuminated condition by a switch at the fire station.

03 The costs of installing and maintaining the flashing beacon for the fire station shall be at 100% local agency or fire department expense.

Section 4L.103(CA) Flashing Beacons at Bus Stops on Freeway Interchanges

Option:

01 At locations of approved bus stops within interchange areas, a flashing beacon may be provided near the top of a lighting standard to provide a flag stop.

Standard:

02 The following design and operational requirements shall be met:

A. A push button shall be provided on the lighting standard with a sign explaining the purpose and operation. The sign shall state that if no bus has arrived within 15 minutes (or other time) after the button has been actuated it will be necessary to actuate it again.
B. The flashing beacon shall consist of a 8-inch, signal section with an uncolored or white lens mounted on the lighting standard in such a position that an approaching bus driver can see it on the freeway.
C. The operation of the control shall be such that the flashing beacon will operate for 15 minutes after the button has been actuated and then go out.

03 The cost of installing and maintaining Flashing Beacons at Bus Stops on Freeway Interchanges shall be 100% State expense.

Figure 4L-101 (CA). Flashing Beacon at School Crossings Worksheet

COUNT DATE _____

_____ DIST _____ CO _____ RTE _____ PM

CALC _____ DATE _____

CHK _____ DATE _____

Major St: _____ Critical Approach Speed _____ mph

Minor St: _____ Critical Approach Speed _____ mph

Speed limit or critical speed on major street traffic > 40 mph..... ☐
or
In built up area of isolated community of < 10,000 population..... ☐
} **RURAL (R)**

☐ **URBAN (U)**

Flashing Yellow Beacon at School Crossings (All Parts Must Be Satisfied) **SATISFIED YES ☐ NO ☐**

Part A

	MINIMUM REQUIREMENTS	U	R		
Vehicle Volume	Each of 2 Hours	200	140		
School Age Pedestrians Crossing Street	Each of 2 Hours	40	40		

SATISFIED YES ☐ NO ☐

AND

Part B

Critical Approach Speed Exceeds 35 mph SATISFIED YES ☐ NO ☐

AND

Part C

Is Nearest Controlled Crossing More Than 600 ft away? SATISFIED YES ☐ NO ☐

CHAPTER 4M. LANE-USE CONTROL SIGNALS

Section 4M.01 Application of Lane-Use Control Signals

Support:

01 Lane-use control signals are special overhead signals that permit or prohibit the use of specific lanes of a street or highway or that indicate the impending prohibition of their use. Lane-use control signals are distinguished by placement of special signal faces over a certain lane or lanes of the roadway and by their distinctive shapes and symbols. Supplementary signs are sometimes used to explain their meaning and intent.

02 Lane-use control signals are most commonly used for reversible-lane control, but are also used in certain non-reversible lane applications and for toll plaza lanes (see Section 4K.02).

Guidance:

03 *An engineering study should be conducted to determine whether a reversible-lane operation can be controlled satisfactorily by static signs (see Section 2B.26) or whether lane-use control signals are necessary. Lane-use control signals should be used to control reversible-lane operations if any of the following conditions are present:*

A. More than one lane is reversed in direction;

B. Two-way or one-way left turns are allowed during peak-period reversible operations, but those turns are from a different lane than used during off-peak periods;

C. Other unusual or complex operations are included in the reversible-lane pattern;

D. Demonstrated crash experience occurring with reversible-lane operation controlled by static signs that can be corrected by using lane-use control signals at the times of transition between peak and off-peak patterns; and/or

E. An engineering study indicates that the safety and efficiency of the traffic operations of a reversible-lane system would be improved by lane-use control signals.

Standard:

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

Option:

05 Lane-use control signals may also be used if there is no intent or need to reverse lanes, but there is a need to indicate the open or closed status of one or more lanes, such as:

A. On a freeway, if it is desired to close certain lanes at certain hours to facilitate the merging of traffic from a ramp or other freeway;

B. On a freeway, near its terminus, to indicate a lane that ends;

C. On a freeway or long bridge, to indicate that a lane may be temporarily blocked by a crash, breakdown, construction or maintenance activities, or similar temporary conditions; and

D. On a conventional road or driveway, at access or egress points to or from a facility, such as a parking garage, where one or more lanes of the access or egress are opened or closed at various times.

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

Standard:

01 **The meanings of lane-use control signal indications shall be as follows:**

A. A steady DOWNWARD GREEN ARROW signal indication (see Figure 4M-101(CA)) **shall mean that a road user is permitted to drive in the lane over which the arrow signal indication is located.**

B. A steady YELLOW X signal indication (see Figure 4M-101(CA)) **shall mean that a road user is to prepare to vacate the lane over which the signal indication is located because a lane control change is being made to a steady RED X signal indication.**

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

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

E. A steady RED X signal indication (see Figure 4M-101(CA)) shall mean that a road user is not permitted to use the lane over which the signal indication is located and that this signal indication shall modify accordingly the meaning of other traffic controls present.

Section 4M.03 Design of Lane-Use Control Signals

Standard:

01 **All lane-use control signal indications shall be in units with rectangular signal faces and shall have opaque backgrounds. Nominal minimum height and width of each DOWNWARD GREEN ARROW, YELLOW X, and RED X signal face shall be 18 inches for typical applications. The WHITE TWO-WAY LEFT-TURN ARROW and WHITE ONE WAY LEFT-TURN ARROW signal faces shall have a nominal minimum height and width of 30 inches.**

02 **Each lane to be reversed or closed shall have signal faces with a DOWNWARD GREEN ARROW and a RED X symbol.**

03 **Each reversible lane that also operates as a two-way or one-way left-turn lane during certain periods shall have signal faces that also include the applicable WHITE TWO-WAY LEFT-TURN ARROW or WHITE ONE WAY LEFT-TURN ARROW symbol.**

04 **Each non-reversible lane immediately adjacent to a reversible lane shall have signal indications that display a DOWNWARD GREEN ARROW to traffic traveling in the permitted direction and a RED X to traffic traveling in the opposite direction.**

05 **If in separate signal sections, the relative positions, from left to right, of the signal indications shall be RED X, YELLOW X, DOWNWARD GREEN ARROW, WHITE TWO-WAY LEFT-TURN ARROW, WHITE ONE WAY LEFT-TURN ARROW.**

06 **The color of lane-use control signal indications shall be clearly visible for 2,300 feet at all times under normal atmospheric conditions, unless otherwise physically obstructed.**

07 **Lane-use control signal faces shall be located approximately over the center of the lane controlled.**

08 **If the area to be controlled is more than 2,300 feet in length, or if the vertical or horizontal alignment is curved, intermediate lane-use control signal faces shall be located over each controlled lane at frequent intervals. This location shall be such that road users will at all times be able to see at least one signal indication and preferably two along the roadway, and will have a definite indication of the lanes specifically reserved for their use.**

09 **All lane-use control signal faces shall be located in a straight line across the roadway approximately at right angles to the roadway alignment.**

10 **On roadways having intersections controlled by traffic control signals, the lane-use control signal face shall be located sufficiently far in advance of or beyond such traffic control signals to prevent them from being misconstrued as traffic control signals.**

11 **Except as provided in Paragraph 12, the bottom of the signal housing of any lane-use control signal face shall be a minimum of 15 feet and a maximum of 19 feet above the pavement grade.**

Option:

12 The bottom of a lane-use control signal housing may be lower than 15 feet above the pavement if it is mounted on a canopy or other structure over the pavement, but not lower than the vertical clearance of the structure.

13 Except for lane-use control signals at toll plazas (see Section 4K.02), in areas with minimal visual clutter and with speeds of less than 40 mph, lane-use control signal faces with nominal height and width of 12 inches may be used for the DOWNWARD GREEN ARROW, YELLOW X, and RED X signal faces, and lane-use control signal faces with nominal height and width of 18 inches may be used for the WHITE TWO-WAY LEFT-TURN ARROW and WHITE ONE-WAY LEFT-TURN ARROW signal faces.

14 Other sizes of lane-use control signal faces larger than 18 inches with message recognition distances appropriate to signal spacing may be used for the DOWNWARD GREEN ARROW, YELLOW X, and RED X signal faces.

15 Non-reversible lanes not immediately adjacent to a reversible lane on any street so controlled may also be provided with signal indications that display a DOWNWARD GREEN ARROW to traffic traveling in the permitted direction and a RED X to traffic traveling in the opposite direction.

16 The signal indications provided for each lane may be in separate signal sections or may be superimposed in the same signal section.

Guidance:

17 *The RED X lane-use control signal face and the downward pointing green arrow symbol should consist of a stroke width of 1.5 inches.*

Section 4M.04 Operation of Lane-Use Control Signals

Standard:

01 **All lane-use control signals shall be coordinated so that all the signal indications along the controlled section of roadway are operated uniformly and consistently. The lane-use control signal system shall be designed to reliably guard against showing any prohibited combination of signal indications to any traffic at any point in the controlled lanes.**

02 **For reversible-lane control signals, the following combination of signal indications shall not be simultaneously displayed over the same lane to both directions of travel:**

A. DOWNWARD GREEN ARROW in both directions,
B. YELLOW X in both directions,
C. WHITE ONE WAY LEFT-TURN ARROW in both directions,
D. DOWNWARD GREEN ARROW in one direction and YELLOW X in the other direction,
E. WHITE TWO-WAY LEFT-TURN ARROW or WHITE ONE WAY LEFT-TURN ARROW in one direction and DOWNWARD GREEN ARROW in the other direction,
F. WHITE TWO-WAY LEFT-TURN ARROW in one direction and WHITE ONE WAY LEFT-TURN ARROW in the other direction, and
G. WHITE ONE WAY LEFT-TURN ARROW in one direction and YELLOW X in the other direction.

03 **A moving condition in one direction shall be terminated either by the immediate display of a RED X signal indication or by a YELLOW X signal indication followed by a RED X signal indication. In either case, the duration of the RED X signal indication shall be sufficient to allow clearance of the lane before any moving condition is allowed in the opposing direction.**

04 **Whenever a DOWNWARD GREEN ARROW signal indication is changed to a WHITE TWO-WAY LEFT-TURN ARROW signal indication, the RED X signal indication shall continue to be displayed to the opposite direction of travel for an appropriate duration to allow traffic time to vacate the lane being converted to a two-way left-turn lane.**

05 **If an automatic control system is used, a manual control to override the automatic control shall be provided.**

Guidance:

06 *The type of control provided for reversible-lane operation should be such as to permit either automatic or manual operation of the lane-use control signals.*

Standard:

07 **If used, lane-use control signals shall be operated continuously, except that lane-use control signals that are used only for special events or other infrequent occurrences and lane-use control signals on non-reversible freeway lanes shall be permitted to be darkened when not in operation. The change from normal operation to non-operation shall occur only when the lane-use control signals display signal indications that are appropriate for the lane use that applies when the signals are not operated. The lane-use control signals shall display signal indications that are appropriate for the existing lane use when changed from non-operation to normal operations. Also, traffic control devices shall clearly indicate the proper lane use when the lane control signals are not in operation.**

Support:

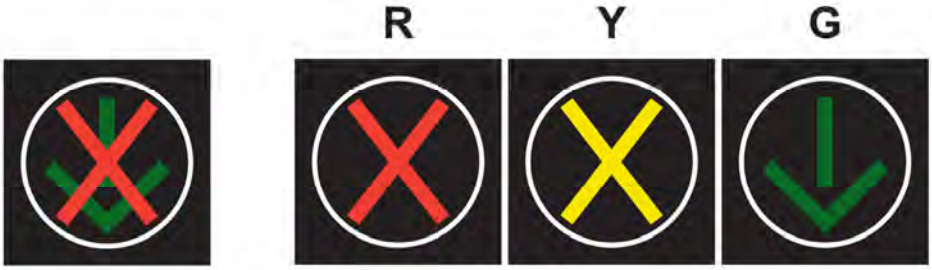
08 Section 2B.26 contains additional information concerning considerations involving left-turn prohibitions in conjunction with reversible-lane operations.

Figure 4M-1. Left-Turn Lane-Use Control Signals

Two-way left-turn arrow | One-way left-turn arrow

White arrows on an opaque 30 x 30-inch background

Figure 4M-101 (CA). Example of Lane Control Signal Face



CHAPTER 4N. IN-ROADWAY LIGHTS

Section 4N.01 Application of In-Roadway Lights

Support:

01 In-Roadway Lights are special types of highway traffic signals installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. This includes situations warning of marked school crosswalks, marked midblock crosswalks, marked crosswalks on uncontrolled approaches, marked crosswalks in advance of roundabouts as described in Chapter 3C, and other roadway situations involving pedestrian crossings.

Standard:

02 **In-Roadway Lights shall not be used for any application that is not described in this Chapter.**

03 **If used, In-Roadway Lights shall not exceed a height of 3/4 inch above the roadway surface.**

04 **When used, In-Roadway Lights shall be flashed and shall not be steadily illuminated.**

Support:

05 Steadily illuminated lights installed in the roadway surface are considered to be internally illuminated raised pavement markers (see Section 3B.11).

Option:

06 In-Roadway Lights may be flashed in a manner that includes a continuous flash of varying intensity and time duration that is repeated to provide a flickering effect (see Section 4N.02).

Section 4N.02 In-Roadway Warning Lights at Crosswalks

Option:

01 In-roadway lights may be installed at certain marked crosswalks, based on an engineering study or engineering judgment, to provide additional warning to road users.

Standard:

02 **If used, In-Roadway Warning Lights at crosswalks shall be installed only at marked crosswalks with applicable warning signs. They shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals.**

03 **If In-Roadway Warning Lights are used at a crosswalk, the following requirements shall apply:**

A. Except as provided in Paragraphs 7 and 8, they shall be installed along both sides of the crosswalk and shall span its entire length.

B. They shall initiate operation based on pedestrian actuation and shall cease operation at a predetermined time after the pedestrian actuation or, with passive detection, after the pedestrian clears the crosswalk.

C. They shall display a flashing yellow light when actuated. The flash rate shall be at least 50, but no more than 60, flash periods per minute. If they are flashed in a manner that includes a continuous flash of varying intensity and time duration that is repeated to provide a flickering effect, the flickers or pulses shall not repeat at a rate that is between 5 and 30 per second to avoid frequencies that might cause seizures.

D. They shall be installed in the area between the outside edge of the crosswalk line and 10 feet from the outside edge of the crosswalk.

E. They shall face away from the crosswalk if unidirectional, or shall face away from and across the crosswalk if bidirectional.

04 **If used on one-lane, one-way roadways, a minimum of two In-Roadway Warning Lights shall be installed on the approach side of the crosswalk. If used on two-lane roadways, a minimum of three In-Roadway Warning Lights shall be installed along both sides of the crosswalk. If used on roadways with more than two lanes, a minimum of one In-Roadway Warning Light per lane shall be installed along both sides of the crosswalk.**

Guidance:

05 *If used, In-Roadway Warning Lights should be installed in the center of each travel lane, at the center line of the roadway, at each edge of the roadway or parking lanes, or at other suitable locations away from the normal tire track paths.*

06 *The location of the In-Roadway Warning Lights within the lanes should be based on engineering judgment.*

Option:

07 On one-way streets, In-Roadway Warning Lights may be omitted on the departure side of the crosswalk.

08 Based on engineering judgment, the In-Roadway Warning Lights on the departure side of the crosswalk on the left side of a median may be omitted.

09 Unidirectional In-Roadway Warning Lights installed at crosswalk locations may have an optional, additional yellow light indication in each unit that is visible to pedestrians in the crosswalk to indicate to pedestrians in the crosswalk that the In-Roadway Warning Lights are in fact flashing as they cross the street. These yellow lights may flash with and at the same flash rate as the light module in which each is installed.

Guidance:

10 *If used, the period of operation of the In-Roadway Warning Lights following each actuation should be sufficient to allow a pedestrian crossing in the crosswalk to leave the curb or shoulder and travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the period of operation.*

Standard:

11 **If pedestrian pushbuttons are used to actuate the in-roadway lights, a Push Button To Turn On Warning Lights (with pushbutton symbol) (R10-25) sign (see Figure 2B-26) shall be mounted adjacent to or integral with each pedestrian pushbutton.**

12 **Where the period of operation is sufficient only for crossing from a curb or shoulder to a median of sufficient width for pedestrians to wait, median-mounted pedestrian actuators shall be provided.**

13 **In-Roadway Warning Lights (IRWLs) shall not be placed on or within the crosswalk markings. If the In-Roadway Warning Lights are activated by a push button, the PUSH BUTTON FOR PEDESTRIAN WARNING LIGHTS, CROSS WITH CAUTION (R62E(CA)) sign shall be used.**

14 **The following shall be considered when evaluating the need for In-Roadway Warning Lights:**

A. Whether the crossing is controlled or uncontrolled.

B. An engineering traffic study to determine if In-Roadway Warning Lights are compatible with the safety and operation of nearby intersections, which may or may not be, controlled by traffic signals or STOP/YIELD signs.

C. Standard traffic signs for crossings and crosswalk pavement markings are provided.

D. At least 40 pedestrians regularly use the crossing during each of any two hours (not necessarily consecutive) during a 24-hour period.

E. The vehicular volume through the crossing exceeds 200 vehicles per hour in urban areas or 140 vehicles per hour in rural areas during peak-hour pedestrian usage.

F. The critical approach speed (85th percentile) is 45 mph or less.

G. In-Roadway Warning Lights are visible to drivers at the minimum stopping sight distance for the posted speed limit.

H. Public education on In-Roadway Warning Lights is conducted for new installations.

Option:

15 Overhead or roadside Flashing Yellow Beacons may be installed in conjunction with In-Roadway Warning Lights. In-Roadway Warning Lights may be installed independently, but are not necessarily intended to be a substitute for standard flashing beacons. Engineering judgment should be exercised.

Guidance:

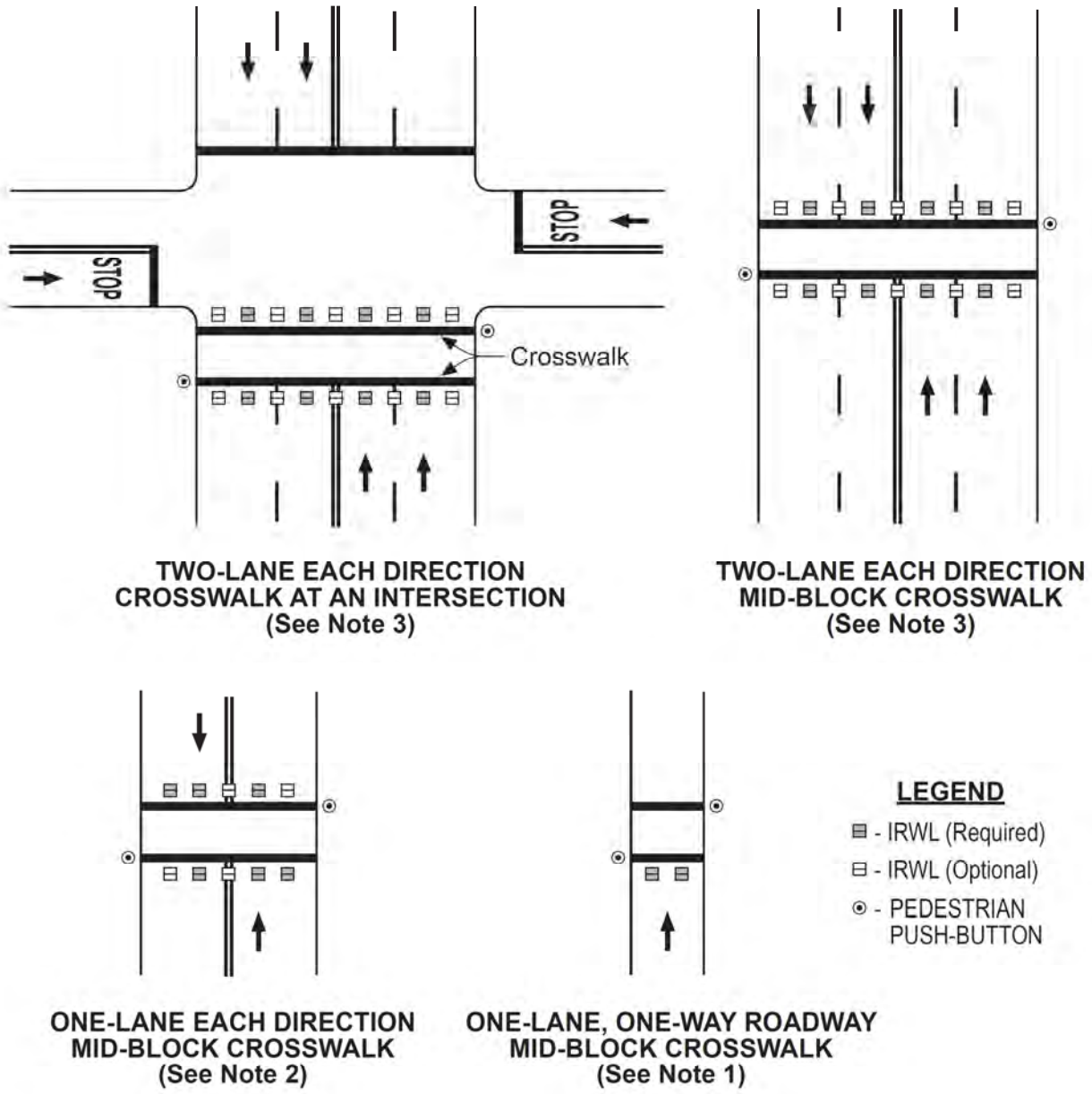
16 *Typical applications of In-Roadway Warning Lights are shown in Figure 4N-101(CA).*

Section 4N.101(CA) In-Roadway Warning Lights at Crosswalks Financing and Maintenance-State Highways

Standard:

01 **When In-Roadway Warning Lights are proposed by Caltrans on State highways, Caltrans shall pay the costs of installation and maintenance. When In-Roadway Warning Lights are proposed and installed by a local agency on State highways, the installation of In-Roadway Warning Lights shall be covered by an Encroachment Permit issued by the local Caltrans District Director. The local agency shall be responsible for installation and maintenance of the In-Roadway Warning Lights.**

Figure 4N-101 (CA). Typical Layout for In-Roadway Warning Lights (IRWLs)



NOTES:

1. One-Lane, One-Way Roadways, a minimum of two IRWLs shall be installed on the approach side ot the crosswalk.
2. One-Lane each direction, a minimum of three IRWLs shall be installed along both sides of the crosswalk.
3. Two-Lanes each direction, a minimum of one IRWLs per lane, shall be installed along both sides of the crosswalk.
4. IRWLs should be located off the tire tracks.