

manual change transmittal

NO. TM03-1

<p>TITLE</p> <p>Traffic Manual</p>	<p>APPROVED</p>	<p>DATE ISSUED 11-13-02</p> <p>PAGE 1 OF 4</p>
<p>SUBJECT AREA</p> <p>Chapter 9, Traffic Signals and Lighting</p>	<p>ISSUING UNIT</p> <p>Traffic Operations Program</p>	
<p>SUPERSEDES Chapter 9, Traffic Signals and Lighting Pages 9-6, 9-24 through 9-40, 9-58, 9-61, 9-62 9-74, 9-80 and 9-81.</p>	<p>DISTRIBUTION</p> <p>All Manual Holders</p>	

Attached is a revised portion of Chapter 9 of the Traffic Manual for new Section 9-01.5, Bicycle Signals, and the updating of Section 9-03.3, Selection of Left-Turn Phasing, Section 9-03.7, Three Phase Operation, Section 9-03.8, Permissive Left-Turn Phasing, Section 9-03.12, Location of Signal Faces, Section 9-03.15, Right-Turn Arrows, Section 9-03.24, Vehicle Detectors, Section 9-03.26, Bicycle Detectors, Section 9-03.27, Signal Plan Schedules, Section 9-03.35, Temporary Signals for Haul Roads, Section 9-04.1, Introduction (Traffic Signal Operations), Section 9-04.2, Review of Traffic Signal Operations, Section 9-04.5, Yellow Change Intervals, Table 9-1, Suggested Detector Setbacks From Limitline, Figure 9-22, Typical Traffic Signal Installation, Section 9-05.1, Introduction (Flashing Beacons), Section 9-05.2, Signal Ahead Flashing Beacons, Section 9-12.2, Roadway Luminaires and Section 9-13.11, Voltage Drop. This also replaces existing Title Page, Table of Contents and pages 9-6, 9-24 through 9-40, 9-58, 9-61, 9-62, 9-74, 9-80 and 9-81 dated July, 1996.

This manual change should be implemented on all new construction and during routine maintenance operations. The following is an explanation of those sections that are changed:

- Section 9-01.5 - Bicycle Signals. This new section has been added to Section 9-01, Traffic Signals, Basic Information and Warrants to address operational problems involving bicycles.
- Section 9-03.8 - Permissive Left-Turn Phasing. This section has been revised to include the use of a Left Turn Yield extinguishable message sign on local roads in place of the R73-7, at signalized intersections that have protected-permissive or permissive-protected left-turn phasing.
- Sections 9-03.9 through 9-03.30 have been repositioned on pages 9-26 through 9-32 to accommodate the revision to Section 9-03.8.
- Section 9-03.26 - The reference to Standard Plan ES-5D is corrected to ES-5B.
- Section 9-04.5 - The Approach Speed is changed to reflect both English and Metric speeds and the Yellow Intervals have been revised.
- Table 9-1, Suggested Detector Setbacks From Limitline, is changed to reflect both English and Metric speeds. The formulas and the corresponding table have also been revised.

- Figure 9-22, Typical Traffic Signal Installation, reference in Note 8 to Traffic Manual Section 9-20 is corrected to Section 9-03.
- Section 9-12.2 - The mounting height for roadway luminaires on conventional highways and at intersections of freeway ramps with surface streets is revised to 9.14 m only.
- Section 9-13.11 - In the Example Equation, the minimum wire size is corrected from No. 8 to No. 6.

The following changes are made to the Traffic Manual at the recommendation of The California Traffic Control Device Committee (CTCDC) to improve text that will carry over into the MUTCD California Supplement.

- Section 9-03.3 Selection of Left-Turn Phasing

Change the second paragraph that reads: “If the left turn volume is 300 vehicles per hour or more, consideration should be given to a two-lane left turn.” **to:** “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 for a two-lane left turn.”

- Section 9-03.7 Three Phase Operation

Change the second paragraph that reads: “This operation is the simplest and the least expensive. It can be either pretimed or traffic-actuated. Since both left turn approaches receive the same amount of green time simultaneously, regardless of directional demand, less efficient operation will result.” **to:** “Three phase operation can be either pretimed or traffic-actuated.”

- Section 9-03.8 Permissive Left Turn Phasing

Change paragraph 5 that reads: “Local authorities may use an extinguishable message sign on local roads . . .” **to:** “Public agencies having jurisdiction may use an extinguishable message sign on local roads . . .”

- Section 9-03.12 Location Of Signal Faces

Change the first paragraph that reads: “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. The signal faces for two or more approaches can often be combined on a single standard. However, where the curb return radius is greater than 3 m, it may be necessary to locate the signal faces on separate standards to provide maximum visibility for the controlled approach.” **to:** “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. The signal faces for two or more approaches can often be combined on a single standard. However, 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. It may be necessary to locate signal faces on separate standards whenever the curb return radius is greater than 3 m.”

Change the second paragraph that reads: “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 practicable in line with the left turn lane . . .” **to:** “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 the center of the left turn lane . . .”

- Section 9-03.15. Right Turn Arrow

Change the third paragraph which reads: “A right-turn green arrow should be used only when the right-turn volume exceeds 200 vehicles per hour, or it is the only movement that traffic is permitted to make” **to:** “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 9-03.24 Vehicle Detectors

Add a new item 5 that reads: “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.”

- Section 9-03.27 Signal Plan Schedule

Change item # 2 that reads: “A conductor and conduit schedule shows the size of each conduit run, and the size and number of conductors in each conduit run.” **to:** “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.”

- Section 9-03.35 Temporary Signals for Haul Roads or One-Way Control in Construction Zones

Change title in item # 2 that reads: “Permit or Contract Requirements” **to:** “Requirements”

Change item 2d which reads: “Timing of the signals will be determined by the District Traffic Engineer.” **to:** Timing of the signals will be determined by the Agency having jurisdiction.”

- Section 9-04.1 Introduction

Add the following sentence to the first paragraph: “Maintenance and operation of highway traffic signals involving State Highways by an agency other than the California Department of Transportation shall require a jointly approved written agreement.”

- Section 9-04.2 Review of Traffic Signal Operation

Change item # 2 that reads: “Time-of-Day Settings” **to:** “Time-of-Day or Traffic Responsive Settings”

Change the last paragraph that reads: “Initial timing of traffic signals and any subsequent changes in timing shall be the responsibility of Traffic Operations. Maintaining the timing is the responsibility of Maintenance. Timing records shall be kept in both Maintenance and Traffic Operations.” **to:** “Initial timing of traffic signals and any subsequent changes in timing shall be the responsibility of Traffic Operations. Timing records shall be kept and be readily available to maintenance and traffic operations staff and other agencies, where appropriate.”

- Section 9-04.6 Red Clearance Interval

Change the last paragraph that reads: “Generally, red clearance intervals are not required. A red clearance interval may be used following the yellow change interval, at very wide intersections, offset intersections, or at other locations where it is desirable to delay the green interval for opposing traffic. Normally, red clearance intervals range from 0.01 seconds to 2.0 seconds.” **to:** “Red clearance intervals which follow yellow change intervals are not required, but may be considered where any of the following conditions exist: intersections that are wide, offset or contain unusual geometry; intersections where the visibility of conflicting traffic is blocked or limited; movements

where the approach speeds are 88 km/hr (55 mph) or more; or where it is desirable to help clear vehicles that recurrently become queued in the intersection where there are permissive left turns. Normally, red clearance intervals range from 0.01 to 2.0 seconds and should not exceed 6 seconds.”

- Section 9-05.1 Introduction

Add item #9 that reads: “At Intersections Where a More Visible Warning is Desired”

- Section 9-05.2 Signal Ahead Flashing Beacon

Change item #3 that reads: “Any traffic signal with limited approach visibility and where approach speeds exceed 80 Km/h (50 mph)”. **to:** “Any traffic signal with limited approach visibility, or where approach speeds exceed 80 Km/h (50 mph)”.

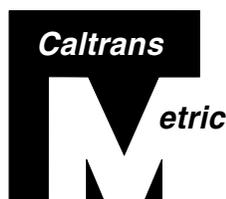
ATTENTION: This hard copy version as well as other chapters of the Traffic Manual may not reflect new or revised policies of the Department of Transportation. To get the latest updates to the entire Traffic Manual, see the "Traffic Operations Program Directive and Policy Memos" web page at <<http://www.dot.ca.gov/hq/traffops/signtech/signdel/policy/policy.htm>>.

TRAFFIC MANUAL

CHAPTER 9

TRAFFIC SIGNALS AND LIGHTING

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November, 2002

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pretimed signal or a background-cycle-controlled actuated signal, a left turn volume of more than two vehicles per approach per cycle for a peak hour; or for a traffic-actuated signal, 50 or more left turning vehicles per hour in one direction with the product of the turning and conflicting through traffic during the peak hour of 100,000 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 is a large percentage of buses and trucks.

9-01.4 Removal of Existing Signals

Changes in traffic patterns may result in a situation where a traffic signal is no longer justified. When this occurs, consideration should be given to removing the traffic signal and replacing it with appropriate alternative traffic control devices.

9-01.5 Bicycle Signals

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

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

A separate signal phase for bicycle movement will be used. Alternative means of handling conflicts between bicycles and motor vehicles shall be considered first. Two alternatives that should be considered are:

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

A bicycle signal phase will 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.

Bicycle Signal Warrant

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

1. *Volume.* When $W = B \times V$ and $W \geq 50,000$ and $B \geq 50$.

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.

Traffic Signal Design 9-03

9-03.1 Introduction

The design of traffic signals by the California Department of Transportation (Caltrans) is based upon the following publications:

1. Traffic Manual (Caltrans)
2. Standard Specifications (Caltrans)
3. Standard Plans (Caltrans)
4. Signal and Lighting Design Guide (Caltrans)
5. Ramp Meter Design Guidelines (Caltrans)
6. Highway Design Manual (Caltrans)
7. Manual on Uniform Traffic Control Devices for Streets and Highways (FHWA)

Additional references that may be used include:

1. Transportation and Traffic Engineering Handbook, Institute of Traffic Engineers (ITE)
2. Manual of Traffic Signal Design (ITE)
3. Traffic Control Systems Handbook (FHWA)
4. Traffic Control Systems Standards, National Electrical Manufacturers Association (NEMA)
5. Traffic Control Devices Handbook (FHWA)

9-03.2 Selection of Traffic Signal Operation

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

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

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

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

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

9-03.3 Selection of Left-Turn Phasing

There are various methods to signalize left turn movements. See Figure 9-11.

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.

9-03.4 Simultaneous or Dual Left

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.

9-03.5 Lead-Lag

This operation can be either pretimed or traffic-actuated.

Normally, "Lead-Lag" phasing should be considered for coordinated signals when the offset timing determined by the system time-space diagram results in the arrival of the two directions of traffic at different times during a cycle. This will provide the most efficient progressive band.

9-03.6 Opposite or Opposing

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. 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.

9-03.7 Three Phase Operation

Three phase operation can be either pretimed or traffic-actuated.

9-03.8 Permissive Left-Turn Phasing

This type of operation allows vehicles to make left turns during a fully-protected interval with a green arrow indication, or to make a permissive left

turn with a circular green indication when there are adequate gaps in opposing traffic. Permissive left turn phasing may be either pre-timed or traffic actuated. Examples of the operation may be found in the Traffic Control Devices Handbook (FHWA).

There are normally two sequences that can be utilized with permissive left turn phasing:

1. *Protected-Permissive.*

With this operation, left turn traffic is first directed to turn left on the display of a green arrow and then permitted to turn during the nonprotected interval on the display of a circular green.

2. *Permissive-Protected.*

With this operation, the left turn traffic is first permitted to turn during the nonprotected interval on the display of a circular green and then directed to turn left on the display of a green arrow.

The advantages of this operation when compared to fully-protected left turn phasing only are:

1. Reduces delay as left turn drivers may have an opportunity to make their left turns during the green interval or yellow change interval for through traffic.
2. Allows the use of shorter cycle lengths in coordinated systems by reducing the time of the fully protected green interval for the left turn movement.
3. Less chance of disrupting traffic in adjacent through lanes as left turn queues are less likely to exceed the length of the left turn lane.

When a protected-permissive or permissive-protected left-turn phasing operation is used for a signal system on a State highway, no information sign is necessary. If a sign is used, it shall be a R73-7, LEFT TURN YIELD ON GREEN (Green Ball symbol) sign on State highways.

Public agencies having jurisdiction may use an extinguishable message sign on local roads in place of the R73-7, on their local roads that are not part of an intersection with a State highway. The message shall say LEFT TURN YIELD in at least 150 mm high letters. The light source shall be designed and constructed so that when illuminated, the message shall be white and remain dark when not in use. The message shall be illuminated only when the green permissive ball is lighted.

The following shall apply to permissive left-turn phasing:

1. This operation shall not be initiated where the left turn accident warrant is satisfied.
2. Signal faces should not be placed in a median facing a left turn lane.
3. Signs are not required for this operation unless U-turns are to be prohibited.
4. Both directions of through traffic shall be terminated simultaneously except where opposing left turns or opposing U-turns are prohibited.

9-03.9 Location of Controller Cabinets

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

1. It should not be vulnerable to traffic.

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

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.

9-03.10 Vehicle Signal Faces and Indications

Arrangement of vehicle signal faces shall conform to the Manual on Uniform Traffic Control Devices (FHWA). Normally, each vehicle signal face will consist of at least three sections. Some of the exceptions are that a single section with a green arrow lens may be used to indicate a continuous movement and a 2-section (red, green) face may be used for ramp metering.

Signal lenses shall be a minimum of 200 mm in diameter. Arrow indications and flashing beacons (except those used in ramp metering) shall have lenses 300 mm in diameter. Mast arm mounted, span-wire mounted and signal bridge mounted indications should have lenses 300 mm in diameter.

9-03.11 Number of Signal Faces

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

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

1. The area is rural.
2. The area is urban and the signal is the first one on a particular highway.
3. The roadway is striped for two or more approach lanes.
4. Where visibility of the signal is affected by alignment or obstructions.

9-03.12 Location of Signal Faces

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. The signal faces for two or more approaches can often be combined on a single standard. However, 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. It may be necessary to locate signal faces on separate standards whenever the curb return radius is greater than 3 m. Where additional signal faces are required, they may be suspended from a mast arm.

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

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

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

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

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

9-03.13 Arrow Indications

A green arrow indication shall be used only to allow vehicular movements which are completely protected from conflict with other vehicles moving on a green indication or with pedestrians crossing in conformance with a walk interval or pedestrian clearance interval.

A red arrow indication shall be used only in a separate signal face which also contains yellow arrow and green arrow indications. A red arrow indication may be used where it is desired to prohibit right-turn-on-red or left-turn-on-red.

9-03.14 Left-Turn Arrows

A left-turn green arrow indicates that a left-turn may be made without conflict from opposing traffic. Normally, protected only left-turn phasing requires the use of three-section signal faces. The sections should have lenses as follows: red arrow, yellow arrow and green arrow.

Protected-permissive or permissive-protected (with full-traffic-actuated operation) left-turn phasing requires the use of five-section signal faces. Normally the far left sections should be arranged vertically. See "m" in Figure 4-1 of the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD). The mast arm indication shall be arranged in cluster or stacked ("s" or "m" in Figure 4-1 of the MUTCD). The five sections shall have lenses as follows: circular red, circular yellow, circular green, yellow arrow and green arrow. The cluster or stack arrangement shall not be used for protected only left-turn phasing.

9-03.15 Right-Turn Arrows

The right-turn green arrow indicates that traffic may make the indicated right-turn without conflict from opposing traffic. It is usually displayed simultaneously with a circular red, circular yellow, or circular green indication or another green arrow indication.

When a right-turn green arrow is to be displayed during the nonconflicting left-turn green interval of the cross street, the U-turn on the cross street shall be prohibited.

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.

A right-turn yellow arrow shall be shown following a right turn green arrow when a circular red or a right-turn red arrow is to follow.

9-03.16 Vertical Green Arrows

A vertical green arrow indicates that traffic may proceed straight through an intersection but shall not turn right or left. It shall not be displayed simultaneously in the same face with a circular red.

9-03.17 Mounting Heights - Vehicle Signal Faces

The bottom of bracket mounted and post-top mounted vehicle signal faces, including left turn signal faces on the far left corner, should be not less than 3 m above the roadway, sidewalk or median grade.

Mounting heights for vehicle signal faces are shown in the Standard Plans.

9-03.18 Signal Face Visibility Control

It is always desirable to limit the visibility of specific signal indications to only those drivers and pedestrians that they are intended to regulate. Some visibility control is provided by proper positioning of a signal face to:

1. Assist mechanical light control devices such as louvers or visors; and
2. Associate the indication with the controlled traffic movement.

However, there are instances where additional visibility control is required. Applications of such control may be classified into lateral (lane or approach) separation and longitudinal (distance) separation.

Examples of conditions where lateral separation should be considered are:

1. Adjacent parallel roadways; and
2. Acute angle intersections.

Examples of conditions where longitudinal separation should be considered are:

1. Closely-spaced intersections;
2. Offset intersections; and
3. Intersections with wide medians.

Devices available for limiting or controlling signal indication visibility include louvers, programmed visibility signal sections, and long visors.

Programmed visibility signal sections can provide either lateral or longitudinal separation. Typical locations or conditions in which they should be considered are at adjacent signalized intersections that are 90 m or less apart or at intersections angled at less than 45 degrees. In order that programmed visibility signal faces function properly, it is important that they be properly located relative to the approach lanes they are intended to control. The proper relationship is available from the manufacturer.

9-03.19 Backplates

Backplates should be installed on all mast arm mounted signal faces, all far median left turn signals, all far right signal faces, and on those signal faces that are in front of a background that could be confused with or could distract from the signal.

9-03.20 Pedestrian Signal Faces

Signal design must provide for or prohibit pedestrian movements. Pedestrians are better controlled by pedestrian signal faces rather than vehicular signal faces. This is because pedestrian signal faces used with appropriate pedestrian timing intervals provide adequate crossing and clearance times and in addition reduce the possibility of pedestrians unnecessarily blocking the intersection by entering a crosswalk near the end of a vehicle green interval.

Pedestrian signal faces should be installed under the conditions listed in Section 4D-3 of the MUTCD.

9-03.21 Types of Pedestrian Signal Faces

Pedestrian signal faces at new signal installations on State highways shall be the international symbol type as shown in the MUTCD, i.e., the WALKING PERSON and the upraised HAND.

Existing "WALK - WAIT" signal faces may continue to be kept in operation. However, they should be replaced as a part of a major modernization project.

9-03.22 Mounting Height - Pedestrian Signal Faces

The bottom of the housing for a pedestrian signal face should be not less than 2.1 m, nor more than 3.0 m, above the sidewalk grade.

9-03.23 Detectors

The proper operation of a traffic-actuated signal is dependent upon the appropriate type and proper placement of vehicle and pedestrian detectors.

9-03.24 Vehicle Detectors

The types and applications of vehicle detectors currently used include the following:

1. *Inductive Loop.*

The inductive loop detector, because of its presence feature, detects a standing vehicle as well as a moving one. The detection area is roughly that enclosed by the loop.

2. *Magnetometer.*

The magnetometer detector detects a standing vehicle, as well as a moving one, and has a detection area up to 1 m in diameter over each sensing element.

3. *Magnetic.*

The magnetic detector detects only vehicles moving in excess of 8 km/h. One sensing element covers one or two traffic lanes.

4. *Pressure-Sensitive.*

No new installations are to be made. Existing units shall be replaced with loop, magnetometer or magnetic types when:

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

5. *Video Detection.*

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.

The normal installation of inductive loop and magnetometer detectors requires sound pavement if the detector is to operate reliably. 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. Typical installation details for inductive loop and magnetometer detectors are shown on the Standard Plans.

The longitudinal location (setback) of detectors relative to the limit line depends on the speed of traffic and the type of detector operation desired. Suggested setbacks are shown in Table 9-1.

9-03.25 Pedestrian Detectors

Where required, pedestrian push buttons should be located convenient to the corresponding crosswalk so as to encourage their use by both pedestrians and people in wheelchairs. Push buttons should be located not more than 1.5 m from the crosswalk and should be placed on signal poles if they are adjacent to the crosswalk area. Separate pedestrian push-button posts should be used when the signal poles are more than 1.5 m from the crosswalk.

9-03.26 Bicycle Detectors

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

A Type D loop configuration shown on Standard Plan ES-5B is effective for detecting bicycles and small motorcycles and shall be installed at the bicycle loop detector locations. Loop detectors shall not be placed within a pedestrian crosswalk or where it could conflict with pedestrian traffic.

The loop detector logo shown on Standard Plan A24C may be used to show a bicyclist where to stop in a bike lane or traffic lane to be detected. The logo should be applied to the pavement in the center of the Type D loop.

See Figure 9-12 for suggested locations of bicycle detectors and the Standard Plans for typical bike lane pavement markings.

9-03.27 Signal Plan Schedules

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

1. Pole and Equipment Schedule.

A pole and equipment schedule shows the types of standards, mast arm lengths, types and mounting for vehicle and pedestrian signal faces, and other equipment. See Figure 9-23 and the Standard Plans.

2. Conductors and Conduit Schedule.

A conductor and conduit schedule shows the size of each conduit run, and the size, type and number of conductors or cables in each conduit run. See Figure 9-24.

Dimensions of conductors and conduit and data for determining conduit size are shown in Tables 9-8 and 9-9.

9-03.28 Preemption

At some signal locations, it is necessary to preempt the normal traffic signal operation by a railroad train, an emergency vehicle or bus/transit vehicles.

The order of priority for various types of preemption shall be:

1. Railroad
2. Emergency Vehicle
3. Bus/Transit Vehicles

9-03.29 Railroad Preemption

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

Typical circumstances where railroad preemption is required and the type of signal operation to be provided during preemption are as follows:

1. Where a railroad grade crossing, provided with grade crossing warning equipment, is within 60 m of a signalized intersection, preemption of the traffic signal should provide the following sequence of operation:
 - a. A yellow change interval and any required red clearance interval for any signal phase that is green or yellow when preemption is initiated and which will be red during the track clearance interval. The length of yellow change and red clearance intervals shall not be altered by preemption. Phases which are in the green interval when preemption is initiated, and which will be green during the track clearance interval, shall remain green. Any pedestrian walk or clearance interval, in effect when preemption is initiated, shall immediately be terminated and all pedestrian signal faces shall display steady DONT WALK or upraised HAND.
 - b. A track clearance interval for the signal phase or phases controlling the approach which crosses the railroad tracks. The signal indication for the clearance interval may be either green or flashing red.
 - c. A yellow change interval if green signal indications were provided during the track clearance interval.
 - d. Depending on traffic requirements and phasing of the traffic signal controller, the traffic signal may then do one of the following:

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

9-03.30 Emergency Vehicle Preemption

Traffic signals on State highways may be preempted by authorized emergency vehicles. 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.

Emergency vehicle preemption should provide the following sequence of operation:

1. A yellow change interval and any required red clearance interval for any signal phase that is green or yellow when preemption is initiated and which will be red during the preemption interval. The length of the yellow change and red clearance intervals shall not be altered by preemption. Phases which are in the green interval when preemption is initiated and which will be green during the preemption period shall remain green. Any pedestrian walk interval in effect when preemption is initiated shall be immediately terminated. The normal pedestrian clearance interval may be abbreviated.
2. An all-red intersection preemption display shall not be used.
3. The traffic signal shall return to normal operation upon termination of the demand for preemption or the termination of the assured green interval.

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

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

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

When performed by a local agency, the installation of emergency vehicle preemption equipment shall be covered by an Encroachment Permit issued by the 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 may be revoked or changed as deemed advisable or necessary by Caltrans.
2. The timing 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 timing requested by Caltrans.
3. The Permittee shall assume all liability for the claims which arise due to or because of the permit.

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.

The State will 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.

9-03.31 Bus/Transit Vehicle Priority

The requirements for bus/transit vehicle priority insofar as installation, encroachment permit, maintenance and funding are the same as stated above for emergency vehicle preemption.

The equipment and operation requirements for bus/transit vehicle priority shall be similar to those above for emergency vehicle priority. Some exceptions to these requirements are:

1. Equipment requirements for the transmitter are set forth in Section 25352 of the California Vehicle Code.
2. Any pedestrian interval in effect when priority is initiated shall not have its timing affected.
3. Normally, bus/transit priority should not occur more than once every other signal cycle.

9-03.32 Modification of Existing Signals

Where existing signals are to be modified, it is desirable that the construction plans include a separate plan of the existing system as well as a plan showing the modifications. 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.

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.

9-03.33 Signals on Poles Owned by Others

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. In such cases, it is necessary to 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 responsible for moving the equipment in the event the pole is removed or relocated.

9-03.34 Additional Capacity at Signalized Intersections

When the vehicular volume on a two-lane State highway is large enough to warrant traffic signals, usually there will be considerable congestion after the signals are installed unless the State highway is widened to four lanes at the intersection. Sometimes, it is also necessary to widen the intersecting road.

Where possible, the State highway approaches and local road approaches should be widened to two lanes for through traffic, for a minimum of 60 m for traffic approaching the intersection and for a minimum of 100 m for traffic leaving the intersection. Additional widening for tapered sections should be provided at the ends of the added lanes. It may be necessary to prohibit parking in these areas and/or to provide left turn lanes. See Section 9-02.4 for financing.

9-03.35 Temporary Signals for Haul Roads or One-Way Traffic Control in Construction Zones1. *General.*

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.

2. *Requirements.*

Each plan for temporary signals should include the equipment details as well as the following operating requirements:

- a. Temporary signals shall meet the design standards described earlier in this section.
- b. Signal faces, detectors and control equipment are to be kept in good operating condition at all times.
- c. When not in use, portable signals are to be removed from the vicinity of the highway and fixed signals are to be placed in flashing operation with yellow indications for the highway and red indications for the haul road.
- d. Timing of the signals will be determined by the Agency having jurisdiction.
- e. A SIGNAL AHEAD (W41) sign (and flashing beacon, if required) is to be placed on each approach of the highway in advance of the signal.
- f. Haul road signals shall be operated using manual control or vehicle detectors. The operation shall provide a green indication to the haul road only if the contractor's equipment is approaching the crossing. The haul road green interval shall not exceed 10 seconds and the highway green interval shall not be less than 20 seconds, unless specific permission is given in writing. A 3-second, minimum, yellow change interval, and any required red clearance interval, shall follow each green interval.
- g. One-way traffic control signals may utilize pretimed or traffic-actuated controller units, or may be manually controlled. A 3-second, minimum, yellow change interval shall follow each green interval. An all-red clearance interval shall follow each yellow change interval. The all-red clearance interval shall permit a vehicle to travel the length of the one-way lane before a green indication is shown to opposing traffic.
- h. Failure to comply with any of the above or other specified conditions will be justification for revoking the permit.

3. *Equipment Details.*

Fixed temporary traffic signals shall be designed for 120-volt operation, while portable temporary signals may be battery operated.

The vehicle signal faces shall be the standard 3-section type with no less than two separate signal faces for each approach, including the haul road approaches.

The signal faces shall be mounted a minimum of 3 m above the roadway and directed so that the indications are readily seen by traffic. The signal faces for highway traffic shall be equipped with backplates.

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

9-03.36 Lane-Use Control Signals

Lane-use control signals are special overhead signals having indications used to permit or prohibit the use of specific lanes of a street or highway or to indicate the impending prohibition of use.

Lane-use control signals shall conform to the requirements in Part IV of the MUTCD.

9-03.37 Ramp Metering Signals

Traffic control signals may be installed on freeway entrance ramps to control the flow of traffic entering the freeway facility.

Ramp metering control signals shall conform to the requirements in Part IV of the MUTCD and Caltrans Ramp Meter Design Guidelines.

9-03.38 Signals at Movable Bridges

Signals installed at movable bridges are a special type of highway traffic signal, the purpose of which is to notify traffic to stop because of a road closure rather than alternately giving the right of way to conflicting traffic movements. They are operated in coordination with the opening and closing of the movable bridges. Unlike traffic control signals, movable bridge signals may be operated frequently or at extremely infrequent intervals depending upon waterway traffic. Signals at movable bridges shall conform to the requirements in Part IV of the MUTCD.

Traffic Signal Operations 9-04

9-04.1 Introduction

The California Department of Transportation is responsible for the operation of all State highway traffic signals, regardless of whether the signal is maintained by the State or by others. State highway traffic signals shall include, but are not necessarily limited to, all signals on a State highway and at ramp connections to local streets. Maintenance and operation of highway traffic signals involving State Highways by an agency other than the California Department of Transportation shall require a jointly approved written agreement.

9-04.2 Review of Traffic Signal Operations

All State highway 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 should be notified, and after corrective work is done, further surveillance should be conducted to be sure no deficiency remains. If a need for a design change is observed, an analysis should be made to determine what improvement might be necessary to improve the design.

Improvements to consider are:

1. Timing of:
 - a. Maximums or Force Offs
 - b. Gap Interval
 - c. Offsets
 - d. Cycle Length

2. Time-of-Day or Traffic Responsive Settings
3. Signal Phasing or Phase Sequence
4. Type of Operation
5. Coordination of Signals
6. Signs, Striping and/or Pavement Markings
7. Roadway Improvements

Initial timing of traffic signals and any subsequent changes in timing shall be the responsibility of Traffic Operations. Timing records shall be kept and be readily available to maintenance and traffic operations staff and other agencies, where appropriate.

Aids for timing are shown in Tables 9-2, 9-3, 9-4, 9-5, 9-6 and 9-7.

9-04.3 Signals at Interchanges

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. Tables 9-3 and 9-4 are guides to be used to determine the timing of traffic signals at diamond interchanges. These tables should be used in conjunction with Table 9-2 to determine the timing of the splits and offsets for diamond interchange signals.

The decision whether to use pretimed or traffic-actuated operation is dependent not only upon traffic conditions in the interchange area, but also upon traffic conditions along the cross street. For example, a coordinated traffic signal system along the cross street may require that the signals at the interchange be coordinated with the cross street progression.

9-04.4 Timing of Green Intervals

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.

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

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.

9-04.5 Yellow Change Intervals

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

The length of the yellow change interval is dependent upon the speed of approaching traffic. Suggested yellow intervals are shown below and are calculated by using the formula as shown in Table 9-1:

Approach Speed mph (km/h)	Yellow Interval (seconds)
25 or less (40 or less).....	3.0
30 (48).....	3.2
35 (56).....	3.6
40 (64).....	3.9
45 (72).....	4.3
50 (80).....	4.7
55 (89).....	5.0
60 (97).....	5.4
65 (105).....	5.8

9-04.6 Red Clearance Intervals

Red clearance intervals which follow yellow change intervals are not required, but may be considered where any of the following conditions exist: intersections that are wide, offset or contain unusual geometry; intersections where the visibility of conflicting traffic is blocked or limited; movements where the approach speeds are 88 km/hr (55 mph) or more; or where it is desirable to help clear vehicles that recurrently become queued in the intersection where there are permissive left turns. Normally, red clearance intervals range from 0.01 to 2.0 seconds and should not exceed 6 seconds.

9-04.7 Operation of Pedestrian Indications

Pedestrian signal faces shall be operated so as to display three indications: Steady WALKING PERSON or “WALK”, flashing upraised HAND or “DONT WALK”, and steady upraised HAND or “DONTWALK”. The flashing indication is displayed following the walk interval.

The total pedestrian crossing time shall consist of the walk interval plus the pedestrian clearance time obtained by using a walking rate of 1.2 m/s. Under normal conditions, the walk interval should be at least four seconds in length. On an undivided highway, the pedestrian clearance time should be no less than the time required to walk from the curb to the center of the farthest traveled lane before opposing vehicles receive a green indication.

On a street with a median sufficient for a pedestrian to wait, the pedestrian clearance time should be no less than the time required to walk from the curb to the median before opposing vehicles receive a green indication.

Pedestrian signal indications should normally be operated in conjunction with a vehicle phase. Pedestrian signals shall be turned off during flashing operation of vehicle signal faces.

9-04.8 Audible Pedestrian Signals1. *General.*

Audible Pedestrian Signals may be installed at signalized intersection crosswalks. These devices supplement visual WALK indications and are designed to aid visually impaired pedestrians. The installation of Audible 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.

It is recommended that the audible devices selected emit a “Cuckoo” walk sound for a crosswalk in the North-South direction and a “Peep-Peep” walk sound for a crosswalk in the East-West direction.

2. *Financing.*

The cost of installing Audible Pedestrian Signals shall be shared with the local agency in the same manner as a traffic signal. See Section 9-02.4.

9-04.9 Continuity of Operation

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 portable signal.

When a traffic signal at an intersection or pedestrian crossing is not to be in operation for a planned, extended period of time, the signal faces should be hooded, turned away from traffic or removed.

Refer to the Highway Maintenance Manual for procedures to provide traffic controls at signalized intersections during planned or unplanned utility company power outages.

9-04.10 Flashing Operation

Flashing operation may be used prior to placing the signal in automatic stop-and-go operation or when required by seasonal traffic conditions. During flashing operation, red/yellow or all red indications may be used.

Pretimed or semi-traffic-actuated traffic signals may be operated in a flashing mode at night. Flashing yellow operation for the major street in a coordinated signal system reduces control of vehicle speed. If such speed control is desired, properly spaced signals should remain in automatic stop-and-go operation.

Actuated signals at an isolated intersection should never be operated in a flashing mode except during emergencies, the operation of a conflict monitoring device, or during railroad preemption.

The emergency mode of operation for all traffic signals shall be flashing operation.

**Table 9-1
SUGGESTED DETECTOR SETBACKS FROM LIMITLINE**

Deceleration Rate $d = 3.05$ m per second²

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

Deceleration Distance $= \frac{1}{2}dt^2$ or $\frac{1}{2}Vt$ or $\frac{V^2}{2d}$

Reaction Time $r = 1.00$ second

Reaction Distance $= Vr$

Total Time = Deceleration Time + Reaction Time $= t + r$ or $\frac{V}{d} + r$

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

Yellow Interval $T = r + \frac{V}{2d}$

V = Speed (meter per second)

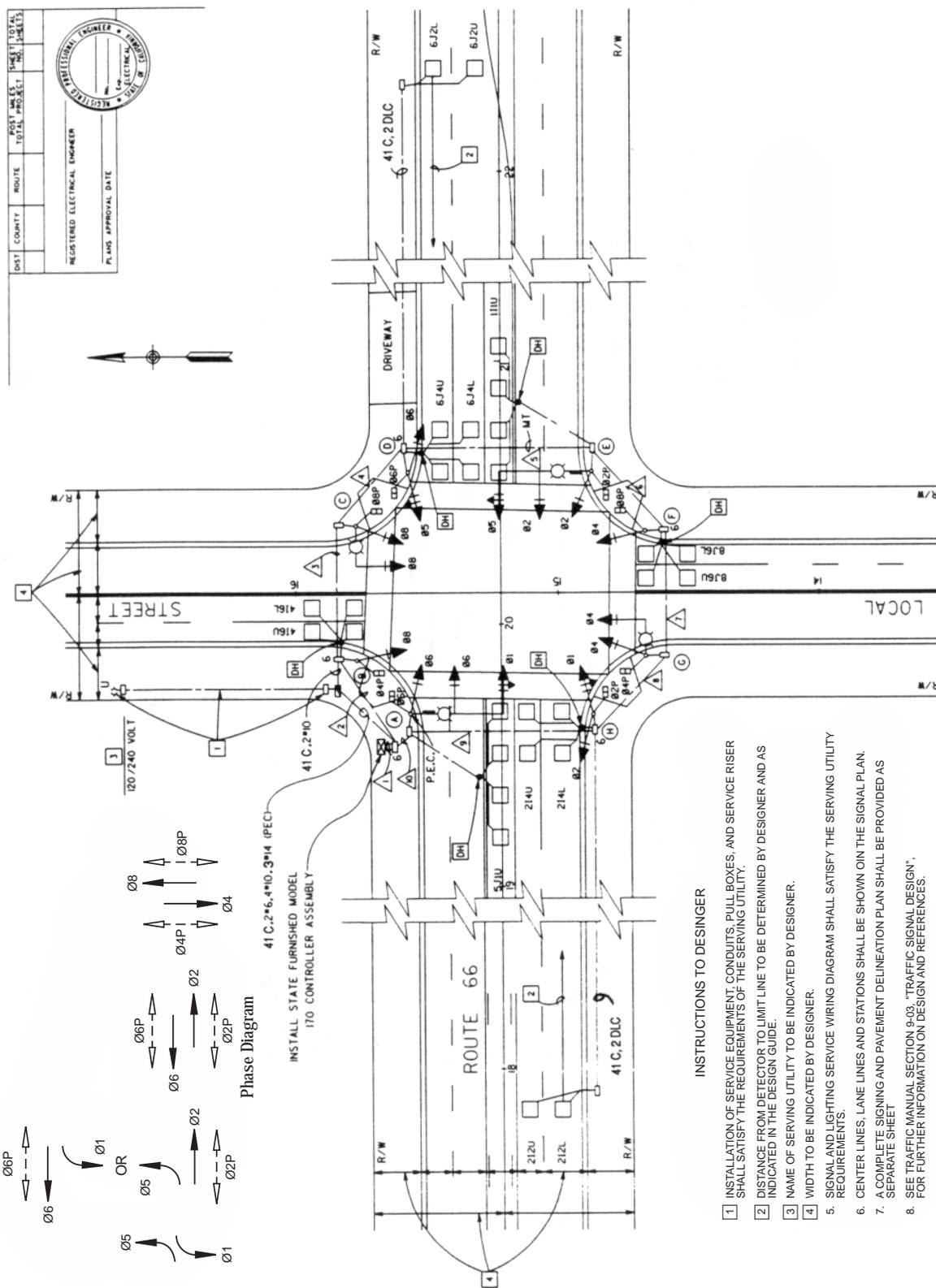
d = Deceleration Rate (meter per second²)

t = Deceleration Time (seconds)

T = Yellow Interval (seconds)

SPEED			DEC. TIME	DEC. DIST.	TOTAL TIME	DETECTOR SETBACKS	
mph	km/h	m/s				ACTUAL	SUGGESTED
mph	km/h	m/s	Seconds	Meters	Seconds	Meters	Meters
25	40	11.18	3.67	20.49	4.67	31.67	30
30	48	13.42	4.40	29.51	5.40	42.93	45
35	56	15.65	5.13	40.17	6.13	55.82	55
40	64	17.89	5.87	52.46	6.87	70.35	70
45	72	20.13	6.60	66.40	7.60	86.52	85
50	80	22.36	7.33	81.97	8.33	104.33	105
55	89	24.60	8.06	99.18	9.06	123.78	125
60	97	26.83	8.80	118.04	9.80	144.87	145
65	105	29.07	9.53	138.53	10.53	167.60	170
70	113	31.29	10.27	160.50	11.27	191.79	190

Figure 9-22
TYPICAL TRAFFIC SIGNAL INSTALLATION



INSTRUCTIONS TO DESIGNER

1. INSTALLATION OF SERVICE EQUIPMENT, CONDUITS, PULL BOXES, AND SERVICE RISER SHALL SATISFY THE REQUIREMENTS OF THE SERVING UTILITY.
2. DISTANCE FROM DETECTOR TO LIMIT LINE TO BE DETERMINED BY DESIGNER AND AS INDICATED IN THE DESIGN GUIDE.
3. NAME OF SERVING UTILITY TO BE INDICATED BY DESIGNER.
4. WIDTH TO BE INDICATED BY DESIGNER.
5. SIGNAL AND LIGHTING SERVICE WIRING DIAGRAM SHALL SATISFY THE SERVING UTILITY REQUIREMENTS.
6. CENTER LINES, LANE LINES AND STATIONS SHALL BE SHOWN ON THE SIGNAL PLAN.
7. A COMPLETE SIGNING AND PAVEMENT DELINEATION PLAN SHALL BE PROVIDED AS SEPARATE SHEET.
8. SEE TRAFFIC MANUAL SECTION 9-03, "TRAFFIC SIGNAL DESIGN", FOR FURTHER INFORMATION ON DESIGN AND REFERENCES.

NOTE: This plan accurate for electrical work only.

Flashing Beacons 9-05

9-05.1 Introduction

Typical applications for flashing beacons include the following:

1. Signal Ahead
2. Stop Signs
3. Speed Limit Signs
4. Other Warning and Regulatory Signs
5. Schools
6. Fire Stations
7. Intersection Control
8. Freeway Bus Stops
9. At Intersections Where a More Visible Warning is Desired

A flashing beacon is one or more traffic signal sections with a flashing indication in each section. Because the effectiveness of flashing beacons has not been consistent from one location to another, the decision whether or not to install a flashing beacon should not be based solely upon the guidelines listed in this section.

Flashing beacons to be installed on a State highway shall conform to the following requirements:

1. Lenses should be 300 mm in diameter, except that lenses for flashing beacons at bus stops, stop sign flashing beacons, speed limit sign flashing beacons and beacons used in connection with ramp metering may be 200 mm in diameter.
2. A dimming device shall be used to reduce the

brilliance of yellow flashing beacons during nighttime operation.

3. Two-section flashing yellow beacons may be connected to flash alternately or simultaneously.

9-05.2 Signal Ahead Flashing Beacons

Yellow flashing beacons may be used with SIGNAL AHEAD (W41) signs in advance of:

1. An isolated traffic signal on either a conventional highway or on an expressway in a rural area.
2. The first traffic signal approaching an urban area.
3. Any traffic signal with limited approach visibility, or where approach speeds exceed 80 km/h (50 mph).

9-05.3 Design

On divided highways where the median is 2.5 m wide, or greater, the installation may consist of:

1. Two Type 1 standards, each with a W41 sign and a 300 mm signal face, with one standard located in the median and the other off of the right shoulder; or
2. A Type 9 cantilever flashing beacon installation with a W41 or W41A sign and two 300 mm signal faces as shown in the Standard Plans.

The above installation designs may result in noncompliance with the 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 the Highway Design Manual and the current instructions pertaining to exceptions from mandatory and advisory design standards.

On undivided highways or on highways where the median is less than 2.5 m wide, the installation may consist of a single standard located off of the right shoulder as described for use on divided highways, or it may be a Type 9 cantilever flashing beacon installation.

9-05.4 Financing

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. See Section 9-02.6.

9-05.5 Warning or Regulatory Sign Flashing Beacons

Flashing beacon shall be used only to supplement an appropriate warning or regulatory sign or marker.

Typical applications include:

1. Obstructions in or immediately adjacent to the roadway.
2. Supplemental to advance warning signs.
3. At mid-block crosswalks.
4. At intersections where a warning is appropriate.

The beacon should be operated only during those hours when the necessity for the warning or regulation exists.

9-05.6 Financing

The cost of installing a Warning or Regulatory Sign Flashing Beacon on a State highway shall be at 100% State expense.

9-05.7 Flashing Beacons at School Crosswalks

Flashing beacons at school crosswalks may be installed on State highways in accordance with Sections 21372 and 21373 of the California Vehicle Code. See Chapter 10 of this Manual for additional guidelines and also Section 9-02.6, Case I.

9-05.8 Speed Limit Sign Flashing Beacons

A Speed Limit Sign Flashing Beacon may be installed on a State highway for use in connection with a fixed or variable speed limit sign. The size and location of the circular yellow lenses are described in the MUTCD. 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.

9-05.9 Intersection Control Flashing Beacons

An Intersection Control Flashing Beacon consists of one or more signal sections, with a flashing circular yellow or circular red indication in each face. Application of Intersection Control Flashing Beacons shall be limited to:

1. Yellow indications on one route (normally the major roadway) and red indications for the remaining approaches; or
2. Red indications for all approaches.

New installations of overhead intersection control flashing beacons shall consist of red indications for each approach.

A stop sign shall be used on each approach with a flashing red indication.

Basic intersection lighting should be installed at intersections where an Intersection Control Flashing Beacon is to be installed.

9-05.10 Financing

The cost of installing an Intersection Control Flashing Beacon and intersection lighting shall be shared with the local agency in the same manner as a traffic signal. See Section 9-02.6.

9-05.11 Flashing Beacons for Fire Stations

Flashing beacons at fire station driveways or at intersections immediately adjacent to a fire station may be installed on State highways. The flashing beacon shall be used only to supplement an appropriate warning or regulatory sign. The flashing beacon shall be actuated from a non-illuminated condition by a switch at the fire station.

9-05.12 Financing

The costs of installing and maintaining the flashing beacon for the fire station shall be at 100% local agency or fire department expense.

9-05.13 Stop Sign Flashing Beacons

A Stop Sign Flashing Beacon consists of one or two signal sections with a flashing circular red indication in each section. The bottom of the housing of a Stop Sign Flashing Beacon shall be not less than 305 mm nor more than 610 mm above the top of the stop sign.

9-05.14 Financing

The cost of installing a Stop Sign Beacon shall be shared with the local agency in the same manner as a traffic signal. See Section 9-02.6.

9-05.15 Flashing Beacons at Bus Stops on Freeway Interchanges

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.

9-05.16 Design and Operations

The following design and operational requirements shall be met:

1. 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.
2. The flashing beacon shall consist of an 200 mm, signal section with an uncolored or white lens mounted on the lighting standard in such a position that it can be seen by an approaching bus driver on the freeway.
3. 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.

9-05.17 Financing

The costs of installing and maintaining Flashing Beacons at Bus Stops on Freeway Interchanges shall be at 100% State expense.

9-11.4 Slip Bases

Slip bases shall be used under Types 30 and 31 standards and under Type 15 standards on freeways, expressways and conventional highways where speeds are in excess of 64 km/h. Exceptions to this policy are that slip bases are not used under lighting standards upon which signals are mounted or under lighting standards located:

- a. On or behind structures, retaining walls or barrier railing;
- b. In sidewalk areas;
- c. Behind guardrail;
- d. More than 9 m from traveled way; or
- e. Where pedestrians would be close enough to be endangered by a pole knockdown.

Luminaires 9-12

9-12.1 General

Normally, the luminaire for a new installation of safety lighting on State highways is a full-cutoff type using a high pressure sodium lamp.

9-12.2 Roadway Luminaires

On freeways, 200-watt lamps shall be used with 9.14 m mounting heights and 310-watt lamps shall be used with 12.19 m mounting heights. On conventional highways and at the intersections of freeway ramps with surface streets, 150-watt lamps shall be used with 9.14 m mounting heights.

Utility owned semi-cutoff type luminaires should be provided with glare shields in rural areas.

9-12.3 Soffit Luminaires

Soffit luminaires are special fixtures either suspended from or flush-mounted into structures to illuminate the roadway under the structure. They shall be used with 70 or 100 watt high-pressure sodium lamps, depending upon lighting requirements. Normally, the fixtures should not be located over the traveled way on freeways.

9-12.4 Wall Luminaires

Wall luminaires are fixtures designed to be surface mounted on vertical surfaces. However, a simple right angle bracket permits mounting them from a horizontal surface such as the bottom slab of a box girder. They are used with the same lamps as soffit luminaires.

9-13.6 Conduit on Structures

Conduits should be run either parallel to or at right angles to the structure girders. A variation of ± 15 degrees is acceptable.

Except for sidewalk joints, a conduit expansion fitting should be installed at each structure joint, hinge or abutment where a longitudinal movement of 12 mm or greater may occur. Where a lateral movement of 6 mm or greater may occur, an expansion-deflection fitting should be installed. Details for placement of expansion fittings and expansion-deflection fittings are shown in the Standard Plans.

9-13.7 Pull Boxes

Pull boxes should be installed to limit the length of conductor pull, to provide a point where conduits can be branched and/or conductors can be spliced and to simplify access to standards, poles and cabinets.

9-13.8 Installation of Pull Boxes

Pull Boxes should be installed:

1. At 60 m, or less, spacing in conduit runs;
2. At locations where conduits branch;
3. Adjacent to the foundation for each signal standard, lighting standard, illuminated sign, controller cabinet or service cabinet; and
4. At the toe of slope or at the hinge point when placed on a slope.

Pull boxes should not be installed in the traveled way if it can be avoided. When it is necessary to

install them in the traveled way, the box, cover and foundation should be capable of supporting heavy wheel loading.

9-13.9 Pull Box Size

The minimum size of pull boxes for various applications should be as follows:

1. Signal or Lighting Conduits	No. 5
2. Adjacent to Signal or Lighting Standards	No. 5
3. Adjacent to Controller Cabinet	No. 6
4. Adjacent to Service Cabinet	No. 5
5. Detector Termination	No. 5
6. With 4, or more, Conduits	No. 6
7. Telephone Conduits	No. 5

Pull boxes with transformers should be provided with extensions.

9-13.10 Wiring

The dimensions of conductors normally used in traffic signal and highway lighting circuits are shown in Table 9-9. The values shown in the table may be used to calculate conduit fill.

9-13.11 Voltage Drop

The conductors between the service point and the load (lamps, ballasts, controller cabinets, etc.) should be sized to limit the voltage drop to less than 5%.

The resistance (ohms per 1,000 m) of conductors commonly used in traffic signal and highway lighting circuits is shown in Table 9-9. The values shown are based on an ambient temperature of 75° C.

Voltage drop can be calculated using:

$$\text{Volts Drop} = 2ILR$$

Where: I = Current
L = Length of Conductor
R = Resistance of Conductor
(1,000 m)

If the voltage drop is known, the following formula can be used to determine the minimum conductor size:

$$R = \text{Volts Drop} \div 2IL$$

Example: The allowable voltage drop for a 380 m run feeding a 6.5 ampere load is 12 volts.

$$R = 12 \div (2)(6.5)(.38) = 2.43$$

From Table 9-9, the minimum wire size is No. 6.

9-13.12 Circuit Voltages

Traffic signal and flashing beacon control equipment normally is designed to operate on a 120-volt AC circuit.

A 120-volt or 240-volt circuit is normally used for highway lighting circuits. For very large lighting circuits, a 480-volt circuit may be required.