

## PART IV. SIGNALS

### A. GENERAL

#### 4A-1 Types

A highway traffic signal is any power-operated traffic control device, other than a barricade warning light or steady burning electric lamp, by which traffic is warned or directed to take some specific action.

The following types and uses of highway traffic signals are discussed in this part of the Manual: traffic control signals, pedestrian signals, beacons, lane-use control signals, traffic control at moveable bridges, priority control of traffic signals and traffic signals for one-lane, two-way facilities.

#### 4A-2 Basis of Installation

In most cases the installation of a highway traffic signal will operate either to the advantage or disadvantage of the vehicles and persons controlled. A careful analysis of traffic operations and other factors at a large number of signalized and unsignalized intersections, coupled with the judgment of experienced engineers, have provided a series of warrants that define the minimum conditions under which signal installations may be justified. Consequently the selection and use of this control device should be preceded by a thorough engineering study of roadway and traffic conditions.

Engineering studies should be made of operating signals to determine if the type of installation and the timing program meet the current requirements of traffic.

#### 4A-3 Definitions Relating to Signals

The following terms are used throughout Part IV:

1. Signal Face—that part of a highway traffic signal which controls one or more traffic movements in a single direction.
2. Signal Head—an assembly of one or more signal faces.
3. Signal Lens—that part of the optical unit which redirects the light coming directly from the light source and its reflector, if any.
4. Signal Indication—the illumination of a signal lens or equivalent device.



## **B. TRAFFIC CONTROL SIGNALS**

### **4B-1 General Aspects**

A traffic control signal (traffic signal) is a type of highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.

Traffic control signals are sometimes described as either pretimed or traffic-actuated. Under pretimed control the red, green, and yellow intervals are predetermined. Under traffic-actuated control, these intervals are varied continuously according to traffic demands.

The features of traffic control signals in which vehicle operators and pedestrians are interested are the location, design, indications, and legal significance of the signals. These are identical for all types of traffic control signals. Uniformity in the design features that affect the traffic to be controlled (as set forth in this Manual) is especially important for safe and efficient traffic operations.

Special police supervision and/or enforcement should be provided for a new non-intersection location.

### **4B-2 Area of Control**

A traffic control signal shall control traffic only at the intersection or mid-block location where the installation is placed.

### **4B-3 Advantages and Disadvantages of Traffic Control Signals**

Traffic control signals are valuable devices for the control of vehicle and pedestrian traffic. However, because they assign the right-of-way to the various traffic movements, traffic signals exert a profound influence on traffic flow.

Traffic control signals, properly located and operated, usually have one or more of the following advantages:

1. They can provide for the orderly movement of traffic.
2. Where proper physical layouts and control measures are used, they can increase the traffic-handling capacity of the intersection.
3. They can reduce the frequency of certain types of accidents, especially the right-angle type.
4. Under favorable conditions, they can be coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route.
5. They can be used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

Many laymen believe that traffic signals provide the solution to all traffic problems at intersections. This has led to their installation at a large number of locations where no legitimate factual warrant exists.

Traffic signal installations, even though warranted by traffic and roadway conditions, can be illdesigned, ineffectively placed, improperly operated, or poorly maintained. The following factors can result from improper or unwarranted signal installations:

1. Excessive delay may be caused.
2. Disobedience of the signal indications is encouraged.
3. The use of less adequate routes may be induced in an attempt to avoid such signals.
4. Accident frequency (especially the rear-end type) can be significantly increased.

#### **4B-4 Portable Traffic Control Signals**

A portable traffic control signal must meet the physical display and operational requirements of conventional traffic signals described herein. A portable traffic control signal should normally not operate longer than 30 days unless associated with a construction or maintenance project, in which case it shall be removed when no longer needed on the project. It is desirable to use advance signing when employing this device. A portable traffic control signal should be used only when an engineering study so indicates.

#### **4B-5 Meaning of Signal Indications**

Unless otherwise determined by law, the following meanings shall be given to highway traffic signal indications, except those on pedestrian signals:

1. Green indications shall have the following meanings:
  - (a) Traffic, except pedestrians, facing a CIRCULAR GREEN may proceed straight through or turn right or left except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, or roadway design. But, vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfully within the intersection or an adjacent crosswalk, at the time such signal indication is exhibited.
  - (b) Traffic, except pedestrians, facing a GREEN ARROW, shown alone or in combination with another indication, may cautiously enter the intersection only to make the movement indicated by such arrow, or such other movement as is permitted by other indications shown at the same time. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

(c) Unless otherwise directed by a pedestrian signal, pedestrians facing any green indication, except when the sole green indication is a turn arrow, may proceed across the roadway within any marked or unmarked crosswalk.

2. Steady yellow indications shall have the following meanings:

(a) Traffic, except pedestrians, facing a steady CIRCULAR YELLOW or YELLOW ARROW signal is thereby warned that the related green movement is being terminated or that a red indication will be exhibited immediately thereafter when vehicular traffic shall not enter the intersection.

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

3. Steady red indications shall have the following meanings:

(a) Vehicular traffic facing a steady CIRCULAR RED signal alone shall stop at a clearly marked stop line, but if none, before entering the crosswalk on the near side of the intersection, or if none, then before entering the intersection and shall remain standing until an indication to proceed is shown except as provided in (c) below.

(b) Vehicular traffic facing a steady RED ARROW signal shall not enter the intersection to make the movement indicated by the arrow and, unless entering the intersection to make a movement permitted by another signal, shall stop at a clearly marked stop line, but if none, before entering the crosswalk on the near side of the intersection, or if none, then before entering the intersection and shall remain standing until an indication permitting the movement indicated by such red arrow is shown except as provided in (c) below.

(c) Except when a sign is in place prohibiting a turn, vehicular traffic facing any steady red signal may cautiously enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping as required by (a) and (b) above. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

(d) Unless otherwise directed by a pedestrian signal, pedestrians facing a steady CIRCULAR RED or RED ARROW signal alone shall enter the roadway.

4. Flashing signal indications shall have the following meanings:

(a) Flashing red (stop signal)—When a red lens is illuminated with rapid intermittent flashes, drivers of vehicles shall stop at a clearly marked stop line, but if none, before entering the crosswalk on the near side of the intersection, or if none, at the point nearest the intersecting roadway

where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection, and the right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.

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

#### **4B-6 Application of Signal Indications**

Basic displays used in signal operations are the steady CIRCULAR RED, CIRCULAR YELLOW, or CIRCULAR GREEN indication, used on each of the approaches. The application for these signal indications shall be as follows:

1. A steady CIRCULAR RED indication:

(a) Shall be given when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal, from entering the intersection or other controlled area. (See sec. 4B-5(3)(c).)

(b) Should be displayed with the appropriate green arrow 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 controlled area. This display is not required where it is physically impossible for traffic to go straight ahead, as at the head of a "T" intersection.

2. A steady CIRCULAR YELLOW indication:

(a) Shall be given following a CIRCULAR GREEN indication in the same signal face, except if the signal face controls an exclusive left turn lane and the CIRCULAR GREEN indication is to be followed by a GREEN ARROW indication.

(b) Is an optional alternative to a yellow arrow indication following a green arrow indication in a separate signal face used exclusively to control a single directional movement.

3. A steady CIRCULAR GREEN indication shall be given only when it is intended to permit traffic to proceed in any direction which is lawful and practical.

4. Steady RED ARROW, YELLOW ARROW and GREEN ARROW indications may be used in lieu of the corresponding circular indications at the following locations:

(a) On an approach intersecting a one-way street.

(b) Where certain movements are prohibited.

(c) Where certain movements are physically impossible.

(d) On an intersection approach which has an exclusive lane for turning movements.

(e) Where turning movements are "protected" from conflicting movements by other indications or by the signal sequence.

(f) Where all the movements on the approach do not begin or end at the same time and where the indications for the turning movements will also be visible to traffic with other allowable movements.

5. Steady arrow indications are used as follows:

(a) A steady YELLOW ARROW indication shall be used following a GREEN ARROW indication which has been displayed simultaneously with a CIRCULAR RED indication in the same signal face. A GREEN ARROW need not be terminated by a displayed interval if a CIRCULAR GREEN permitting the turn to continue on a permissive basis is displayed in the same signal face simultaneously with the GREEN ARROW or immediately following the GREEN ARROW termination.

IV-27 (c)  
Rev. 3

(b) A steady YELLOW ARROW indication or optional CIRCULAR YELLOW shall follow a GREEN ARROW indication in a signal face which is used exclusively to control a single directional movement.

Editorial  
Change  
Rev. 4

(c) A steady YELLOW ARROW indication may be used to indicate the clearance interval following the termination of a GREEN ARROW indication which has been displayed simultaneously with a continuing CIRCULAR GREEN indication in the same signal face.

(d) A steady GREEN ARROW indication shall be used only to allow vehicular movements which are completely protected from conflict with other vehicles moving on a green or yellow indication or with pedestrians crossing in conformance with a WALK or flashing DONT WALK indication.

(e) A steady left GREEN ARROW indication shall be used as the green display on a signal face which controls an exclusive left turn lane, if that left turn movement is protected by the signal sequence.

(f) A YELLOW ARROW shall not be displayed when any conflicting movement has a CIRCULAR GREEN or CIRCULAR YELLOW.

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

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

IV-27 (c)  
Rev. 3

The above combinations shall not be simultaneously displayed in different signal faces on any one approach unless:

(a) One of the faces is a turn signal controlling only an exclusive turn lane and a sign LEFT (or RIGHT) TURN SIGNAL (sec. 4B-12(3)) is located adjacent to each such signal face.

(b) One of the faces is a turn signal controlling only an exclusive turn lane and consists entirely of arrow indications.

(c) The signal faces are shielded, hooded, louvered, positioned or designed so that the combination is not confusing to approaching drivers.

The following signal indications shall not be displayed on any signal face, either alone, or in combination with any other indication:

- (a) Straight-through RED ARROW
- (b) Straight-through YELLOW ARROW

IV-27 (c)  
Rev. 3

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

(a) A CIRCULAR YELLOW indication shall be flashed instead of any YELLOW ARROW indication which may be included in that signal face.

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

(c) All signal faces on an approach shall flash the same color of circular indication, except that left turn signal indications may be flashed CIRCULAR RED when adequately shielded or positioned so that through traffic on the approach will not be exposed to substantial visual conflict from the left turn signal indications. The flashing yellow signal indication for through traffic does not have to be shielded or positioned to prevent visual conflict for drivers in the left turn lane.

#### **4B-7 Number of Lenses per Signal Face**

Each signal face, except in pedestrian signals, shall have at least three lenses, but not more than five. The lenses shall be red, yellow or green in color, and shall give a circular or arrow type of indication. Allowable exceptions to the above are:

1. Where a single section green arrow lens is used alone to indicate a continuous movement.
2. As discussed under Unexpected Conflicts During Green or Yellow Interval (sec. 4B-16).
3. Where one or more indications are repeated for reasons of safety or impact.
4. Where a variable indication signal section is used to display alternately a green arrow and a yellow arrow.

IV-27 (c)  
Rev. 3

#### **4B-8 Size and Design of Signal Lenses**

The aspect of all signal lenses, except in pedestrian signals, shall be circular. There shall be two sizes for lenses, 8 inches and 12 inches nominal diameter.



Different sizes of lenses may be used in the same signal head except that an 8-inch red indication shall not be used in combination with 12-inch CIRCULAR GREEN or 12-inch CIRCULAR YELLOW indications.

1. Twelve inch lenses shall be used:

(a) For signal indications for approaches\* where drivers view both traffic control and lane use control signals simultaneously.

(b) Where the nearest signal face is between 120 feet and 150 feet beyond the stop line, unless a supplemental near side signal indication is used.

(c) For signal indications located more than 150 feet from the stop line (also see 4B-12.9).

2. Twelve-inch lenses shall be used for all signal approaches for which the minimum visibility distance requirements of Section 4B-12.1 cannot be met.

3. Twelve-inch lenses should be used for all signal indications for:

(a) Approaches with 85 percentile approach speeds exceeding 40 mph.

(b) Approaches where signalization might be unexpected.

(c) Arrows.

(d) All approaches with rural cross sections where only post mounted signals are used.

4. Twelve-inch lenses, or 12-inch red lenses, may be used for approaches where an engineering study indicates a need for extra visibility or target value.

Arrows shall be pointed vertically upward to indicate a straight-through movement and in a horizontal direction to indicate a turn at approximately right angles. When the angle of the turn is substantially different from a right angle, the arrow should be positioned on an upward slope at an angle approximately equal to that of the turn.

Each arrow lens shall show only one arrow direction. The alternate display of two arrow indications in the same lens, a green arrow or a yellow arrow, shall be permitted. The arrow shall be the only illuminated part of the lens visible.

In no case shall letters or numbers be displayed as part of a vehicular signal indication.

Except for the requirements of this section, all lenses shall conform to the Vehicle Traffic Control Signal Head Equipment Standards.\*\*

\*Approach definition: all lanes of traffic moving toward a location from one direction.

\*\* Available from the Institute of Transportation Engineers, see page iv.

#### 4B-9 Arrangement of Lenses in Signal Faces

The lenses in a signal face shall be arranged in a vertical or horizontal straight line, except that in a vertical array, lenses of the same color may be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement (fig. 4-1). Such clusters shall be limited to two identical lenses or to two or three different lenses of the same color.

In each signal face, all red lenses in vertical signals shall be located above, and in horizontal signals shall be located to the left of all yellow and green lenses.

A CIRCULAR YELLOW lens shall be located between the red lens or lenses and all other lenses.

In vertically arranged signal faces, each YELLOW ARROW lens shall be located immediately above the GREEN ARROW lens to which it applies. When a variable indication arrow lens (capable of showing either a green or a yellow arrow) is used, the lenses shall be in the same position relative to other lenses as are the GREEN ARROW lenses in a vertical signal face.

In horizontally arranged signals, the YELLOW ARROW lens shall be located immediately to the left of the GREEN ARROW lens. When a variable indication arrow lens (a green arrow and a yellow arrow) is used, the LEFT TURN ARROW lens shall be located immediately to the right of the CIRCULAR YELLOW lens, the STRAIGHT THROUGH ARROW lens shall be located immediately to the right of the CIRCULAR GREEN lens, and the RIGHT TURN ARROW lens shall be located to the right of all other lenses.

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

1. In a vertical signal face from top to bottom:

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

The location of the CIRCULAR GREEN below the Straight Through GREEN ARROW is an acceptable alternative, although the position of the CIRCULAR GREEN shown in the above tabulation is preferred.

2. In a horizontal signal face from left to right:

CIRCULAR RED  
Left turn RED ARROW

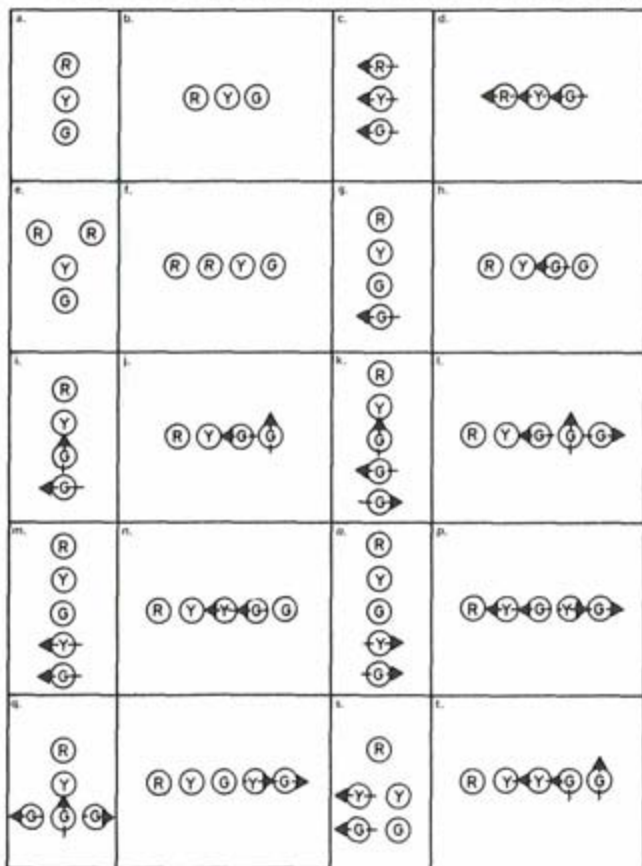
Right turn RED ARROW  
 CIRCULAR YELLOW  
 Left turn YELLOW ARROW  
 Left turn GREEN ARROW  
 CIRCULAR GREEN  
 Straight through GREEN ARROW  
 Right turn YELLOW ARROW  
 Right turn GREEN ARROW

IV-27 (c)  
 Rev. 3

3. In a cluster, identical signal indications may be repeated in adjacent vertical or horizontal locations within the same signal face. If adjacent indications in a cluster are not identical, their arrangement shall follow paragraph 1 or 2 above, as applicable.

Basic horizontal and vertical display faces may be used on the same approach provided they are separated to meet the lateral clearance required in section 4B-12.

Figure 4-1 shows more possible arrangements of lenses in signal faces.



IV-27(c)  
 Rev. 3

Figure 4-1. Typical arrangements of lenses in signal faces.

#### 4B-10 Illumination of Lenses

Each signal lens shall be illuminated independently.

The intensity and distribution of light from each illuminated signal lens should conform to the current editions of Vehicle Traffic Control Signal Head Equipment Standards \*, and A Standard for Traffic Signal Lamps \*.

IV-42 (c)  
Rev. 4

When 12-inch signals with 150 watt lamps are placed on flashing for nighttime operation and the flashing yellow indication is so bright as to cause excessive glare, an automatic dimming device should be used to reduce the brilliance of the flashing 12-inch yellow.

#### 4B-11 Visibility and Shielding of Signal Faces

Each signal face shall be so adjusted that its indications will be of maximum effectiveness to the approaching traffic for which they are intended.

Visors should be used on all signal faces to aid in directing the signal indication specifically to approaching traffic, as well as to reduce "sun phantom" resulting from external light entering the lens. A back-plate is a strip of thin material which extends outward parallel to the signal face, on all sides of the signal housing to increase the signal target value. Target value enhancement should be used on signals viewed against a sky or bright or confusing background.

In general, vehicular signal faces should be aimed so that the continuation of the optical axis of the signal passes through a point on the approach, which is located at least the minimum visibility distance from the stop line (specified in Section 4B-12.1) and at driver's eye height. If the approach sight distance is limited by horizontal or vertical alignment, the signals shall be aimed at a point on the approach at which the signal indication first becomes visible.

IV-42 (c)  
Rev. 4

Irregular street design frequently necessitates placing signals for different street approaches with a comparatively small angle between their indications. In these cases, each signal indication shall, to the extent practicable, be shielded or directed by visors, louvers, or other means so that an approaching driver can see only the indication controlling his movement. Tunnel visors exceeding 12 inches in length shall not be used on free-swinging signals.

The use of visors, or the use of signals or devices which direct the light without a reduction in intensity should be considered as an alternative to louvers due to the reduction in light output caused by louvers.

IV-42 (c)  
Rev. 4

The foregoing does not preclude the use of special signal faces such that the driver does not see their indications before seeing other indications, when simultaneous viewing of both signal indications could cause the driver to be misdirected.

\* Available from the Institute of Transportation Engineers, see page iv.

#### 4B-12 Number and Location of Signal Faces

The primary consideration in signal face placement shall be visibility. Drivers approaching a signalized intersection or other signalized area, such as a mid-block crosswalk, shall be given a clear and unmistakable indication of their right-of-way assignment. Critical elements are lateral and vertical angles of sight toward a signal face, as determined by typical driver eye position, vehicle design, and the vertical, longitudinal and lateral position of the signal face. The geometry of each intersection to be signalized, including vertical grades, horizontal curves, and obstructions should be considered in signal face placement.

IV-42(c)  
Rev. 4

The visibility, location and number of signal faces for each approach to an intersection of a mid-block crosswalk shall be as follows:

1. For through traffic, a minimum of two signal faces shall be provided, and should be visible to traffic approaching the signals, from a point at least the following "minimum visibility distance" indicated in Table 4-1, continuously, until the traffic reaches the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or there is another signalized intersection within this range.

Table 4-1

<i>85 Percentile Speed (mph)</i>	<i>Minimum Visibility Distance (ft.)</i>
20	175
25	215
30	270
35	325
40	390
45	460
50	540
55	625
60	715

IV-42 (c)  
Rev. 4

2. Where the visibility requirements in Table 4-1 cannot be met, a suitable sign shall be erected to warn approaching traffic. Such sign may be supplemented by a Hazard Identification Beacon (Section 4E-1), if drivers do not have a continuous view of at least one signal indication for the minimum visibility distance. A beacon used in this manner may be interconnected with the traffic signal controller in such a manner as to flash yellow during the period when drivers passing this beacon, at the legal speed for the roadway, may encounter a red signal upon arrival at the signalized location.

3. Where a turn signal is operated in the protected turn mode only, at least one signal face is required for the control of a single turn lane. Such a

signal face shall be in addition to the minimum of two signal faces for through-traffic. When the indications of a separate signal face or faces controlling only an exclusive turn lane will also be visible to traffic with other allowable movements, a sign LEFT (or RIGHT) TURN SIGNAL (sec. 2B-37) shall be located adjacent to each such signal face. When the face consists entirely of arrow indications, such a sign is not required. If two or more lanes are provided for the separately controlled turn movement, or if the turn movement represents the major movement from the approach, two signal faces should be provided.

IV-42 (c)  
Rev. 4

4. Except where the width of the intersecting street or other conditions make it physically impractical, at least one and preferably both of the signal faces required by paragraph (1) above shall be located not less than 40 feet nor more than 120 feet beyond the stop line. Where both of the signal faces required by paragraph (1) above 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 driver. The signal faces required by paragraph (3) above shall conform to the same location requirements as the signal faces required by paragraph (1) to the extent practical.

5. Except where the width of the intersecting street or other conditions make it physically impractical, at least one and preferably both of the signal faces required by paragraph (1) above shall be located between two lines intersecting with the center of the approach lanes at the stop line, one making an angle of approximately 20 degrees to the right of the center

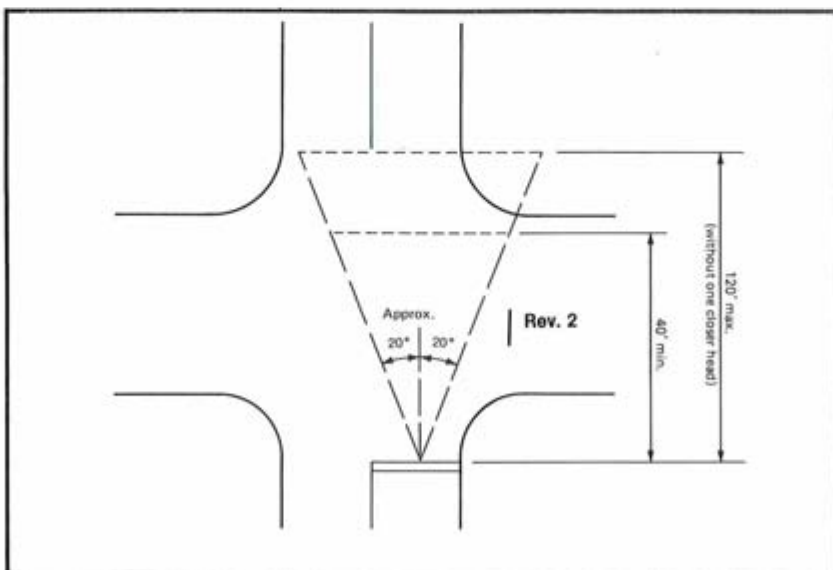


Figure 4-2. Desirable location of signal faces.

of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended (fig. 4-2). This requirement is to be applied simultaneously with paragraph (4) above.

6. Near-side signals should be located as near as practicable to the stop line.

7. Where a signal face controls a specific lane or lanes of approach, its position should make it readily visible to drivers making that movement.

IV-42(c)  
Rev. 4

8. Required signal faces for any one approach shall be not less than 8 feet apart measured horizontally between centers of faces.

9. Where the nearest signal face is 150 feet or more beyond the stop line, a supplemental near-side signal face shall be used.

IV-42(c)  
Rev. 4

10. A signal face mounted on a span wire or mast arm should be located as near as practicable to the line of the driver's normal view.

11. Supplemental signal faces should be used when an engineering study has shown that they are needed to achieve both advance and immediate intersection visibility. When used, they should be located to provide optimum visibility for the movement to be controlled. The following limitations apply:

- (a) Left turn arrows shall not be used in near-right faces.
- (b) Right turn arrows shall not be used in far-left faces. A far-side median mount signal shall be considered as a far-left signal for this application.

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

The transverse location of a signal face, shall, if mounted on the top of a post or on a short bracket from it, conform with section 4B-14.

Supplementary pedestrian signals shall be used where warranted as provided in section 4D-3.

If a signal face(s) displays control for a particular vehicular movement during any interval of a sequence, it must display control for that same movement during all intervals of the sequence.

IV-27 (c)  
Rev. 3

#### 4B-13 Height of Signal Faces

The bottom of the housing of a signal face, not mounted over a roadway, shall not be less than 8 feet nor more than 15 feet above the sidewalk or, if none, above the pavement grade at the center of the highway, except that the bottom of center median, near-side signal faces may be mounted at a minimum of 4½ feet above the median island grade.

The bottom of the housing of a signal face suspended over a roadway shall not be less than 15 feet nor more than 19 feet above the pavement grade at the center of the roadway.

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

#### **4B-14 Transverse Location of Traffic Signal Supports and Controller Cabinets**

In the placement of signal supports, primary consideration shall be given to ensuring the proper visibility of signal faces as described in sections 4B-12 and 13. However, in the interest of safety, signal supports and controller cabinets should be placed as far as practicable from the edge of the traveled way without adversely affecting signal visibility.

Supports for post-mounted signal heads at the side of a street with curbs shall have a horizontal clearance of not less than 2 feet from the face of a vertical curb. Where there is no curb, supports for post-mounted signal heads shall have a horizontal clearance of not less than 2 feet from the edge of a shoulder, within the limits of normal vertical clearance. A signal support should not obstruct a crosswalk.

No part of a concrete base for a signal support should extend more than 4 inches above the ground level at any point, except that this limitation does not apply to the concrete base for a rigid (non-breakaway) support.

On medians, the above minimum clearances for signal supports should be obtained where practicable. Any supports which cannot be located with the required clearances should be of the breakaway type or should be guarded if at all practicable.

#### **4B-15 Vehicle Change Interval**

A yellow vehicle change interval shall be used, where applicable, following each CIRCULAR GREEN or GREEN ARROW interval, as discussed in section 4B-6(2) and (4). In no case shall a CIRCULAR YELLOW indication be displayed in conjunction with the change from CIRCULAR RED to CIRCULAR GREEN.

The exclusive function of the steady yellow interval shall be to warn traffic of an impending change in the right-of-way assignment.

Yellow vehicle change intervals should have a range of approximately 3 to 6 seconds. Generally the longer intervals are appropriate to higher approach speeds.

The yellow vehicle change interval may be followed by a short all-way red clearance interval, of sufficient duration to permit the intersection to clear before cross traffic is released.

A clearance interval shall be provided between the termination of a GREEN ARROW indication and the showing of a green indication to any conflicting traffic movement.



A YELLOW ARROW shall not be terminated by a GREEN ARROW. It may be terminated by a CIRCULAR GREEN if the movement controlled by the arrow is to continue on a permissive basis, or by a CIRCULAR YELLOW, CIRCULAR RED, or RED ARROW.

IV-27 (c)  
Rev. 3

#### **4B-16 Unexpected Conflicts During Green or Yellow Interval**

No movement that may involve an unexpected crossing of pathways of moving traffic should be indicated during any green or yellow interval, except when:

IV-27 (c)  
Rev. 3

1. The movement involves only slight hazard;
2. Serious traffic delays are materially reduced by permitting the conflicting movement; and
3. Drivers and pedestrians subjected to the unexpected conflict are effectively warned thereof.

When such conditions of possible unexpected conflict exist, warning may be given by a sign or by the use of an appropriate signal indication as set forth in section 4B-7. The foregoing applies to vehicle-pedestrian conflicts as well as to vehicle-vehicle conflicts.

#### **4B-17 Coordination of Traffic Control Signals**

Traffic control signals within  $\frac{1}{2}$  mile of one another along a major route or in a network of intersecting major routes should be operated in coordination, preferably with interconnected controllers. However, coordination need not be maintained across boundaries between signal systems which operate on different time cycles. Coordinated operation normally should include both pre-timed signals and traffic-actuated signals within the appropriate distances.

For coordination with railroad grade crossings signals see section 8C-6.

#### **4B-18 Flashing Operation of Traffic Control Signals**

All traffic signal installations shall be provided with an electrical flashing mechanism supplementary to the signal timer. A manual switch, or where appropriate, automatic means, shall be provided to actuate the flashing mechanism. The signal timer shall be removable without affecting the flashing operation. The mechanism shall operate in a manner similar to that of an Intersection Control Beacon (sec. 4E-3) to provide intermittent illumination of selected signal lenses.

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

When traffic control signals are put on flashing operation, the signal indications given to the several streets shall be as specified in section 4B-6(7).

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

The change from the flashing to stop-and-go operation, or from stop-and-go to flashing operation by manual switch may be made at any time.

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

#### **4B-19 Continuity of Operation**

A traffic signal installation, except as provided below, shall be operated as a stop-and-go device or as a flashing device.

When a signal installation is not in operation, such as prior to placing it in service, during seasonal shutdowns, or when it is not desirable to operate the signals, they should be hooded, turned or taken down to clearly indicate that the signal is not in operation.

When a traffic signal installation is being operated in the usual (stop-and-go) manner, at least one indication in each signal face shall be illuminated.

When a traffic signal is being operated as a flashing device, all signal faces on an approach shall be flashed.

The above provisions do not apply to emergency traffic signals, movable bridge signals or ramp control signals.

When a single-section, continuously illuminated GREEN ARROW lens is used alone to indicate a continuous movement, it may be continuously illuminated when the other signal indications in the signal installation are flashed.

#### **4B-20 Signal Operation Must Relate to Traffic Flow**

Traffic control signals shall be operated in a manner consistent with traffic requirements. Data from engineering studies shall be used to determine the proper phasing and timing for a signal.

Since traffic flows and patterns change, it is necessary that the engineering data be updated and re-evaluated regularly.

To assure that the approved operating pattern including timing is displayed to the driver, regular checks including the use of accurate timing devices should be made.

#### **4B-21 Traffic Signals Near Grade Crossings**

When a railroad-highway grade crossing with active traffic control devices is within or near a highway intersection controlled by traffic control signals, the two signal systems should be interconnected as provided in section 8C-6.

#### **4B-22 Priority Control of Traffic Signals**

Traffic control signals may be modified in timing, sequence, or display to grant priority control to authorized special classes of vehicles, (such as emergency, transit, construction, trains, boats, etc.). When the display of a traffic control signal is modified to grant priority control, change or clearance intervals shall be provided (4B-15, 4D-7). A distinctive indication may be provided at the intersection to show that an emergency vehicle has achieved control of the traffic signal (Uniform Vehicle Code 11-106).

Priority control of traffic signals may also be applicable in specialized nonintersection locations as a means of assigning priority right-of-way to specified classes of vehicles (such as on the approaches to one-lane bridges and tunnels, drawbridges, highway maintenance and construction activities, metered freeway entrance ramps, and transit operations).

Traffic signals operating under priority assignment should be operated in a manner designed to keep traffic moving. Prolonged all-red or flashing signal sequences are to be avoided.

When a priority sequence is initiated, the display may proceed from steady yellow to steady green. This exception does not apply to the termination of priority or to any display during priority operation.

IV-27 (c)  
Rev. 3

#### **4B-23 Maintenance of Traffic Control Signals**

Prior to the installation of any traffic control signal, the responsibility for its maintenance should be clearly established. The responsible agency should provide for the maintenance of the signal and all of its appurtenances in a responsible manner. To this end the agency should:

1. Provide for alternate operation of the signal during a period of failure, either on flash or manually, or by having manual traffic direction by proper authority as may be warranted by traffic volumes or congestion, or by erecting other traffic control devices.
2. Have properly skilled maintenance available without undue delay for all emergency calls, including lamp failures.
3. Provide properly skilled maintenance for all components.
4. Maintain the appearance of the installation in a manner consistent with the intention of this Manual, with particular emphasis on painting and on cleaning of the optical system.

5. Service equipment and lamps as frequently as experience proves necessary to prevent undue failures.

6. Provide adequate stand-by equipment to minimize the interruption of signal operation due to equipment failure.

Every controller should be kept in effective operation in strict accordance with its predetermined timing schedule.

A careful check of the correctness of time operation of the controller should be made frequently enough to insure its operating in accordance with the planned timing schedule. Timing changes should be made only by authorized persons. A written record should be made of all timing changes.

Controllers should be carefully cleaned and serviced at least as frequently as specified by the manufacturer and more frequently if experience proves it necessary.

#### **4B-24 Painting**

The insides of visors (hoods) and the entire surface of louvers, and fins, and the front surface of backplates shall have a dull black finish to minimize light reflection to the side of the signals.

To obtain the best possible contrast with the visual background, it is desirable to paint signal head housings highway yellow.

#### **4B-25 Vehicle Detectors**

The placement of vehicle detectors in the roadway in relation to the Stop line is a very important factor in the proper operation of traffic-actuated signals and should be a factor in signal design.

Where the total entering traffic on one street is more than twice that on the cross street, detectors on the cross street should be placed closer to the stop line than on the main street.

Additional "ceiling" detectors may be required on lower volume streets to handle traffic entering the street from driveways between the basic detector and the Stop line.

The transverse placement of detectors should be such that vehicles traveling away from the intersection do not register "false-calls." On narrow two-way roadways this may require use of directional detectors.

#### **4B-26 Auxiliary Signs**

Signal instruction signs (sec. 2B-37) used with traffic signals should be located adjacent to the signal face to which they apply. Minimum clearance of the total assembly shall conform to the provisions of sections 2A-23 and 4B-13.

Stop signs shall not be used in conjunction with any signal operation, except:

1. When the indication flashes red at all times or
2. When a minor street or driveway is located within or adjacent to the controlled area, but does not warrant separate signal control due to extremely low potential for conflict.

When used in conjunction with traffic signals, illuminated signs shall be designed and mounted in such a manner as to avoid glare and reflections that seriously detract from the signal indications. The traffic control signal shall be given dominant position and brightness to assure its target priority in the overall display.

Traffic Signal Speed signs (sec. 2D-48) may be used to inform drivers of the speed of progression in effect on streets in the signal system.

#### **4B-27 Removal of Confusing Advertising Lights**

There should be legal authority to prohibit the display of any unauthorized sign, signal, marking, or device which interferes with the effectiveness of any official traffic control device. Specific reference is made to Section 11-205, Uniform Vehicle Code (1968, Supp. II 1976).



## C. WARRANTS

### 4C-1 Advance Engineering Data Required

A comprehensive investigation of traffic conditions and physical characteristics of the location is required to determine the necessity for a signal installation and to furnish necessary data for the proper design and operation of a signal that is found to be warranted. Such data desirably should include:

1. The number of vehicles entering the intersection in each hour from each approach during 16 consecutive hours of a representative day. The 16 hours selected should contain the greatest percentage of the 24-hour traffic.

2. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, and public-transit vehicles), during each 15-minute period of the two hours in the morning and of the two hours in the afternoon during which total traffic entering the intersection is greatest.

3. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in paragraph (2) above and also during hours of highest pedestrian volume. Where young or elderly persons need special consideration, the pedestrians may be classified by general observation and recorded by age groups as follows:

- (a) under 13 years
- (b) 13 to 60 years
- (c) over 60 years.

4. The 85-percentile speed of all vehicles on the uncontrolled approaches to the location.

5. A conditions diagram showing details of the physical layout, including such features as intersectional geometrics, channelization, grades, sight-distance restrictions, bus stops and routings, parking conditions, pavement markings, street lighting, driveways, location of nearby railroad crossings, distance to nearest signals, utility poles and fixtures, and adjacent land use.

6. A collision diagram showing accident experience by type, location, direction of movement, severity, time of day, date, and day of week for at least one year.

The following data are also desirable for a more precise understanding of the operation of the intersection and may be obtained during the periods specified in (2) above:

- 1. Vehicle-seconds delay determined separately for each approach.

2. The number and distribution of gaps in vehicular traffic on the major street when minor-street traffic finds it possible to use the intersection safely.

3. The 85-percentile speed of vehicles on controlled approaches at a point near to the intersection but unaffected by the control.

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

Adequate roadway capacity at a signalized intersection is desirable. Widening of both the main highway and the intersecting roadway may be warranted to reduce the delays caused by assignment of right-of-way at intersections controlled by traffic signals. Widening of the intersecting roadway is often beneficial to operation on the main highway because it reduces the signal time that must be assigned to side-street traffic. In urban areas, the effect of widening can be achieved by elimination of parking at intersectional approaches. It is always desirable to have at least two lanes for moving traffic on each approach to a signalized intersection. Additional width may be necessary on the leaving side of the intersection, as well as the approach side, in order to clear traffic through the intersection effectively. Before an intersection is widened, the additional green time needed by pedestrians to cross the widened streets should be checked to ensure that it will not exceed the green time saved through improved vehicular flow.

#### **4C-2 Warrants for Traffic Signal Installation**

Traffic control signals should not be installed unless one or more of the signal warrants in this Manual are met. Information should be obtained by means of engineering studies and compared with the requirements set forth in the warrants. If these requirements are not met, a traffic signal should neither be put into operation nor continued in operation (if already installed).

For the purpose of warranting signalization, a wide-median intersection should be considered as one intersection.

When a traffic control signal is indicated as being warranted, it is presumed that the signal and all related traffic control devices and markings are installed according to the standards set forth in this Manual. It is further presumed that signal indications are properly phased, that roadways are properly designed, that adjacent traffic signals are properly coordinated, that there is adequate supervision of the operation and maintenance of the signal and all of its related devices, and that the traffic signal controller will be selected on the basis of engineering study and judgment.



An investigation of the need for traffic signal control should include where applicable, at least an analysis of the factors contained in the following warrants:

- Warrant 1—Minimum vehicular volume.
- Warrant 2—Interruption of continuous traffic.
- Warrant 3—Minimum pedestrian volume.
- Warrant 4—School crossings.
- Warrant 5—Progressive movement.
- Warrant 6—Accident experience.
- Warrant 7—Systems.
- Warrant 8—Combination of warrants.
- Warrant 9—Four Hour Volumes.
- Warrant 10—Peak Hour Delay.
- Warrant 11—Peak Hour Volume.

IV-43 (c)  
IV-20 (c)  
Rev. 4

#### 4C-3 Warrant 1, Minimum Vehicular Volume

The Minimum Vehicular Volume warrant is intended for application where the volume of intersecting traffic is the principal reason for consideration of signal installation. The warrant is satisfied when, for each of any 8 hours of an average day, the traffic volumes given in the table below exist on the major street and on the higher-volume minor-street approach to the intersection. An "average" day is defined as a weekday representing traffic volumes normally and repeatedly found at the location.

MINIMUM VEHICULAR VOLUMES FOR WARRANT 1

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		
1.....	1.....	500	150
2 or more.....	1.....	600	150
2 or more.....	2 or more.....	600	200
1.....	2 or more.....	500	200

These major-street and minor-street volumes are for the same 8 hours. During those 8 hours, the direction of higher volume on the minor street may be on one approach during some hours and on the opposite approach during other hours.

When the 85-percentile speed of major-street traffic exceeds 40 mph in either an urban or a rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the Minimum Vehicular Volume warrant is 70 percent of the requirements above.

#### 4C-4 Warrant 2, Interruption of Continuous Traffic

The Interruption of Continuous Traffic warrant applies to operating conditions where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or hazard in entering or crossing the major street. The warrant is satisfied when, for each of any 8 hours of an average day, the traffic volumes given in the table below exist on the major street and on the higher-volume minor-street approach to the intersection, and the signal installation will not seriously disrupt progressive traffic flow.

MINIMUM VEHICULAR VOLUMES FOR WARRANT 2

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		
1.....	1.....	750	75
2 or more.....	1.....	900	75
2 or more.....	2 or more.....	900	100
1.....	2 or more.....	750	100

These major-street and minor-street volumes are for the same 8 hours. During those 8 hours, the direction of higher volume on the minor street may be on one approach during some hours and on the opposite approach during other hours.

When the 85-percentile speed of major-street traffic exceeds 40 mph in either an urban or a rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the Interruption of Continuous Traffic warrant is 70 percent of the requirements above.

#### 4C-5 Warrant 3, Minimum Pedestrian Volume

The Minimum Pedestrian Volume warrant is satisfied when, for each of any 8 hours of an average day, the following traffic volumes exist:

1. On the major street, 600 or more vehicles per hour enter the intersection (total of both approaches); or where there is a raised median island 4 feet or more in width, 1,000 or more vehicles per hour (total of both approaches) enter the intersection on the major street; and
2. During the same 8 hours as in paragraph (1) there are 150 or more pedestrians per hour on the highest volume crosswalk crossing the major street.

When the 85-percentile speed of major-street traffic exceeds 40 mph in either an urban or a rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than

10,000, the Minimum Pedestrian Volume warrant is 70 percent of the requirements above.

A signal installed under this warrant at an isolated intersection should be of the traffic-actuated type with push buttons for pedestrians crossing the main street. If such a signal is installed at an intersection within a signal system, it should be equipped and operated with control devices which provide proper coordination.

Signals installed according to this warrant shall be equipped with pedestrian indications conforming to requirements set forth in other sections of this Manual.

Signals may be installed at nonintersection locations (mid-block) provided the requirements of this warrant are met, and provided that the related crosswalk is not closer than 150 feet to another established crosswalk. Curbside parking should be prohibited for 100 feet in advance of and 20 feet beyond the crosswalk. Phasing, coordination, and installation must conform to standards set forth in this Manual. Special attention should be given to the signal head placement and the signs and markings used at nonintersection locations to be sure drivers are aware of this special application.

#### **4C-6 Warrant 4, School Crossing**

A traffic control signal may be warranted at an established school crossing when a traffic engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of school children at the school crossing shows that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period (sec. 7A-3).

When traffic control signals are installed entirely under this warrant:

1. Pedestrian indications shall be provided at least for each crosswalk established as a school crossing.

2. At an intersection, the signal normally should be traffic-actuated. As a minimum, it should be semi-traffic-actuated, but full actuation with detectors on all approaches may be desirable. Intersection installations that can be fitted into progressive signal systems may have pretimed control.

3. At non-intersection crossings, the signal should be pedestrian-actuated, parking and other obstructions to view should be prohibited for at least 100 feet in advance of and 20 feet beyond the crosswalk, and the installation should include suitable standard signs and pavement markings. Special police supervision and/or enforcement should be provided for a new non-intersection installation.

#### **4C-7 Warrant 5, Progressive Movement**

Progressive movement control sometimes necessitates traffic signal installations at intersections where they would not otherwise be warranted, in order to maintain proper grouping of vehicles and effectively regulate group speed. The Progressive Movement warrant is satisfied when:

1. On a one-way street or a street which has predominantly unidirectional traffic, the adjacent signals are so far apart that they do not provide the necessary degree of vehicle platooning and speed control, or
2. On a two-way street, adjacent signals do not provide the necessary degree of platooning and speed control and the proposed and adjacent signals could constitute a progressive signal system.

The installation of a signal according to this warrant should be based on the 85-percentile speed unless an engineering study indicates that another speed is more desirable.

The installation of a signal according to this warrant should not be considered where the resultant signal spacing would be less than 1000 feet.

#### **4C-8 Warrant 6, Accident Experience**

The Accident Experience warrant is satisfied when:

1. Adequate trial of less restrictive remedies with satisfactory observance and enforcement has failed to reduce the accident frequency; and
2. Five or more reported accidents, of types susceptible to correction by traffic signal control, have occurred within a 12-month period, each accident involving personal injury or property damage to an apparent extent of \$100 or more; and
3. There exists a volume of vehicular and pedestrian traffic not less than 80 percent of the requirements specified either in the Minimum Vehicular Volume warrant, the Interruption of Continuous Traffic warrant, or the Minimum Pedestrian Volume warrant; and
4. The signal installation will not seriously disrupt progressive traffic flow.

Any traffic signal installed solely on the Accident Experience warrant should be semi-traffic-actuated (with control devices which provide proper coordination if installed at an intersection within a coordinated system) and normally should be fully traffic-actuated if installed at an isolated intersection.

#### **4C-9 Warrant 7, Systems Warrant**

A traffic signal installation at some intersections may be warranted to encourage concentration and organization of traffic flow networks. The Systems warrant is applicable when the common intersection of two or

more major routes has a total existing, or immediately projected, entering volume of at least 800 vehicles during the peak hour of a typical weekday, or each of any five hours of a Saturday and/or Sunday.

A major route as used in the above warrant has one or more of the following characteristics:

1. It is part of the street or highway system that serves as the principal network for through traffic flow;
2. It connects areas of principal traffic generation;
3. It includes rural or suburban highways outside, entering or traversing a city;
4. It has surface street freeway or expressway ramp terminals;
5. It appears as a major route on an official plan such as a major street plan in an urban area traffic and transportation study.

#### **4C-10 Warrant 8, Combination of Warrants**

In exceptional cases, signals occasionally may be justified where no single warrant is satisfied but where two or more of Warrants 1, 2, and 3 are satisfied to the extent of 80 percent or more of the stated values.

Adequate trial of other remedial measures which cause less delay and inconvenience to traffic should precede installation of signals under this warrant.

#### **4C-10.1 Warrant 9—Four Hour Volumes**

The Four Hour Volume Warrant is satisfied when each of any four 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 curve in Figure 4-7 for the existing combination of approach lanes.

IV-43 (c)  
Rev. 4

When the 85th percentile speed of the major street traffic exceeds 40 miles per hour or when the intersection lies within a built-up area of an isolated community having a population less than 10,000, the four hour volume requirement is satisfied when the plotted points referred to fall above the curve in Figure 4-8 for the existing combination of approach lanes.

#### **4C-10.2 Warrant 10, Peak Hour Delay**

The peak hour delay warrant is intended for application where traffic conditions are such that for one hour of the day minor street traffic suffers undue delay in entering or crossing the major street. The peak hour delay warrant is satisfied when the conditions given below exist for one hour (any four consecutive 15-minute periods) of an average weekday.

IV-20 (c)  
Rev. 4

The peak hour delay warrant is met when:

1. The total delay experienced by the 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 and five vehicle hours for a two-lane approach, and

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

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.

IV-20 (c)  
Rev. 4

#### **4C-10.3 Warrant 11, Peak Hour Volume**

The peak hour volume warrant is also intended for application when traffic conditions are such that for one hour of the day minor street traffic suffers undue traffic delay in entering or crossing the major street.

The peak hour volume warrant is satisfied when the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicle per hour of the higher volume minor street approach (one direction only) for one hour (any four consecutive 15-minute periods) of an average day falls above the curve in Figure 4-5 for the existing combination of approach lanes.

When the 85th percentile speed of major street traffic exceeds 40 mph or when the intersection lies within a built-up area of an isolated community having a population less than 10,000, the peak hour volume requirements is satisfied when the plotted point referred to above falls above the curve in Figure 4-6 for the existing combination of approach lanes.

IV-20 (c)  
Rev. 4

#### **4C-11 Factors Governing Selection of Type of Control**

The principal factors that may lead to the favorable consideration of traffic-actuated control in the selection of the type of signal control include:

1. Low, fluctuating or unbalanced traffic volumes.
2. High side street traffic volumes and delays only during the peak hours.
3. The pedestrian or accident warrant is the only warrant which is met.
4. The installation is to provide for one-way movement of two-way traffic.
5. The installation is at a non-intersection location.

#### **4C-12 Pedestrian-Actuated Control**

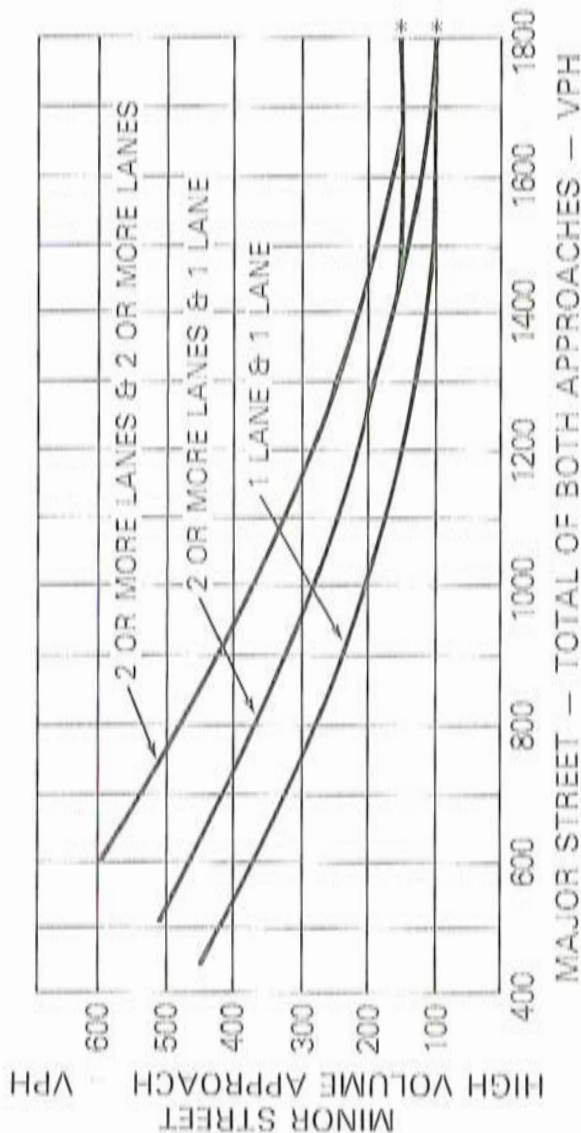
Operation of traffic-actuated signals must take into consideration the needs of pedestrians as well as vehicular traffic. This can be accomplished in the following ways:

1. When pedestrian signals are not warranted (sec. 4D-3) in conjunction with a traffic-actuated signal installation but where occasional pedestrian movement exists and there is inadequate opportunity to cross without undue delay, pedestrian detectors shall be installed and operated as prescribed in sections 4D-6 and 7.

2. When pedestrian signals are not otherwise warranted but a pedestrian movement exists which would not have adequate crossing time during the green interval, pedestrian signals and detectors shall be installed and operated as prescribed in sections 4D-6 and 7.

3. When pedestrian signals are warranted and installed in conjunction with a traffic-actuated signal, the operation should follow the patterns described in sections 4D-6 and 7.

FIGURE 4.5. PEAK HOUR VOLUME WARRANT

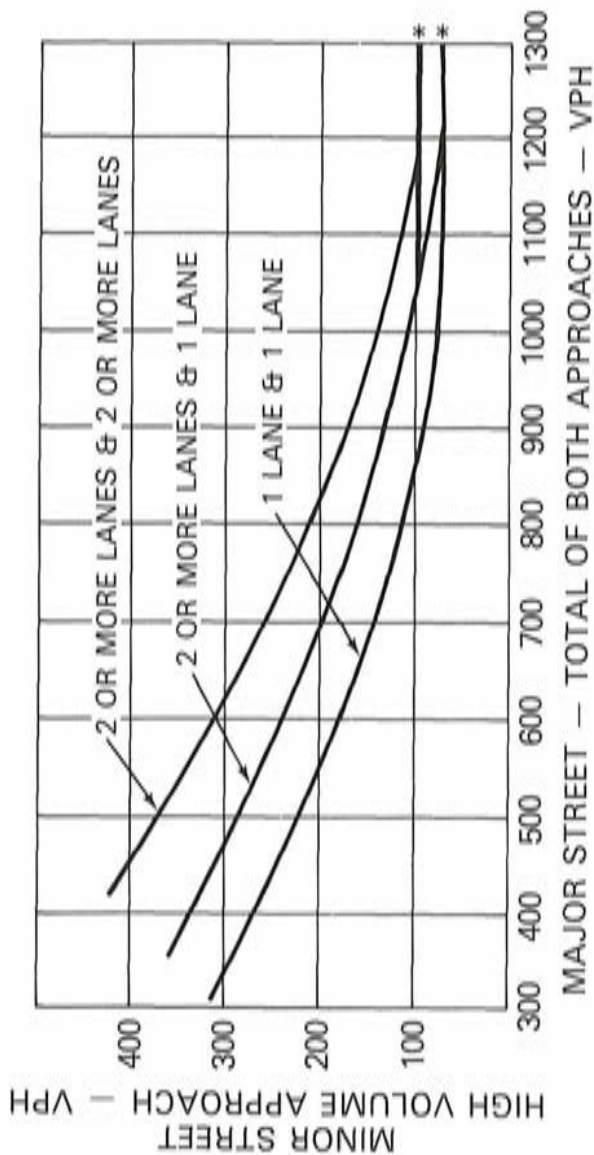


\*NOTE: 150 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACH WITH TWO OR MORE LANES AND 100 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACHING WITH ONE LANE.



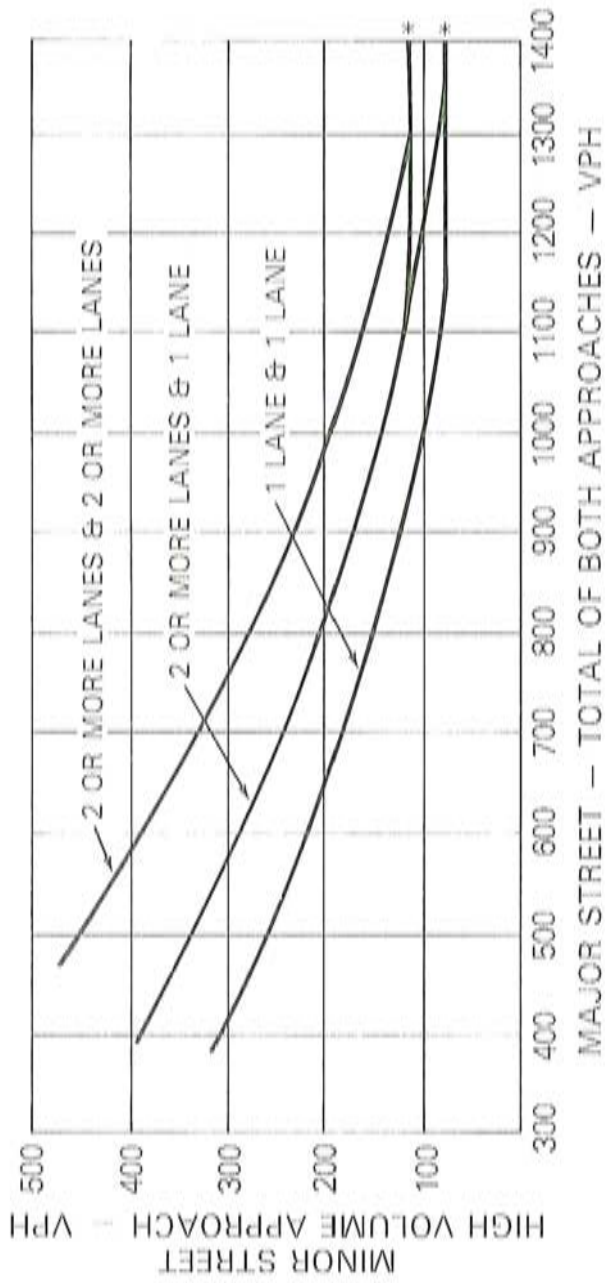
### FIGURE 4-6. PEAK HOUR VOLUME WARRANT

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



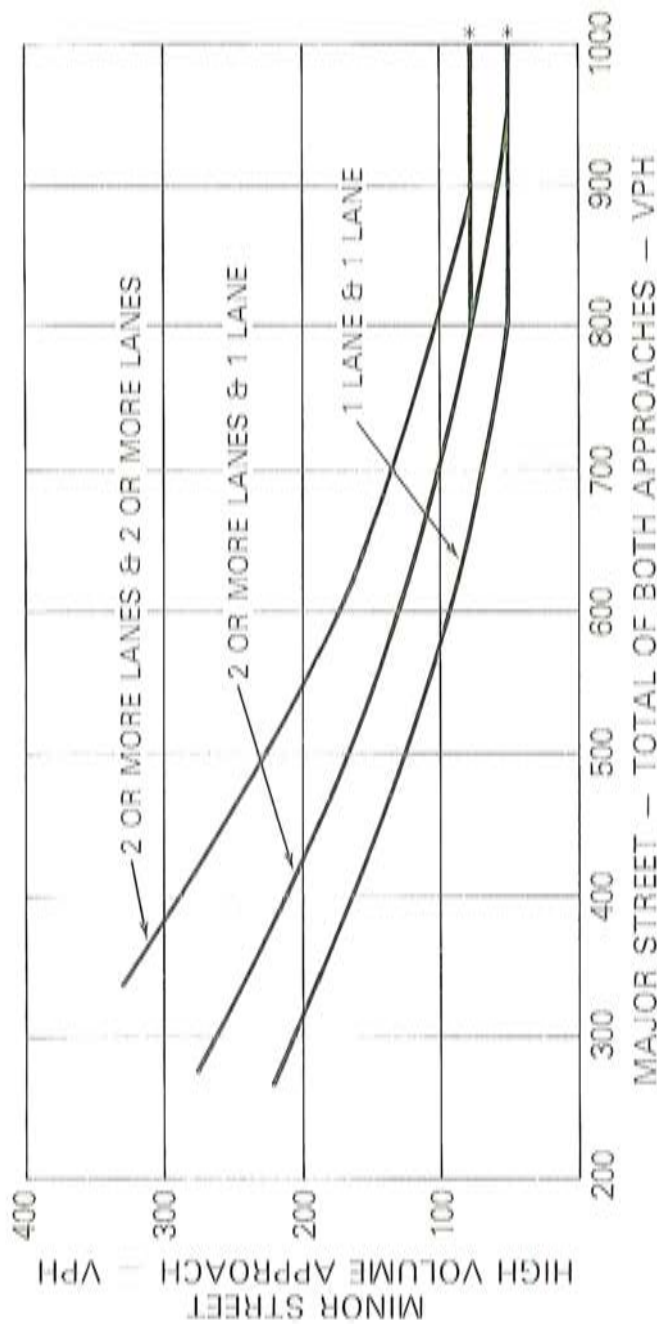
\*NOTE: 100 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACH WITH TWO OR MORE LANES AND 75 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACHING WITH ONE LANE.

FIGURE 4-7. FOUR HOUR VOLUME WARRANT



\*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 APPROACHING WITH ONE LANE.

**FIGURE 4-8. FOUR HOUR VOLUME WARRANT**  
 (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 APPROACHING WITH ONE LANE.



## D. PEDESTRIAN SIGNALS

### 4D-1 Pedestrian Signal Indications

Pedestrian signal indications are special types of traffic signal indications intended for the exclusive purpose of controlling pedestrian traffic. These indications consist of the illuminated words WALK and DONT WALK or the illuminated symbols of a walking person (symbolizing WALK) and an upraised palm (symbolizing DONT WALK).

### 4D-2 Meaning of Pedestrian Indications

The meanings of pedestrian signal indications are as follows:

1. The DONT WALK indication, steadily illuminated, means that a pedestrian shall not enter the roadway in the direction of the indication.

2. The DONT WALK indication, while flashing, means that a pedestrian shall not start to cross the roadway in the direction of the indication, but that any pedestrian who has partly completed his crossing during the steady WALK indication shall proceed to a sidewalk, or to a safety island.

3. A WALK indication, whether steady or flashing, means that pedestrians facing the signal indication may proceed across the roadway in the direction of the indication. In addition a WALK indication indicates one of the following:

(a) A steady WALK indication, when used in an area where the optional flashing WALK (see 3b below) is not used, indicates that there may or may not be possible conflicts of pedestrians with vehicles turning on a CIRCULAR GREEN indication.

(b) A flashing WALK (use optional) indication means that there is a possible conflict of pedestrians with vehicles turning on a CIRCULAR GREEN indication.

(c) A steady WALK indication when used in an area where the optional flashing WALK is used indicates the absence of conflicts of pedestrians with vehicles turning on a CIRCULAR GREEN indication.

### 4D-3 Applications of Pedestrian Signal Indications

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

1. When a traffic signal is installed under the Pedestrian Volume or School Crossing warrant.

2. When an exclusive interval or phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped.

3. When vehicular indications are not visible to pedestrians such as on one-way streets, at "T" intersections; or when the vehicular indications are in a position which would not adequately serve pedestrians.

4. At established school crossings at intersections signalized under any warrant.

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

1. When any volume of pedestrian activity requires use of a pedestrian clearance interval to minimize vehicle-pedestrian conflicts or when it is necessary to assist pedestrians in making a safe crossing.

2. When multi-phase indications (as with split-phase timing) would tend to confuse pedestrians guided only by vehicle signal indications.

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

#### **4D-4 Design Requirements**

Design requirements for pedestrian signals include the following:

1. Pedestrian indications should attract the attention of, and be readable to, the pedestrian (both day and night) at all distances from 10 feet to the full width of the area to be crossed.

2. All pedestrian indications shall be rectangular in shape and shall consist of the lettered or symbolized messages WALK and DONT WALK. Only internal illumination shall be used (fig. 4-3). Symbol designs are set forth in the Standard Highway Signs booklet.

3. When illuminated, the WALK indication shall be white conforming to the Pedestrian Traffic Control Signal Indications, \*with all except the letters or symbols obscured by an opaque material.

4. When illuminated, the DONT WALK indication shall be Portland orange conforming to the Pedestrian Traffic Control Signal Indications, \*with all except the letters or symbols obscured by an opaque material.

5. When not illuminated, the WALK and DONT WALK messages shall not be readily distinguishable by pedestrians at the far end of the crosswalk they control.

6. For crossings where the distance from the near curb to the pedestrian signal indication is 60 feet or less, the letters, if used, shall be at least 3

\* Available from the Institute of Transportation Engineers, see page iv.



Single Section with Cut-out Letters



Two Section Type

Figure 4-3. Pedestrian signal face designs.

inches high or the symbols, if used, shall be at least 6 inches high. For distances over 60 feet, the letters, if used, should be at least 4 ½ inches high and the symbols, if used, should be at least 9 inches high.

7. The light source shall be designed and constructed so that in case of an electrical or mechanical failure of the word DONT, the word WALK of the DONT WALK message will also remain dark.

#### **4D-5 Location**

Pedestrian signal faces shall be mounted with the bottom of the housing not less than 7 feet nor more than 10 feet above the sidewalk level, and so there is a pedestrian indication in the line of pedestrians' vision which pertains to the crosswalk being used.

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

Pedestrian signal heads may be mounted separately or on the same support with other signal heads. When mounted with other signal heads there shall be a physical separation between the two heads.

The pedestrian signal head shall be so positioned and adjusted as to provide maximum visibility at the beginning of the controlled crossing.

#### **4D-6 Detectors**

Pedestrian detectors (usually push buttons) should be conveniently located near each end of crosswalks where pedestrian actuation is required. A mounting height of 3 ½ to 4 feet above the sidewalk has been found best adapted to general usage. Permanent-type signs (sec. 2B-37) shall be mounted above or in unit with the detectors, explaining their purpose and use. At certain locations, it may be desirable to supplement this sign with a larger sign suspended over the sidewalk to call attention to the push button. Where two crosswalks, oriented in different directions, end at or near the same location, the positioning of pedestrian push buttons should clearly indicate which crosswalk signal is actuated by each push button. Additional push-button detectors may be required on islands or medians where a pedestrian might become stranded.

Special purpose push-buttons (to be operated only by authorized persons) should include a housing capable of being locked to prevent access by the general public. Instruction signs are not necessary in this case.

A pilot light or other means of indication may be installed with a pedestrian push button and normally shall not be illuminated. Upon actuation, it shall be illuminated until the pedestrian's green or WALK indication is displayed.



#### 4D-7 Pedestrian Intervals and Phases

The four basic combinations of pedestrian signal intervals with vehicular signal operation are as follows:

1. Combined Pedestrian-Vehicular Interval—a signal phasing wherein pedestrians may use certain crosswalks and vehicles are permitted to turn across these crosswalks (the pedestrian indication shall be flashing WALK or steady WALK).

2. Exclusive Crosswalk Interval—a signal phasing wherein pedestrians may use certain crosswalks but vehicles are not permitted to move across these crosswalks during the pedestrian movement (the pedestrian indication shall be steady WALK).

3. Leading Pedestrian Interval—a signal phasing wherein an exclusive pedestrian interval, in advance of the vehicular indication shall be steady WALK. When the leading pedestrian interval is terminated, and a combined pedestrian-vehicular interval begins, the WALK indication may begin to flash.

4. Exclusive Pedestrian Phase—a signal phasing wherein pedestrians may proceed to cross the intersection in any direction during an exclusive phase while all vehicles are stopped (the pedestrian indication shall be steady WALK).

Pedestrians should be assured of sufficient time to cross the roadway at a signalized intersection. Where traffic signals are of the actuated type, control equipment should provide sufficient pedestrian crossing time when there has been a pedestrian actuation and the minimum vehicular time is less than that needed by the pedestrians. Where traffic signals are not of the vehicle-actuated type, pedestrian actuation may be used to provide sufficient pedestrian crossing time, or the vehicular time should be adjusted to provide the crossing time needed by pedestrians.

Under normal conditions, the WALK interval should be at least 4 to 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb before the clearance interval is shown. The lower values may be appropriate where it is desired to favor the length of an opposing phase and if pedestrian volumes and characteristics do not require the longer interval, the WALK interval itself need not equal or exceed the total crossing time calculated for the street width, as many pedestrians will complete their crossing during the flashing DONT WALK clearance interval.

A pedestrian clearance interval shall always be provided where pedestrian signal indications are used. It shall consist of a flashing DONT WALK indication. The duration should be sufficient to allow a pedestrian crossing in the crosswalk to leave the curb and travel to the center of the farthest traveled lane before opposing vehicles receive a green indication (normal walking speed is assumed to be 4 feet per second). On a street with a median at least 6 feet in width, it may be desirable to allow only enough

pedestrian clearance time on a given phase to clear the crossing from the curb to the median. In the latter case, if the signals are pedestrian actuated, an additional detector shall be provided on the island (sec. 4D-6).

At intersections equipped with pedestrian signals, the pedestrian signals shall be displayed except when the traffic signal is being operated as a flashing device. At those times, the pedestrian indications shall not be illuminated.

## E. OTHER HIGHWAY TRAFFIC SIGNALS

### 4E-1 Hazard Identification Beacon

A Hazard Identification Beacon is one or more sections of a standard traffic signal head with a flashing CIRCULAR YELLOW indication in each section. 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 warning is required.
5. Supplemental to regulatory signs, except the STOP, YIELD and DO NOT ENTER signs.

A Hazard Identification Beacon shall be used only to supplement an appropriate warning or regulatory sign or marker. The beacon shall not be included within the border of the sign except for School Speed Limit signs (secs. 4E-2 and 7B-12).

Hazard Identification Beacons, when used at intersections, shall not face conflicting vehicular approaches.

### 4E-2 Speed Limit Sign Beacon

A Speed Limit Sign Beacon is two CIRCULAR YELLOW lens sections each having a visible diameter of not less than 6 inches, or as an alternate, one or more CIRCULAR YELLOW lenses, each having a visible diameter of not less than 8 inches. Where two lenses are used, they shall be vertically aligned, except that they may be horizontally aligned if the speed sign is longer horizontally than vertically, and they shall be alternately flashed.

A Speed Limit Sign Beacon is intended for use with a fixed or variable speed limit sign. Where applicable, a flashing speed limit beacon (with an appropriate accompanying sign) may be used to indicate that the speed limit shown is in effect. The lenses of a Speed Limit Beacon when used with a School Speed Limit sign may be positioned within the face of the sign.

### 4E-3 Intersection Control Beacon

An Intersection Control Beacon consists of one or more sections of a standard traffic signal head, having flashing CIRCULAR YELLOW or CIRCULAR RED indications in each face. They are installed and are used only at an intersection to control two or more directions of travel. Supplemental indications may be needed on one or more approaches in order to provide adequate visibility to approaching motorists.

Intersection Control Beacons are intended for use at intersections where traffic or physical conditions do not justify conventional traffic signals but where high accident rates indicate a special hazard.

Application of Intersection Control Beacons shall be limited to:

1. Yellow on one route (normally the major roadway) and red for the remaining approaches.
2. Red for all approaches (where all-way stop is warranted).

A stop sign should be used with a flashing red Intersection Control Beacon (fig. 4-4).

Flashing yellow indications shall not face conflicting vehicular approaches.

#### **4E-4 Stop Sign Beacon**

A Stop Sign Beacon is one or more sections of a standard traffic signal head with a flashing CIRCULAR RED indication in each section. Where a single lens is used, it may be either 8 or 12 inches nominal diameter. Where two lenses are used, they shall be not less than 8 inches nominal diameter; if aligned horizontally they shall be flashed simultaneously, and if aligned vertically, they shall be flashed alternately.

The bottom of the housing of a Stop Sign Beacon shall be not less than 12 nor more than 24 inches above the top of a stop sign (sec. 2B-4).

#### **4E-5 General Design and Operation of Beacons**

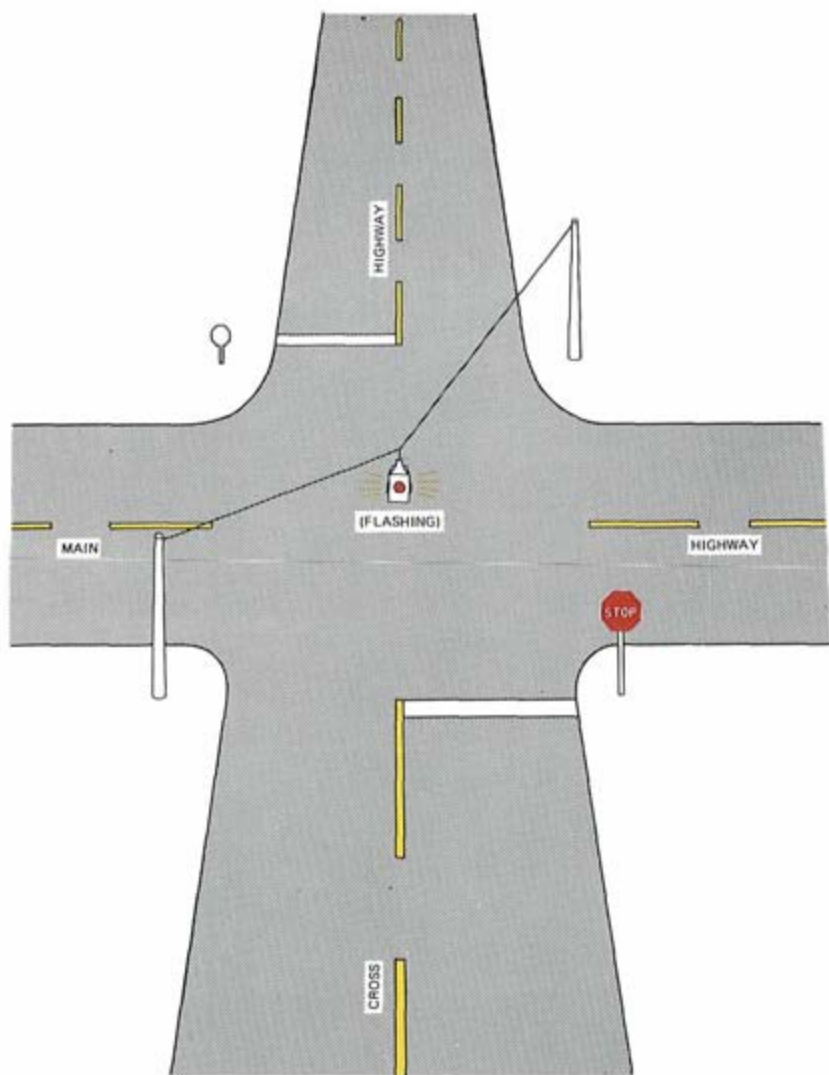
Flashing beacon units and their mounting shall follow the general design specifications for traffic control signals, which shall include the following essentials:

1. Each signal unit lens shall have a visible diameter of not less than 8 inches, except for Speed Limit Sign Beacons described in section 4E-2.
2. When illuminated, the beacon shall be clearly visible (to all drivers it faces) for a distance of at least  $\frac{1}{4}$  mile under normal atmospheric conditions, unless otherwise physically obstructed.
3. The red and yellow lens colors shall be in accordance with the Vehicle Traffic Control Signal Head Equipment Standard. \*

All flashing contacts should be equipped with filters for suppression of radio interference.

Beacons shall be flashed at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall not be less than one-half and not more than two-thirds of the total cycle. When Hazard Identification Beacons have more than one section, they may be flashed alternately.

\* Available from the Institute of Transportation Engineers, see page iv.



**Figure 4-4. Typical intersection control beacon installation.**

Hazard Identification Beacons should be operated only during those hours when the hazard or regulation exists.

A flashing yellow beacon interconnected with a traffic signal controller may be used with an advance traffic signal warning sign (sec. 2C-17).

If a 150 watt lamp is used in a 12-inch lens flashing yellow beacon and the flashing yellow is so bright as to cause excessive glare during night

operation, an automatic dimming device should be used to reduce the brilliance during night operation.

If used to supplement a warning or regulatory sign, individual flashing beacon units should be horizontally or vertically aligned. The edge of housing should normally be located no closer than 12 inches outside of the nearest edge of the sign (not applicable to School Speed Limit Beacons located within the sign—secs. 4E-2 and 7B-12).

#### **4E-6 Hazard Identification Beacon Location**

The hazard or other condition warranting Hazard Identification Beacons should largely govern their location with respect to the roadway. If used alone and located at the roadside, the bottom of the beacon unit shall be at least 8 feet and not more than 12 feet above the pavement. If suspended over the roadway, the clearance above the pavement shall not be more than 19 feet nor less than 15 feet. In no case should they be mounted on pedestals in the roadway unless the pedestal is within the confines of a traffic or pedestrian island. Where 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 is desirable, in addition to the beacon.

#### **4E-7 Intersection Control Beacon Location**

An Intersection Control Beacon is generally suspended over the center of an intersection; however, it may be used at other suitable locations. If suspended over the roadway the clearance above the pavement shall be at least 15 feet but not more than 19 feet. If pedestal mounting is used, the bottom of the signal head shall be at least 8 feet but not more than 15 feet above the pavement. In no case should it be mounted on a pedestal in the roadway unless the pedestal is within the confines of a traffic or pedestrian island.

#### **4E-8 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 prohibitions of use. Installations are distinguished by placement of these special signals over a certain lane or lanes of the roadway and by their distinctive shapes and symbols. Supplementary signs are often used to explain their meaning and intent.

Lane-use control signals are most commonly used for reversible-lane control. This type of control should be used only when a competent engineering study shows that there is need and also that the planned operation is practicable. Reversible-lane operation may be appropriate at toll-booth areas.

Lane-use control also may be used where there is no intent or need to reverse lanes. Some applications of this type are:

1. On a freeway, where it is desired to keep traffic out of certain lanes at certain hours to facilitate the merging of traffic from a ramp or other freeway.
2. On a freeway, near its terminus, to indicate a lane that ends.
3. On a freeway or long bridge, to indicate a lane which may be temporarily blocked by an accident, breakdown, etc.

#### **4E-9 Meaning of Lane-use Control Signal Indications**

The meanings of lane-use control signals are as follows:

1. A steady **DOWNWARD GREEN ARROW** means that a driver is permitted to drive in the lane over which the arrow signal is located.
2. A steady **YELLOW X** means that a driver should prepare to vacate, in a safe manner, the lane over which the signal is located because a lane control change is being made, and to avoid occupying that lane when a steady **RED X** is displayed.
3. A flashing **YELLOW X** means that a driver is permitted to use a lane over which the signal is located for a left turn. The driver is cautioned that he may be sharing that lane with opposite flow left-turning vehicles.
4. A steady **RED X** means that a driver shall not drive in the lane over which the signal is located, and that this indication shall modify accordingly the meaning of all other traffic controls present. The driver shall obey all other traffic controls and follow normal safe driving practices.

#### **4E-10 Design of Lane-use Control Signals**

All lane-use control signal indications shall be in units with rectangular faces. Nominal minimum height and width of each face shall be 12 inches for typical applications. However, other sizes with message recognition distances appropriate to signal spacing may be employed for unusual applications.

Each lane to be reversed shall have signal faces with a **DOWNWARD GREEN ARROW** on an opaque background, and a **RED X** symbol on an opaque background. Signal faces with a **YELLOW X** symbol on an opaque background may be provided for operation as described in section 4E-12.

Each nonreversible lane immediately adjacent to a reversible lane shall have signal indications which display a **DOWNWARD GREEN ARROW** to traffic traveling in the permitted direction and a **RED X** to traffic traveling in the opposite direction. Other nonreversible lanes on any street so controlled may also be provided with these indications.

The indications provided for each lane may be in separate units or may be superimposed in the same unit. When in separate units, the RED X symbol shall be on the left, the YELLOW X symbol, if used, shall be in the middle and the DOWNWARD GREEN ARROW symbol shall be on the right.

The color of lane-use control signal indications shall be clearly visible for  $\frac{1}{4}$  mile at all times under normal atmospheric conditions, unless otherwise physically obstructed.

The visibility angle of the lane-use control signal shall be at least as great as that specified for the standard circular traffic signal (sec. 4B-11).

#### **4E-11 Location of Lane-use Control Signals**

Lane-use control signal units shall be located approximately over the center of the lane controlled.

If the area to be controlled is more than  $\frac{1}{4}$  mile in length, or if the vertical or horizontal alignment is curved, intermediate lane-use control signal indications shall be placed over each controlled lane at frequent intervals. This placement shall be such that a motorist will at all times be able to see at least one indication, and preferably two (due to the possibility of a burnout of a single indication) along the roadway, and will have a definite indication of the lanes specifically reserved for his use.

All lane-use control indications shall be located in a straight line across the roadway at right angles to the roadway alignment.

The bottom of any lane-use control signal unit shall be not less than 15 feet nor more than 19 feet above the pavement grade.

On roadways having intersections controlled by traffic signals, the lane-use control indication shall be placed sufficiently far in advance of or beyond such traffic signals to prevent them from being misconstrued as traffic control signals. Twelve-inch lenses may be necessary in the intersection traffic control signals to aid in distinguishing between the two types of signals.

#### **4E-12 Operation of Lane-use Control Signals**

All reversible-lane control signals shall be coordinated and wired to a master control which will operate so as to permit signal indications for each direction in any of the reversing lanes to change from a steady RED X to a DOWNWARD GREEN ARROW or from a DOWNWARD GREEN ARROW to a steady YELLOW X when used, and then to a steady RED X. The showing of a DOWNWARD GREEN ARROW or steady YELLOW X or any combination thereof, in both directions over the same lane, shall be guarded against by electrical interlock.

During change-over periods, a steady YELLOW X indication may be used to notify traffic in a reversible lane to prepare to vacate the lane.



Alternatively the steady RED X may immediately follow the termination of the steady DOWNWARD GREEN ARROW, and in this case a clearance period of appropriate length shall be provided, during which the steady RED X shall be shown in both directions over the lane before the steady DOWNWARD GREEN ARROW indication is shown for traffic from the opposite direction.

Where feasible, a flashing YELLOW X for both directions may be used over a lane to permit use of that lane for left turns, with due caution.

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. If an automatic system is used, a manual control to override the automatic control shall be provided.

When used, lane-use signals shall be operated continuously.

#### **4E-13 Traffic Control at Movable Bridges**

Traffic control at movable bridges shall include both signals and warning gates except:

1. Neither is required when other traffic control devices or measures are used which are considered appropriate for conditions at the site: (a) on low volume roads (roads of less than 400 average daily traffic), or (b) at manually operated bridges where electric power is not available.

2. Only signals are required in urban areas when intersecting streets or driveways make gates ineffective.

3. Only warning gates are required where a stop and go traffic control signal which is controlled as part of the bridge operations exists within 500 feet of the warning gates and no intervening traffic entrances exist.

Resistance gates are often required at movable bridges to provide a physical barrier for moving vehicles. Resistance gates are considered a design feature not a traffic control device and requirements for them are contained in the Standard Specifications for Movable Highway Bridges. \* However, the location of the movable bridge signals and gates will be determined from the location of the resistance gates (where used) rather than by the location of the movable spans. Resistance gates for high speed highways are preferably located 50 ft. 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.

#### **4E-14 Movable Bridge Signals and Gates**

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 the road closure rather than alternately giving the right-of-way to conflicting traffic

\* Available from the American Association of State Highway and Transportation Officials, 444 N. Capitol St., NW., Suite 225, Washington, D.C. 20001.

movements. They are operated in coordination with the opening and closing of the movable bridges, and with the operation of resistance and warning gates, barriers, or other devices and features used to warn, control and stop vehicles. Unlike traffic control signals, movable bridge signals may be operated frequently or at extremely infrequent intervals depending upon waterway traffic.

Warning gates installed at movable bridges are for the purpose of decreasing the likelihood of vehicles and pedestrians passing the stop line and entering an area where hazards exist because of the operation of the bridge.

#### **4E-15 Design of Movable Bridge Signals and Gates**

The signal heads and mountings of movable bridge signals shall follow the standard design specifications for traffic control signals.

Nominal 8-inch signal indications are standard. However, if prevailing approach speeds are in excess of 25 mph, or when considerations such as roadway width or geometrics, signal location, conflicting lights or objects in the background, etc., indicate the need for greater signal effectiveness, signal heads with 12-inch diameter lenses should be provided.

Movable bridge signals may be supplemented with bells to provide additional warning to drivers and pedestrians.

Since movable bridge operation covers so wide a range of time periods between openings, two types of signals are provided. The first type consists of the standard three color (red, yellow, and green) traffic signal indications, generally to be used when movable bridge operation is quite frequent. The second type consists of two red signal indications in vertical array separated by a STOP HERE ON RED sign (sec. 2B-37).

Where physical conditions prevent a driver (traveling at the 85 percentile approach speed) from having a continuous view of at least one signal indication for approximately 10 seconds before reaching the stop line, an auxiliary device shall be provided in advance of movable bridge signals and gates. This device may be either a supplemental signal or the mandatory DRAWBRIDGE AHEAD sign to which has been added a Hazard Identification Beacon interconnected with the movable bridge controller.

A DRAWBRIDGE AHEAD warning sign shall be used in advance of movable bridge signals and gates to give advance warning to motorists, except in urban conditions where such signing would not be practicable. Such signs may be supplemented by a Hazard Identification Beacon (sec. 4E-1). The beacon is not required except as noted in the above paragraph.

Warning gates shall be at least standard RR size striped with 16-inch alternate diagonal, fully reflectorized red and white stripes. They shall preferably be of light weight construction. Flashing red lights may be included on the gate arm where all traffic is to be stopped but shall only be

operated when the gate is closed or in the process of being opened or closed. In its normal upright position the gate arm should be either vertical or nearly so and provide adequate lateral clearance. In the horizontal position the top of the gate shall be approximately 4 feet above the pavement. If the movable bridge is close to a railroad grade crossing and there is a possibility that traffic may be stopped on the crossing as a result of the bridge opening, a traffic control device should be provided to give notification to the driver not to stop on the railroad tracks. Extreme care should be used in planning such installations to avoid creating confusion or hazardous conditions.

Signals on adjacent streets and highways should be interconnected with the drawbridge control, if indicated by engineering considerations.

#### **4E-16 Location of Movable Bridge Signals and Gates**

Two signal indications shall be provided for each approach to the movable span regardless of which signal type is selected.

Insofar as practicable, the height and lateral placement of signals should conform to the requirements for other traffic control signals in accordance with sec. 4B-12. They should be located not more than 50 feet in advance of the warning gate or other barrier except as otherwise noted.

Warning gates, where used, shall extend at least across the full width of the approach lanes where resistance gates are used. If resistance gates are not used on undivided highways, warning gates, if used, should extend across the full width of the roadway. On divided highways in which the roadways are separated by a barrier median, warning gates, if used, shall extend across all roadway lanes approaching the span openings. A single full width gate or two half-width gates may be used. Except as indicated below, wherever practical, warning gates shall be located 100 feet or more from the resistance gates or, when no resistance gates are used, 100 feet or more from the movable span.

On bridges or causeways that cross a long reach of water and which may be impacted by large marine vessels, it may be desirable, within the limitations of practicability, to halt traffic on a section of the bridge or causeway that is not subject to impact. In some cases, such as long causeways, it may not be practical to halt traffic on a span which is completely safe from impact. In such cases the traffic should be halted at least one span from the opening. Where traffic is halted by signals and gates more than 330 feet from the resistance gates or from the span opening when no resistance gates are used, a second set of gates should be installed approximately 100 feet from the resistance gate or span opening. Traffic signals need not accompany the gates nearest the span opening but there shall be flashing red lights on the warning gate.

#### **4E-17 Operation of Movable Bridge Signals and Gates**

Traffic control devices at movable bridges shall be coordinated with the movable span, so that signals, gates and movable span are controlled by the bridge tender through an interlocked control.

Where the three-color type of signal is used, the green signal indication shall be illuminated at all times between bridge opening periods, except that when the bridge is not expected to be open for continuous periods in excess of 5 hours a flashing yellow indication may be used. The signal shall display continuous red when traffic is required to stop.

The yellow interval between the display of green and red shall be predetermined and shall be displayed normally approximately 3 to 6 seconds.

When the vertical array of red signals is selected, it shall be operated with alternate flash and shall operate only during periods when traffic is required to stop.

#### **4E-18 Traffic Signals for Emergency Vehicle Movements**

An emergency-traffic signal is a special adaptation of a traffic control signal to obtain the right-of-way for an authorized emergency vehicle. An emergency-traffic signal may be installed at a location that does not meet the warrants prescribed for the various types of other traffic signal installations. It may be installed at an intersection or at other locations where there is direct access from a building housing the emergency vehicle.

Right-of-way for emergency vehicles at signalized locations shall be obtained as specified in section 4B-22.

#### **4E-19 Applications of Emergency-Traffic Signals**

At an unsignalized location, an emergency-traffic signal may be justified if adequate gaps in traffic do not exist to permit safe entrance of emergency vehicles, or the stopping sight distance for vehicles approaching on the through street is insufficient to permit safe entrance of emergency vehicles.

The sight distance determination is based on the location of the visibility obstruction for the critical approach lane for each street or drive, and the posted or 85th percentile speed on the through street, whichever is higher.

If warrants for a traffic control signal (sec. 4C) are met, a signal normally should be installed to the standards required for that type of signal (sec. 4B).

The use of emergency-traffic signals to permit direct access to a street from a building housing emergency equipment is optional.

#### **4E-20 Design of Emergency-Traffic Signals**

Except as specified in this section, a traffic control signal for emergency vehicle movements shall meet the requirements of this Manual.

At least one signal face should be located over the roadway.

A sign, legible at all times, bearing the legend EMERGENCY SIGNAL should be mounted adjacent to each signal face.

A Hazard Identification Beacon may be installed in advance of an emergency-traffic signal. Such beacon shall be accompanied by an appropriate warning sign. The design and location of the beacon shall conform to the standards specified in sections 4E-1 and 4E-5.

A minimum of one signal face shall face the direction of approach of the emergency vehicle.

#### **4E-21 Operation of Emergency-Traffic Signals**

As a minimum, the indications, sequence and manner of operation of an emergency traffic control signal installed at a mid-block location shall be as follows:

1. The signal indication, between emergency vehicle actuations, shall be either a steady green or flashing yellow. When used in lieu of the steady green, the flashing yellow shall be displayed in the normal position of the steady green while the red and steady yellow will be displayed in their normal positions.

2. There shall always be a steady yellow change indication shown to traffic on the street, but a change indication is not required for the emergency vehicle driveway.

3. There shall be a steady red signal indication for traffic on the street. The duration of the red period should be determined on the basis of on-site test run-time studies, but should normally not exceed 1.5 times the emergency vehicle passage or clearance time.

4. It has been found advantageous to use the following size lenses: 12-inch diameter for red and steady yellow indications, and 8-inch diameter for flashing yellow indications and steady green indications. Other appropriate means to reduce the flashing yellow light output may be used.

An intersectional or mid-block emergency-traffic signal may be actuated manually from a local control point such as a fire station, police headquarters or civil defense office, or from an emergency vehicle equipped for remote operation of the signal.

Hazard Identification Beacons, used with an emergency-traffic signal, shall be actuated from a nonilluminated condition at the same time as the emergency-traffic signal is changed to steady yellow.

Emergency-traffic signals located at intersections should be operated either in the flashing mode between emergency actuations (sec. 4B-18) or should be semi- or fully traffic-actuated, to accommodate normal vehicular and pedestrian traffic on the streets.

#### **4E-22 Traffic Signals at Freeway Entrance Ramps**

Traffic control signals may be installed on freeway entrance ramps to control the flow of traffic entering the freeway facility. Except as noted herein, these ramp control signals shall meet all of the standard design specifications for traffic control signals.

1. The standard display for freeway entrance ramp control signals shall be either a two-indication signal face containing red and green lenses or a standard three-indication signal face containing red, yellow, and green lenses.

2. There shall be a minimum of two signal faces per ramp facing entering traffic.

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

4. The required signal faces should be mounted such that the height to the bottom of the housing of the lowest signal face is between 4 ½ and 6 feet. The height of any supplemental signal faces should be consistent with sound design principles and engineering judgment within the limitations provided in section 4B-13.

5. All ramp control signals shall utilize vertically aligned lenses with a minimum nominal diameter of 8 inches.

6. Ramp control signals need not be illuminated when not in use.

#### **4E-23 Guidelines for Freeway Entrance Ramp Control Signals**

There are too many variables that influence freeway capacity (number of lanes, trucks, gradients, merging, weather, etc.) to permit developing numerical volume warrants that are applicable to the wide variety of conditions found in practice. However, general guidelines have been identified for successful application of ramp control.

The installation of ramp control signals should be preceded by an engineering analysis 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 which would be affected by the ramp control, as well as the freeway section concerned. Types of traffic data which should be obtained include, but are not limited to traffic volumes, traffic accidents, freeway operating speeds, travel time and delay on the freeway and on alternate surface routes.

Capacities and demand/capacity relationships should be determined for each freeway section. The locations and causes of capacity restrictions and those sections where demand exceeds capacity should be identified. From these and other data, estimates can be made of desirable metering rates, probable reductions in delay of freeway traffic, likely increases in delay to traffic on ramps, and the potential impact on surface streets. The analysis should include an evaluation of storage capacities on the ramp for

IV-29 (c)  
Rev. 3

vehicles delayed at the signal, the impact of queued traffic on the local street intersection, and the availability of suitable alternate surface routes having adequate capacity to accommodate any additional traffic volume.

Before installing ramp control signals, consideration should be given to public acceptance potential and enforcement requirements of ramp control, as well as alternate means of increasing the capacity, reducing the demand, or improving characteristics of the freeway.

Installation of freeway entrance ramp control signals may be justified when the total expected delay to traffic in the freeway corridor, including freeway ramps and local streets, is expected to be reduced with ramp control signals and when at least one of the following instances occurs:

1. There is recurring congestion on the freeway due to traffic demand in excess of the capacity; or there is recurring congestion or a severe accident hazard at the freeway entrance because of inadequate ramp merging area. A good measure of recurring freeway congestion is freeway operating speed. An early indication of a developing congestion pattern would be freeway operating speeds less than 50 mph, occurring regularly for a period of half an hour. Freeway operating speeds less than 30 mph for a half-hour period would be an indication of severe congestion.
2. The signals are needed to accomplish transportation system management objectives identified locally for freeway traffic flow, such as:
  - (a) maintenance of a specific freeway level of service, or (b) priority treatments with higher levels of service, for mass transit and carpools.
3. The signals are needed to reduce (predictable) sporadic congestion on isolated sections of freeway caused by short-period peak traffic loads from special events or from severe peak loads of recreational traffic.

IV-29 (c)  
Rev. 3

#### **4E-24 Traffic Signals for One-Lane, Two-Way Facilities**

A traffic signal for control of traffic at a narrow bridge or tunnel is a special adaptation of a signal to assign right-of-way for vehicles passing over a bridge or through a tunnel which is not sufficient in width for two opposing vehicles to meet and pass safely. A narrow bridge or tunnel signal may be installed at locations that do not meet the warrants prescribed for the various types of other traffic signal installations.

#### **4E-25 Applications of One-Lane Bridge or Tunnel Signals**

At an unsignalized location, a signal may be justified if gaps in opposing traffic do not permit safe operation of traffic flow through the one-lane section of roadway. Sight distance across or through the structure must

also be considered as well as the approach speed and sight distance approaching the bridge or tunnel.

#### 4E-26 Design of Bridge and Tunnel Signals

The signal heads and mounting of the narrow bridge or tunnel signal shall follow the standard design specifications for traffic control signals.

Nominal 8-inch signal indications are standard; however, if prevailing approach speeds are in excess of 40 mph or when considerations, such as roadway width or geometrics, signal locations with conflicting lights or objects in the background, etc., indicate the need for greater signal effectiveness, signal heads with 12-inch diameter lenses and 100 watt or larger lamps should be provided.

Visibility for each approach signal shall be provided and should be continuously visible from a point at least the following distances in advance of and to the stop line, unless physical obstruction of their visibility exists:

Table 4-1

<i>85 Percentile Speed (mph)</i>	<i>Minimum Visibility Distance (ft.)</i>
20	175
25	215
30	270
35	325
40	390
45	460
50	540
55	625
60	715

IV-42 (c)  
Rev. 4

Where physical conditions prevent drivers from having a continuous view of at least two signal indications as specified herein, a suitable sign shall be erected to warn approaching traffic. It may be supplemented by a Hazard Identification Beacon (sec. 4E-1). A beacon utilized in this manner may be interconnected with the traffic signal controller in such a manner as to flash yellow during the period when drivers passing this beacon, at the legal speed for the roadway, may encounter a red signal upon arrival at the signalized location.

#### 4E-27 Location of Narrow Bridge or Tunnel Signals

Two signal indications shall be provided for each approach to the bridge or tunnel. One signal shall be at the left or over the left half of the roadway and the other at the right or over the right half of the roadway.

Insofar as is practical, the height and lateral placement of the signal should conform to the requirements for other traffic control signals. The signal should ordinarily be from 40 to 120 feet beyond the stop bar position.



#### **4E-28 Operation of Narrow Bridge or Tunnel Signals**

Signals at narrow bridges or tunnels shall operate in a manner consistent with traffic requirements, except that an adequate clearance must be provided to allow the structure to clear before the opposing traffic is allowed to move.

Data from engineering studies shall be used to determine the proper timing for the signal.

Since traffic flows and patterns change, it is necessary that the engineering data be updated and reevaluated regularly.

To assure that the approved operation timing is correct, regular checks, including the use of accurate timing devices, should be made.

When required for flashing operations, the signals shall be flashed red.

