

Part IV. SIGNALS

A. GENERAL

4A-1 Types

This part of the Manual relates to a group of devices called highway traffic signals. These devices include: traffic control signals, beacons, lane-use control signals, drawbridge signals, emergency traffic control signals and train approach signals and gates.

4A-2 Basis of Installation

In most cases the installation of a highway traffic control 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.

B. TRAFFIC CONTROL SIGNALS

4B-1 General Aspects

There are two types of traffic control signals, pretimed and traffic-actuated.

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 control 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 ill-designed, 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 not meeting all the requirements of this Manual, is not recognized as a standard traffic control device.

4B-5 Meaning of Signal Indications

The following meanings shall be given to highway traffic signal indications, except those on pedestrian signals:

1. Green indications shall have the following meanings:¹
 - a. Traffic, except pedestrians, facing a CIRCULAR GREEN may proceed straight through or turn right or left unless a sign at such place prohibits either such turn. But vehicular traffic, includ-

¹ Section 11-202, Uniform Vehicle Code, Revised 1968.

ing vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfully within the intersection or an adjacent crosswalk, at the time such signal is exhibited.

b. 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:²

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:³

a. Traffic, except pedestrians, 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 b below.

b. When a sign is in place permitting a turn, traffic, except pedestrians, facing a steady CIRCULAR RED signal may cautiously enter the intersection to make the turn indicated by such sign after stopping as provided in a 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.

c. Unless otherwise directed by a pedestrian signal, pedestrians facing a steady CIRCULAR RED signal alone shall not enter the roadway.

² Ibid.

³ Ibid.

d. Traffic, except pedestrians, facing a steady RED ARROW indication may not enter the intersection to make the movement indicated by such arrow, and unless entering the intersection to make such other movement as is permitted by other indications shown at the same time, 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 make the movement indicated by such arrow is shown.

e. Unless otherwise directed by a pedestrian signal, pedestrians facing a steady RED ARROW signal indication shall not enter the roadway.

4. Flashing signal indications shall have the following meanings:⁴

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, then 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 from entering the intersection or other controlled area.

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 optional where it is physically impossible for traffic to go straight ahead, as at the head of a "T" intersection.

c. Shall be given when it is intended to prohibit all traffic, except pedestrians directed by a pedestrian signal, from entering the intersection or other controlled area.

⁴ Section 11-204, *op. cit.*

2. A steady CIRCULAR YELLOW indication:

a. Shall be given following a CIRCULAR GREEN indication in the same signal face.

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.

If steady arrow indications are used:

a. A steady RED ARROW indication shall be used only in a separate signal face which also contains steady YELLOW ARROW and GREEN ARROW indications. It shall be used for controlling only a single traffic movement.

b. 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).

c. A steady YELLOW ARROW indication may be used (in a separate signal face) following a GREEN ARROW indication, when that face is used exclusively to control a single directional movement.

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

e. A steady GREEN ARROW indication shall be used only when there would be no conflict with other vehicles or with pedestrians crossing in conformance with the WALK indication.

5. The following combinations of signal indications shall not be simultaneously displayed on any one signal face, and shall not be simultaneously displayed in different signal faces on any one approach to an intersection unless the signal faces are shielded, hooded, louvered, positioned or designed so that none of these prohibited combinations of signal indications is readily visible to drivers:

- 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.
- e. CIRCULAR GREEN with RED ARROW.

6. 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.

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 Interval (sec. 4B-16).
3. Where one or more indications are repeated for reasons of safety or impact.

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.

Twelve-inch lenses normally should be used:

1. For intersections with 85 percentile approach speeds exceeding 40 mph.
2. For intersections where signalization might be unexpected.
3. For special problem locations, such as those with conflicting or competing background lighting.
4. For intersections where drivers may view both traffic control and lane-direction-control signs simultaneously.
5. For all arrow indications.

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 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 Standard for Adjustable Face Vehicle Traffic Control Signal Heads, 1970 Edition.⁵

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. In horizontally arranged signals, the YELLOW ARROW shall be located immediately to the left of the GREEN ARROW lens.

⁵ Available from the Institute of Traffic Engineers, Washington, D.C. 20006.

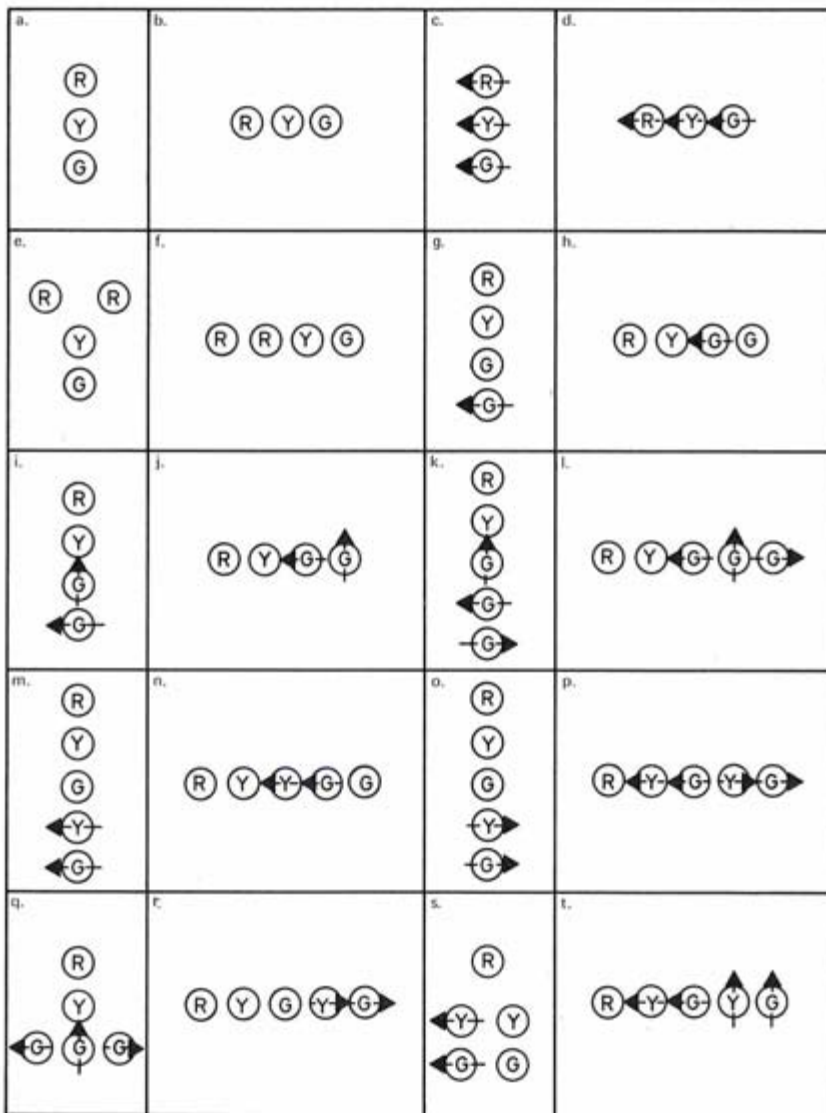


Figure 4-1. Typical arrangements of lenses in signal faces.

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

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

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 YELLOW ARROW
Straight through GREEN ARROW
Right turn YELLOW ARROW
Right turn GREEN ARROW

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 some possible arrangements of lenses in signal faces.

4B-10 Illumination of Lenses

Each signal lens shall be illuminated independently.

When a signal lens, except in a pedestrian signal, is illuminated and the view of such an indication is not otherwise physically obstructed, it shall be clearly visible (to drivers and controls) for a distance of at least $\frac{1}{4}$ mile under normal atmospheric conditions.

The intensity and distribution of light from each illuminated signal lens should conform to the Standard for Adjustable Face Vehicle Traffic Control Signal Heads, Revised 1970; and the Standard for Traffic Signal Lamps, December 1967.

When 12" lens 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" 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. Back-plates normally should be used on one-way and back-to-back two-way overhead signals, and when one signal face controls a movement.

In general, vehicular signal faces should be aimed to have maximum effectiveness for an approaching driver located a distance from the stop line equal to the distance traversed while stopping. This distance should include that covered while reacting to the signal as well as that covered while bringing the vehicle to a stop from an average approach speed. The influence of curves, grades, and obstructions should be considered in directing and locating signals.

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" in length shall not be used on free-swinging signals.

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

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 and horizontal curves, should be considered in signal face placement.

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

1. A minimum of two signal faces for through-traffic 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:

85 Percentile Speed	Minimum Visibility Distance (Ft.)
20	100
25	175
30	250
35	325
40	400
45	475
50	550
55	625
60	700

2. 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.

3. A single signal face is permissible for the control of an exclusive 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 an exclusive turn lane will also be visible to traffic with other allowable movements, a sign LEFT (or RIGHT) TURN SIGNAL (sec. 2B-35) shall be located adjacent to such signal face. When the face consists entirely of arrow indications, such a sign is not required.

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 or on the median island if practical. The signal face 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 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).

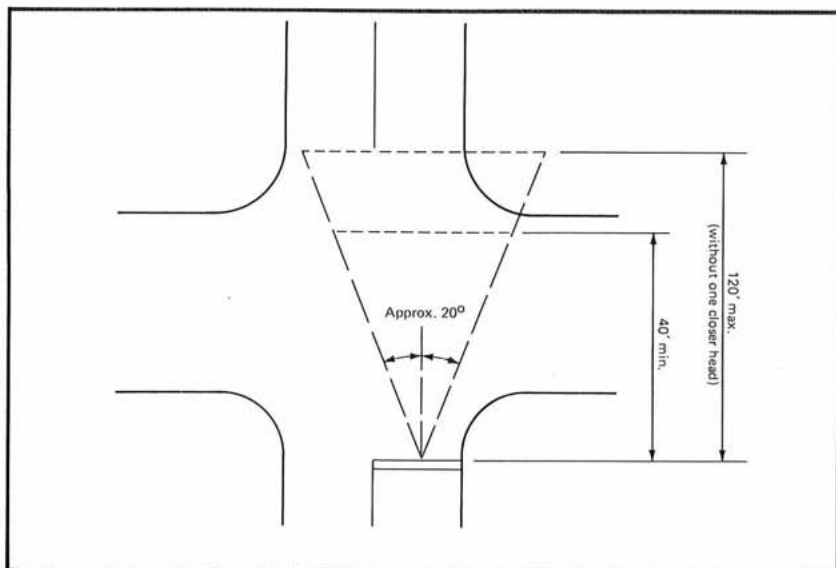


Figure 4-2. Desirable location of signal faces.

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 transverse position should be unmistakably in line with the path of that movement.

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

9. When the nearest signal face is more than 120 feet beyond the stop line, a supplemental near side signal indication shall be provided.

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 lo-

cated 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.

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.

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 two 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 two 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 following each CIRCULAR GREEN interval and, where applicable after each GREEN ARROW interval. In no case shall a CIRCULAR YELLOW indication be displayed in conjunction with the change from CIRCULAR RED to CIRCULAR GREEN. Separate signal faces should be used when exclusive turning movements are controlled by GREEN ARROWS (sec. 4B-6).

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.

4B-16 Unexpected Conflicts During Green Interval

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

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 one-half of a 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 4B-21.

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.

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 installation is being operated as a flashing device, the yellow indication shall be flashed in at least two required signal faces (sec. 4B-12) on each approach on which traffic is not stopped and the red indication shall be flashed in at least two required signal faces (sec. 4B-12) on each approach on which traffic is required to stop.

The above provisions do not apply to emergency-traffic signals or draw-bridge 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 grade crossing, protected by train-approach signals (secs. 4F-1 and 2), is within or near an intersection controlled by a traffic control signal, the control of the traffic signal should be preempted from the signal controller upon approach of trains to avoid conflicting aspects of the traffic signal and the train-approach signal. This preemption feature requires a closed electrical circuit between the control relay of the train-approach signals and the preemptor in order to establish and maintain the preempted condition during the time that the train-approach signals are in operation. Except under unusual circumstances, the interconnection should be limited to the traffic signals within 200 feet of the crossing.

Traffic control signals shall not be used on mainline railroad crossings in lieu of railroad grade crossing protection devices. However, at industrial track crossings and other places where train movements are very slow (as in switching operations), traffic control signals may be used in lieu of conventional train-approach signals to warn motorists of the approach or presence of a train. The provisions of this part relating to traffic signal design, installation and operation are applicable as appropriate where traffic control signals are so used.

At crossings where train movements are regulated or limited to the extent that train-approach signals are not required, preemption of the adjacent signalized intersections may be desirable to permit non-conflicting highway traffic to proceed during the time the crossing is blocked by a train. Except under unusual circumstances, the inter-connection should be limited to the traffic signals within 200 feet of the crossing.

The preemption sequence initiated when the train first enters the approach circuit, shall at once bring into effect a signal display which will permit all vehicles to clear the tracks before the train reaches the intersection or any approach thereto.

When the green indication is preempted by train operation, a yellow change interval must be inserted in the signal sequence in the interest of safety and consistency. To avoid misinterpretation during the time that the clear-out signals are green, consideration should be given to the use of 12-inch red lenses in the signals which govern movement over the tracks (sec. 4B-8).

After the track clearance phase, the traffic control signal may be operated to permit vehicle movements that do not cross the tracks, but in all cases shall prohibit movements over the tracks.

Where feasible the location and the normal (no trains involved) phasing and timing of traffic control signals near railroad grade crossings should be designed so that vehicles are not required to stop on the tracks even though in some cases this will increase the waiting time. The exact nature of the display and the location of the signals to accomplish this will depend on the physical relationship of the tracks to the intersection area.

When the train clears the crossing it is necessary to return the signal to a designated phase, normally the traffic movement crossing the tracks.

As used herein, the terms "train" and "railroad" shall include transit vehicles operating upon stationary rails or tracks on private right-of-way.

4B-22 Emergency Operation of Traffic Signals

Systems in which traffic control signals are preempted by emergency vehicles shall operate to permit a normal change interval to

take place in the change from green to yellow to red (or flashing red) before arrival of the emergency vehicle at the preempted location. Systems in which traffic control signals are preempted by emergency vehicles shall be designed and installed so as to provide an indication to the driver of any emergency vehicle approaching an intersection when the equipment fails to preempt the traffic signal at that intersection. This indication shall be designed to be given whether the failure results from a prior preemption by an emergency vehicle on the cross street, by a railroad preemption, from equipment malfunction, or from any other cause.

Traffic signals operating in congested areas during emergency conditions should be operated in a manner designed to keep traffic moving. Prolonged all-red or flashing signal sequences are to be avoided.

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 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 "calling" 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-35) used with traffic signals shall 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-49) may be used to inform drivers of the speed of progression, if this speed is substantially lower than the speed limits 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—Revised 1968.

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).

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.

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.

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 miles per hour, 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 (in recognition of differences in the nature and operational characteristics of traffic in urban and rural environments and smaller municipalities).

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 miles per hour, 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 (in recognition of differences in the nature and operational characteristics of traffic in urban and rural environments and smaller municipalities).

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 miles per hour, 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 re-

quirements above (in recognition of differences in the nature and operational characteristics of traffic in urban and rural environments and smaller municipalities).

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' to another established crosswalk. Curbside parking should be prohibited for 100' in advance of and 20' 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 1,000 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 of 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 of, 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-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 in conjunction with a traffic-actuated signal installation (sec. 4D-3) 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.

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.

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. The WALK indication, steadily illuminated, means that pedestrians facing the signal indication may proceed across the roadway in the direction of the indication.

4. The WALK indication, while flashing, means that there is a possible conflict of pedestrians with vehicles.

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 movement 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 messages WALK and DONT WALK. Only internal illumination shall be used (fig. 4-3).

3. When illuminated, the WALK indication shall be lunar white conforming to the Standard for Adjustable Face Pedestrian Signal Heads, 1963.⁶ All except the letters shall be obscured by an opaque material.

4. When illuminated, the DONT WALK indication shall be Portland orange conforming to the Standard for Adjustable Face Pedestrian Signal Heads, 1963, with all except the letters obscured by an opaque material.

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

6. The letters shall be at least 3 inches high for a crossing where the distance from the near curb to the pedestrian signal indication is 60 feet or less. For distances over 60 feet, the letters should be at least 4½ inches high.

⁶ Available from the Institute of Traffic Engineers, Washington, D.C. 20006.

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.



Single Section with Cut-out Letters



Two Section Type

Figure 4-3. Pedestrian signal face designs.

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 side-

walk 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 of the push-button or other type shall be designated to operate on a circuit not to exceed 18 volts. They may be mounted on signal standards, wood or steel poles, or individual posts. They should be conveniently located near each end of crosswalks where actuation is required. A mounting height of $3\frac{1}{2}$ to 4 feet above the sidewalk has been found best adapted to general usage. Permanent-type signs (sec. 2B-35) 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 per-

mitted to turn across these crosswalks (the pedestrian indications 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 7 seconds, so that pedestrians will have adequate opportunity to leave the curb, before the clearance interval is shown. However, 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).

When a traffic signal installation is being operated as a flashing device, 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.

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 six inches, as an alternate, one or more CIRCULAR YELLOW lenses, each having a visible diameter of not less than eight inches. Where two lenses are used, they shall be vertically aligned, 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.

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).

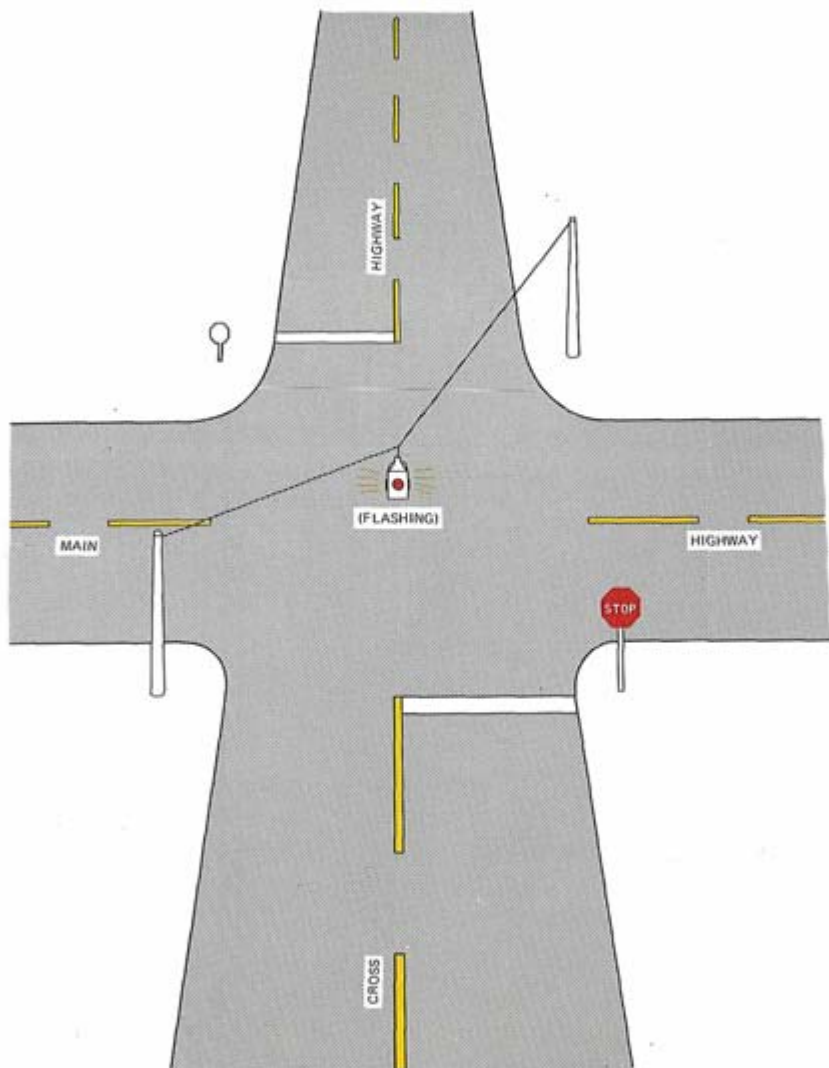


Figure 4-4. Typical intersection control beacon installation.

Flashing yellow indications shall not face conflicting vehicular approaches.

4E-4 Stop Sign Beacon

A Stop Sign Beacon is one or two sections of a standard traffic signal head with a flashing CIRCULAR RED indication in each section. Where two lenses are used, they shall be the 8" nominal diameter size, aligned horizontally and they shall be flashed simultaneously. Where a single lens is used, it may be either 8" or 12" nominal diameter.

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 requirements of the Standard for Adjustable Face Vehicle Traffic Control Signal Heads, Revised 1970.⁷

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.

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-16).

If a 150 watt lamp is used in a 12" 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.

⁷ Available from the Institute of Traffic Engineers, Washington, D.C. 20006.

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 signals 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, using proper caution.

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 a DOWNWARD GREEN ARROW displayed to traffic traveling in the permitted direction and a RED X symbol displayed 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 over-ride the automatic control shall be provided.

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

4E-13 Traffic Signals at Drawbridges

Signals installed at drawbridges 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 movements. They are manually operated in coordination with the opening and closing of the drawbridge, and with the operation of gates, barriers, or other devices used to warn, control and stop vehicles. Unlike traffic control signals, drawbridge signals may be operated frequently or at extremely infrequent intervals depending upon the nature of the physical conditions and waterway traffic.

4E-14 Application of Drawbridge Signals

Drawbridge signals shall always be used in conjunction with gates and other types of protection commonly employed at drawbridges.

4E-15 Design of Drawbridge Signals

The signal heads and mountings of drawbridge signals shall follow the standard design specifications for traffic control signals. Drawbridge signals may be supplemented with bells to provide additional warning to drivers and pedestrians.

Nominal 8-inch signal indications are standard. However, if prevailing approach speeds are in excess of 25 miles per hour, 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 and 100-watt or larger lamps should be provided.

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. This device may be either an auxiliary signal or a DRAWBRIDGE AHEAD sign with a Hazard Identification Beacon interconnected with the drawbridge controller.

A DRAWBRIDGE AHEAD sign shall always be used at the proper distance from the drawbridge to give advance warning to motorists, except in urban conditions where such signing would not

be feasible. Such signs shall be supplemented by a Hazard Identification Beacon (sec. 4E-1) under the conditions described above as well as for other conditions. It is desirable to control this beacon from the bridge-tender's station so it will be flashed only when needed to warn of drawbridge operation.

Since drawbridge operation covers so wide a range of time periods between openings, two types of signals are provided and engineering judgment must be exercised in determining which to use under particular circumstances. The first type consists of the standard three-color (red, yellow, and green) traffic signal indications, generally to be used when drawbridge 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-35).

4E-16 Location of Drawbridge Signals

Two signal indications shall be provided for each approach to the movable span. One signal shall be at the right side of the roadway, and the other at the left side or over the left half of the roadway, directly across the roadway from the right hand indication. Insofar as practicable, the height and lateral placement of signals at drawbridges should conform to the requirements for other traffic control signals. They should ordinarily be from 20 to 50 feet in advance of the first gate or other barrier.

4E-17 Operation of Drawbridge Signals

Signals at drawbridges shall be interconnected with the drawbridge gates or other warning or control devices, and with the movable span, so that signals, gates and movable span are controlled manually by the bridge tender through an interlocked switching control. Signals on adjacent streets and highways should be interconnected with the drawbridge control, if indicated by engineering considerations. If the drawbridge 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 supplementary traffic signal coordinated with the drawbridge signal should be provided to prevent traffic from being stopped on the railroad crossing. Extreme care should be used in planning such signal installations to avoid creating confusion or hazardous conditions.

Where bridge openings are frequent and the three-color type of signal is used, the green signal shall be illuminated at all times between bridge opening periods. When the bridge is to be opened, the signal shall change to yellow for a predetermined interval (normally approximately 3 to 5 seconds) and shall change to red not less than 15 seconds before the gates or other devices begin to operate to

close the roadway. While the gates are closed, the signals shall show a continuous red indication. After the bridge has been closed and the gates have been opened, the signal indications shall return to steady green. The sequence of signal, gate and bridge operation shall be automatic, through interconnection with the bridge control mechanism. The duration of each signal indication interval, except the yellow interval, shall therefore be controlled by the bridge operation.

Where bridge openings are less frequent or where for some other reason the double-red type of signal installation is selected, the signal shall not be illuminated between bridge opening periods. When the bridge tender initiates the bridge opening procedure, the signal shall start alternate flashing of the red indications. After a minimum period of approximately 20 seconds, the gates may be lowered. When the bridge has been again closed and the gates have been raised, the red signal indications shall be discontinued.

When a Hazard Identification Beacon is used with the DRAW-BRIDGE AHEAD sign (sec. 4E-15) it should be interconnected with the drawbridge controller in such a manner as to begin operation sufficiently in advance of the beginning of the bridge opening signal sequence as to warn drivers that they will encounter a red signal or vehicles stopped by the signal. It may frequently be desirable to continue this beacon in flashing operation after the draw-bridge cycle has been completed until all stopped vehicles have started to move and traffic is again flowing freely.

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.

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" diameter for red and steady yellow indications, and 8" 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 non-illuminated 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.

F. TRAIN-APPROACH SIGNALS AND GATES

4F-1 Railroad-Highway Grade-Crossing Protection

At railroad-highway grade-crossings where studies indicate the need of protection beyond that provided by signs, signals should be installed which indicate the approach or presence of trains. The signals may be supplemented by gates which extend across the lane or lanes of the approaching traffic while trains are approaching and occupying the crossing. The following sections apply only to signals, with or without gates as described in Railroad-Highway Grade-Crossing Protection, Bulletin No. 6, Association of American Railroads:⁸

Where traffic signals are located at intersections in close proximity to the train-approach signals, particular attention must be given to the coordination of the two installations (sec. 4B-21).

As used herein, the terms "train" and "railroad" shall include transit vehicles operating upon stationary rails or tracks on private or separate right-of-way.

The applicable techniques of railroad grade-crossing protection also should be considered for the grade-crossings of other preemptive-type traffic using exclusive rights-of-way.

4F-2 Application of Railroad Grade Crossing Signals, Gates and Variable Signs

A flashing-light signal is used to indicate the approach or presence of trains by means of two horizontal red lights flashing alternately at predetermined intervals.

A railroad-highway grade-crossing gate (appearing to the driver as an arm being lowered or in a horizontal position) is an effective adjunct to the flashing light signal in indicating the approach or

⁸ Association of American Railroads, Train Operations, Control and Signals Committee, Railroad-Highway Grade Crossing Protection, Bulletin No. 6, Washington, D.C. 1966.

presence of trains. When used, the gate should extend over the traveled roadway a sufficient distance to cover the lanes used by traffic approaching the crossing.

A NO RIGHT TURN or NO LEFT TURN variable sign is used to indicate turn prohibitions required upon the approach or presence of trains by presenting the legend NO RIGHT TURN or NO LEFT TURN.

Signals and signs or signals, signs and gates of the type described herein shall be installed at railroad-highway grade-crossings where a study of the crossing by competent engineers indicates a need for advance warning of the approach of trains. These exact assemblies of devices shall be used for no other purpose.

4F-3 Proper Motorist Response to Railroad-Highway Grade-Crossing Signals

Whenever a clearly visible electric or mechanical signal device is activated, a crossing gate is lowered, or a human flagman gives or continues to give a signal indicating the approach or passage of a railroad train, the driver of an approaching vehicle should:

1. Stop within 50 feet, but not less than 15 feet, from the nearest rail of such railroad and shall not proceed until he can do so safely and,
2. No person shall drive any vehicle through, around or under any crossing gate or barrier at a railroad crossing while such gate or barrier is closed or is being opened or closed.

4F-4 Types of Control, Design, Location, Installation, Operation and Maintenance

The types of control, design, location, installation, operation and maintenance of railroad-highway grade-crossing signals shall be in accordance with AAR Bulletin #6 (sec. 4F-1), except as modified in this section.

The transverse location of railroad-highway grade-crossing signals shall comply with the requirements of section 4B-14.

The railroad-highway grade-crossing gate arms shall be striped on both sides with 16-inch alternate diagonal reflectorized stripes of red and white.

