DESIGN CRITERIA FOR TRAFFIC SIGNALS

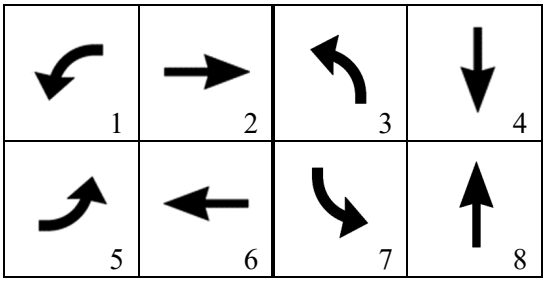
A. SCOPE. These criteria shall be adhered to for the design of all traffic signal systems to be installed in the public street right-of-way. The traffic signal System shall consist of the signal controller, signal poles, mast arms, signal heads, cable, conduit, detectors, and any other appurtenances required to provide a complete, operable traffic signal system. The City Engineer shall be responsible for determining the scope of a traffic signal system.

B. SIGNAL DESIGN. These criteria are established to provide uniform procedures to aid the Design Engineer in preparing improvement plans. These criteria are not to be a rigid set of rules that would restrict the Design Engineer from utilizing creative or original design; however these criteria may be modified only with prior authorization by the City Engineer.

In addition to these requirements, all work shall conform to the requirements of the latest edition of the *Manual on Uniform Traffic Control Devices* (MUTCD).

C. SIGNAL PHASING. When designing a traffic signal (new installation or modification), the signal phasing (number and sequence of the phases) shall be discussed with the City Engineer. Traffic signal phasing will be illustrated on the plans using a NEMA diagram. The City uses a standard phasing sequence which is shown and illustrated below:

Phase 1 – Westbound Left-Turn
Phase 2 – Eastbound Through
Phase 3 – Northbound Left-Turn
Phase 4 – Southbound Through
Phase 5 – Eastbound Left-Turn
Phase 6 – Westbound Through
Phase 7 – Southbound Left-Turn
Phase 8 – Northbound Through



D. SIGNAL HEADS. All traffic signal head shall be located in accordance with the MUTCD. Vehicular signal heads shall be 12 inches in diameter, and pedestrian signal heads shall be 18 inches wide by 16 inches in height. See the General Notes Standard Drawing for signal head types. To standardize the placement of signal heads, some guidelines are provided below:

- Typically, a standard three-section head (Signal Head Type A) should be centered over each exiting lane for all through lanes of traffic.
- When a left-turn lane is provided without left-turn phasing, a separate signal displaying the red arrow, yellow arrow, and flashing yellow arrow (Signal Head Type G) should be centered over the left-turn lane for the permissive left-turn movement.
- When protected left-turn phasing is specified, a three-section head (Signal Head Type B) should be centered over the left-turn lane. Likewise, when dual left-turn movements are specified, separate three-section heads should be centered over each left-turn lane.
- When protected/permissive left-turn phasing is specified, a four-section head with a flashing yellow arrow display (Signal Head Type F) should be centered over the left-turn lane.
- A sidemount signal head shall be installed on a signal pole on the far right-hand side of each intersection. Protected right-turn phasing is generally not used, unless otherwise justified by a traffic study. Right-turn overlaps shall not be used if right-turn movement would be in conflict with U-turning traffic, where permitted.

Conductors Entering	Type of Pull

All traffic signal and pedestrian indications shall have light emitting diode (LED) displays. Countdown displays shall be used for pedestrian indications. In addition, backplates shall be provided for all traffic signal heads that are mounted to mast arms. Signal heads that are mounted to the signal pole or pedestal poles should not be equipped with backplates, unless the posted speed limit for the approach is 45 mph or more.

E. SIGNAL POLES. All traffic signals shall include metal poles with mast arm mounted signal heads. Wood poles and/or span wire mounted signal heads will only be allowed for temporary traffic signal installations at the discretion of the City Engineer.

Signal poles shall typically be located a minimum of 6 feet from the back of curb (or edge of pavement where there is no curb) to the center of the pole. However, no signal pole or base shall be located within 2 feet of the face of curb or edge of pavement. Signal pole bases should be flush mounted at all locations with curbed streets. At locations without curbs a foundation that extends above ground may be used. Mast arm lengths shall be designed with an extra two feet in length in order to accommodate varying field conditions.

Pedestrian signals and pushbuttons are required for all crosswalks. Pushbuttons shall be located per the provisions of the MUTCD and the Americans with Disabilities Act (ADA); therefore, pole locations must be coordinated with the design of curb ramps. A separate pushbutton shall be installed for each curb ramp, adjacent to a level landing area. The pushbutton shall be located within 5 feet of the crosswalk line extended, and no further than 10 feet from the edge of curb or pavement. Where two pushbuttons are located on the same corner, the two buttons should be located on separate poles, spaced at least 10 feet apart. If any of these conditions cannot be met, it should be discussed with the City Engineer.

F. CONDUIT. All conduit for traffic signal systems shall be either Schedule 40 polyvinyl chloride (PVC) conduit or SDR 11 high density polyethylene (HDPE) conduit. Signal conduit shall typically be per the sizes below:

- 3-inch PVC conduit for secondary service cables
- 4-inch conduit between signal poles and pull boxes for 120 Volt equipment
- 4-inch conduit between pull boxes for 120 Volt equipment
- Two 4-inch conduits between signal controller and adjacent pull box for 120 Volt equipment
- 1.5-inch conduit for loop detector lead-in cable from pull box to junction boxes
- 1.5-inch conduit for loop detector from junction box to curb (2 loops max. per conduit)
- 2-inch conduit for low voltage cables (EVP, video, radar, loops, etc.)
- 2-inch conduit for signal interconnect, if required.

The conduit sizes above are typical applications. The Design Engineer shall verify that the signal conduit is properly sized so that no more than 40 percent of the conduit cross-sectional area is filled.

The quantity of conduit is calculated by adding the center to center distances between equipment. All of the center to center distances should be subtotaled and multiplied by 102% to allow for bending of conduit to avoid obstructions. The method of conduit installation is not quantified.

G. PULL AND JUNCTION BOXES. Pull boxes shall typically be provided whenever conduit changes direction and adjacent to signal poles and controllers. The type of pull box used is based on the number of conductors entering the box, as shown in the table to the right. Type 2 Junction boxes should typically be used adjacent to detector loop locations for the splicing of loop wire to the lead-in cable.

Pull Box	Box
0 – 22	Class 1
23 – 68	Class 2
> 68	Class 3

Pull and junction boxes shall be installed at least 2 feet from the back of curb to the edge of the box and no closer than 10 feet from any pole. The distance between pull and junction boxes shall not exceed 300 feet to facilitate the pulling of cable. The installation of boxes in streets, driveways, and curb ramps is unacceptable. In addition, the City prefers that boxes not be installed in the sidewalk. Boxes should be located on level ground, clear of ditches.

H. SIGNAL CONTROLLER CABINET. Signal controller cabinets are typically located behind the sidewalk, or at least 10 feet from the back of the curb (or edge of pavement where there is no curb). Cabinets should be located on level ground, clear of ditches, and clear of sight lines for right-turning traffic. The cabinet shall be oriented such that when a technician is facing the front of the cabinet, they can look over the top and see the intersection ahead of them.

I. SECONDARY SERVICE ENCLOSURE. The Design Engineer shall coordinate and verify the location of the secondary service point with the electric utility company to ensure availability of service. Secondary service for traffic signals shall be three-wire 120/240 Volt single phase. Service enclosures are typically attached to signal controller cabinets, and installed on the same foundation. Service enclosures shall contain a photoelectric cell, to be oriented to the north or east.

A 3-inch Schedule 40 PVC conduit with power cables shall be installed from the service enclosure to the base of the secondary service point (utility pole, secondary pedestal, or pad-mount transformer) as designated by the electrical utility company. The conduit should be installed in a straight horizontal line in accordance with the Standard Drawings, and should be 100 feet or less in length. Junction or pull boxes are not permitted in the conduit run between the service enclosure and secondary service point unless authorized by the electrical utility company. Power cables shall be three #2 USE cables. The electrical utility company will supply the meter and connect the power cables to the transformer.

J. WIRING. City staff has standardized the number of conductors required for various types of traffic signal equipment as indicated below:

- Vehicular signal head – 7 conductor #14 (IMSA specification 19-1)
- Pedestrian signal head – 5 conductor #14 (IMSA specification 19-1)
- Pedestrian pushbutton detector – 2 conductor #14 (IMSA specification 19-1)
- Loop detector lead-in cable – 2 conductor #14 (IMSA specification 50-2)
- Loop detector – 1 conductor #14 (IMSA specification 51-7)
- Pole and bracket cable – 3 conductor #14 (IMSA specification 19-1)

Control cables shall be run continuous from the controller to the base of each signal pole. Splicing of traffic signal cable is not allowed unless shown on the Plans. In pole bases, control cables are spliced and individual cables are run to each signal head on the pole. Jumpers are allowed to adjacent mast arm mounted signal head(s) of the same phase.

Luminaires on signal poles should be LED per the City of Liberty's Approved Products List. In general, Class A luminaires are installed at 35 foot mounting heights, and Class D luminaires are installed at 30 foot mounting heights. Luminaires are to operate on 120 Volt circuit(s) powered from the secondary service enclosure. Street lighting cable for luminaires shall be spliced in pole bases, not in pull boxes. Splices will be made using multiple tap connectors. Two pole and bracket cable conductors shall run inside the pole from the multiple tap connectors to the luminaire. The third conductor is the equipment ground, which shall run inside the pole from the luminaire to the grounding lug in the pole base.

Equipment	**Slack for each cable**
Pull Box	6 feet
Junction Box	3 feet
Controller	8 feet
Service Enclosure	8 feet
Pedestal Signal Head	13 feet
Mast Arm Signal Head	21 feet, plus distance along arm to head
Pedestrian Signal Head	10 feet
Pedestrian Pushbutton	9 feet
Illuminated Sign	30 feet
Luminaire	50 feet

Cable quantities should include the center to center horizontal distance between equipment. The distance is subtotaled and multiplied by 105% to account for conduit bends and snaking. Cable slack should also be included in the estimate of cable quantities. Cable slack should be computed according to the table to the right, which includes vertical distances to equipment.

K. GROUNDING. All traffic signal equipment shall be bonded together to form a continuous system. Ground rods shall be installed adjacent to each signal pole foundation and controller. A single #6 bare solid copper ground wire shall run through traffic signal conduit runs, and shall be bonded to each ground rod.

L. TRAFFIC SIGNAL DETECTION. All signalized intersection shall be fully actuated. Actuation shall typically be achieved through the use of vehicle detection systems, such as induction loop detectors, video detection camera systems, and radar detection systems. When designing a traffic signal (new installation or modification), the type of vehicle detection to be used shall be discussed with the City Engineer. Radar detection is the City's preferred method of vehicle detection.

M. RADAR DETECTION SYSTEM. Radar detection systems shall be per the City's Approved Products List for both presence and advance vehicle detection. Presence detection is required at the stop bar on each intersection approach. Advance detection may be necessary if the posted speed limit for approaching traffic is 35 mph or higher. Typically, one detector per approach will be used for each type of detection, unless special needs dictate otherwise. The detector(s) should typically be mounted to the signal mast arm. The manufacturer's representative shall be consulted to determine the proper placement of the detectors; and documentation shall be obtained from the manufacturer's representative indicating that the placement is acceptable. In addition to the radar detectors, detection zones should also be illustrated and numbered on the signal plan. Detection zones are typically shown as 6 ft. x 50 ft., centered in the lane, with the leading end of the zone 15 to 20 feet from the nearest edge of the through lane of the intersecting road extended.

N. VIDEO CAMERA DETECTION SYSTEM. Video camera detection systems shall be per the City's Approved Products List, as directed by the City Engineer. Typically, one camera per approach will be used, unless special needs dictate otherwise. The camera should typically be mounted to the signal mast arm between the signal heads for the left-turn and through movements

using a six-foot riser arm. The manufacturer's representative shall be consulted to determine the proper placement of the video cameras; and documentation shall be obtained from the manufacturer's representative indicating that the placement is acceptable. In addition to the video detectors, detection zones should also be illustrated and numbered on the signal plan. Detection zones are typically shown as 6 ft. x 50 ft., centered in the lane, with the leading end of the zone 15 to 20 feet from the nearest edge of the through lane of the intersecting road extended.

O. INDUCTION LOOP DETECTORS. Standard loop dimensions for stop bar detection include 6 ft. x 50 ft. Quadrapole detector loops. All advance detector loops shall be 6 ft. x 6 ft. detector loops. Advance detection is only used on streets with posted speeds of 35 mph or more, and should be placed at standard distances as indicated in the table below (measured from the back of the stop bar to the back of the loop).

Posted Speed (mph)	Distance to 1st Detector (feet)	Distance to 2nd Detector (feet)	Distance to 3rd Detector (feet)
35	210	--	--
40	210	260	--
45	210	320	--
50	210	380	--
55	210	320	485

In order to determine where to place a 6 ft. x 50 ft. stop bar detector loop, the City typically places the front of the loop 15 to 20 feet from the nearest edge of the through lane of the intersecting road extended.

P. PEDESTRIAN PUSHBUTTON DETECTORS. Pushbuttons shall meet ADA and MUTCD requirements for Accessible Pedestrians Signals, per the City's Approved Product List. Each pushbutton shall be wired to the adjacent corresponding pedestrian signal head using a 4 conductor #14 signal control cable (IMSA specification 19-1).

Q. EMERGENCY VEHICLE PRE-EMPTION. Emergency vehicle pre-emption (EVP) equipment shall be as shown on the signal plans and per the City's Approved Product List. Emergency vehicle pre-emption shall be designed for all directions of traffic at an intersection, with the possible exception of private drives. Generally, detectors should be placed on the same mast arm as the vehicular signal indications for the corresponding direction of travel. Detectors should typically be located between the signal heads for the through phase.

R. TRAFFIC SIGNAL SIGNS. Typically, overhead street name signs should be located on the mast arm. The Design Engineer will compute the sign dimensions and show them on the plans. Any other signage to be installed on mast arms or signal poles shall be shown on the plans. In general, overhead lane control signs (MUTCD Number R3-5 series) are to be installed on mast arms adjacent to left-turn signal heads or flashing yellow arrow signal heads instead of other regulatory signage. Each pedestrian pushbutton shall include a pedestrian sign (MUTCD Number R10-3e) that is installed on the same mounting assembly as the pushbutton.

S. INTERCONNECT. Interconnection of traffic signals is required at locations specified by the City Engineer. Interconnection will be per Missouri Department of Transportation Standards and Specifications.

PLAN REQUIREMENTS

The traffic signal plans shall include all information necessary to build and check the design of a traffic signal system. Traffic signal plans shall meet all plan submittal requirements for the City of Liberty in addition to the requirements listed in this section.

Traffic signal plans shall consist of the following sheets:

- Title Sheet
- General Notes and Legend Sheet
- Traffic Signal Plan Sheet
- Traffic Signal Interconnect Plan Sheet(s) (if necessary)
- Wiring Diagram
- Signal Equipment Quantities Sheet
- Cable and Conduit Quantities Sheet
- Standard Detail Sheets

Title Sheet: Title sheet is only required for stand-alone traffic signal projects. If traffic signal plans are part of a larger plan set, a title sheet is not necessary. The title sheet shall meet the City's plan requirements for public improvement projects.

General Notes and Legend Sheet: This sheet should contain the following:

A. List of general notes to the Contractor
B. Any project specific notes
C. Legend of symbols that apply to all sheets
D. Standard sign face details
E. Traffic signal head legend
F. List of existing signal equipment to be removed

Traffic Signal Plan Sheet: The plan sheet(s) shall include the following information:

A. One or more plan sheets adequately showing the traffic signal system in relation to the streets and adjacent properties, with a north arrow, and a bar scale at a minimum scale of 1 inch equals 20 feet.
B. All existing and proposed utilities such as power, gas, water, telephone, cable, sanitary sewer, storm sewer, and other items shall be accurately shown according to the best available information in the records of the owner of the facility, or field location, and shall be identified as to type, size, material, etc., as may be applicable. Existing utilities should be shown in gray.
C. All existing and known proposed improvements within 50 feet each side of the right-of-way and 100 feet beyond the project limits shall be shown at their proper locations unless otherwise approved or required by the City Engineer. These improvements shall include items such as street pavement, curbs and gutters, sidewalks and driveways, storm and sanitary sewers, water mains and fire hydrants, utility poles and pedestals, trees and shrubs, fences and walls, buildings, and similar items, and shall be identified as to type, size, material, etc., as may be applicable. Irrelevant items may be omitted for new developments. Existing items should be shown in gray. New non-signal items may be shown with a thin black line. Future non-signal items may be shown with a dashed line.
D. Typically, signal equipment does not need to be identified by station and offset unless stationing is available. When stationing is not available, all pole, box, and controller locations should be dimensioned from the curbs, pavement edges, or other prominent topographical features identified on the base mapping. If the signal is part of an improvement project for which stationing and controls have been developed, street centerline stations should be shown and marked at 100-foot intervals for consistency between the signal and improvement plans.

E. Pushbutton location should be shown on a diagram to indicate the location of pushbuttons on signal poles in plan view. The diagram should include pole numbers and arrows adjacent to the pushbuttons to indicate the direction of crossing that is associated with the pushbutton.

Traffic Signal Interconnect Plan Sheet: If interconnect to an adjacent signal (or signals) is part of the design, a separate interconnect plan may be included. This plan should be at a minimum scale of 1 inch equals 50 feet and should identify all conduit and boxes necessary to provide a complete interconnect system. The plan should also include notes (and details, if necessary) identifying how connections will be made in each controller. The plan should include a quantity table indicating total length of conduit and wiring; as well as the total number of boxes.

Wiring Diagram: This sheet should include an overall schematic of the traffic signal system, including interconnect (if necessary). The type and size of each conduit run will be identified. The number and types of cables in the conduits will also be labeled. The sheet should also include the following:

A. Signal Phasing Diagram
B. Table of NEMA load switch assignments
C. Table of flash operations

Signal Equipment Quantities Sheet: This sheet should contain the following:

A. Signal pole table indicating mast arm length, signal head and equipment spacing along arms, equipment types, and foundations
B. Pull boxes table
C. Controller and miscellaneous equipment table
D. Traffic signal phase timings

Cable and Conduit Quantities Sheet: This sheet should contain the following:

A. Conduit table, indicating size, type, and length for each run
B. Cable table, indicating type and length between all equipment.

TRAFFIC SIGNAL TIMING GUIDELINES

The City has developed some typical signal timings and guidance that should be used when developing timings for traffic signals. In general, these guidelines are based on the Federal Highway Administration's Traffic Signal Timing Manual. They are as follows:

Minimum Green:

Through Phases	Arterial Streets with Speed Limit > 40 mph	10 to 15 seconds
	Arterial Streets with Speed Limit ≤ 40 mph	7 to 15 seconds
	Collector or Local Streets	5 to 10 seconds
Left-Turn Phases	Any Street Classification	5 seconds

Maximum Green:

Through Phases	Arterial Streets with Speed Limit > 40 mph	40 to 60 seconds
	Arterial Streets with Speed Limit ≤ 40 mph	30 to 50 seconds
	Collector or Local Streets	20 to 40 seconds
Left-Turn Phases	Any Street Classification	15 to 30 seconds

Passage:

Through Phases	Speed Limit > 40 mph	3 seconds
	Speed Limit ≤ 40 mph	2 second
Left-Turn Phases	Any Street Classification	2 seconds

Yellow Change: Calculated based on the following formula:

$$\text{Yellow Change} = t + \frac{v}{2a + 64.4g} = 1.5 + \frac{v}{22.4 + 64.4g}$$

t = Perception reaction time = 1.5 seconds
v = Posted speed limit in feet/second
a = Deceleration rate = 11.2 feet/second^2
g = Grade in percent divided by 100

Additional Remarks:

- Minimum Yellow Change time should be 3 seconds, and the maximum should be 6 seconds.
- Grade is the average from the stop bar to the following distances:
  - 100 feet for posted speed limits ≤ 30 mph
  - 150 feet for posted speed limits = 35 mph
  - 200 feet for posted speed limits = 40 mph
  - 250 feet for posted speed limits = 45 mph
- Grade = 0 for grades of of -3% to 3%.
- The speed for left-turn movements should be 20 mph.
- For protected/permissive phasing, the same Yellow Change time should be used for both approaches (i.e. opposing approaches). When determining the Yellow Change time, use the greatest value for opposing approaches.

Red Clearance: Calculated based on the following formula:

$$\text{Red Clearance} = \frac{w}{v}$$

w = Width of intersection in feet. Measured from stop bar to near side of crosswalk
v = Posted speed limit in feet/second

Additional Remarks:

- Minimum Red Clearance time should be 1 second.
- The speed for left-turn movements should be 20 mph.
- Measure the width of the intersection for through and left-turn movements per Figures 1 and 2.
- For protected/permissive phasing, the same Red Clearance time should be used for both approaches (i.e. opposing approaches). When determining the Red Clearance time, use the greatest value for opposing approaches.

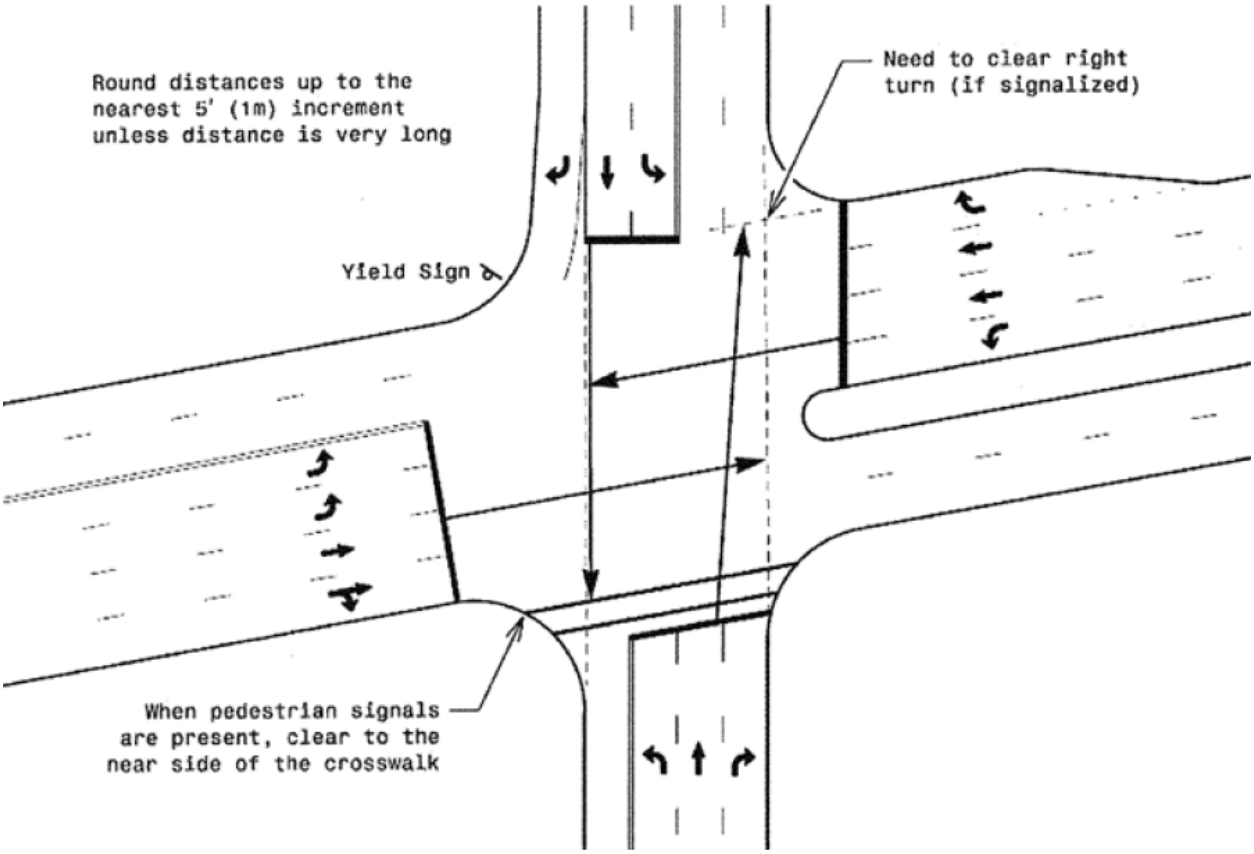


Figure 1 – Measurement for Red Clearance Interval for Through Traffic

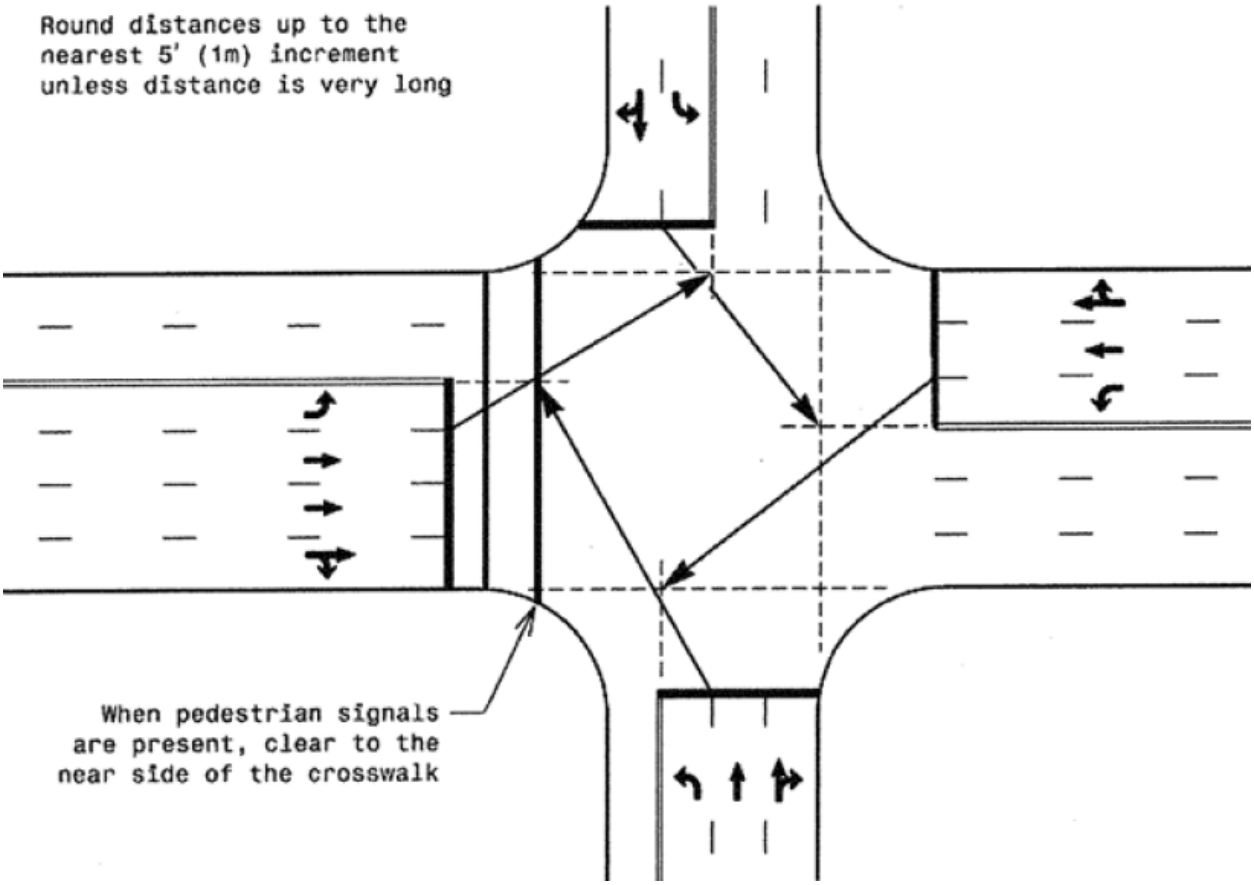


Figure 2 – Measurement for Red Clearance Interval for Left-Turn Traffic

Delay: A 10 second delay is added for detectors in exclusive right-turn lanes. A 3 second delay is added for detectors in a left-turn lanes that are not separated from opposing traffic by a raised median.

Recall Mode: Minimum recalls should generally be used for the through phases of arterial streets.

Dual Entry: Dual entry is generally used for all through phases.

Walk: 7 seconds

Flashing Don't Walk (FDW): Distance in feet is measured between curb faces along the centerline of the crosswalk and then divided by 3.5 feet per second. Additionally, the sum of the Walk and FDW times shall be greater or equal to the distance in feet measured between the pushbutton and the far curb face along the centerline of the crosswalk divided by 3.0 feet per second.

Gap reduction features of volume-density timings should be used when signals are operating in fully actuated mode, but not with coordinated timing plans. These parameters include Minimum Gap, Time Before Reduction, and Time To Reduce. Refer to the Traffic Signal Timings Manual for guidance.

In the Emergency Flash Table, the indications for all vehicular signal phases shall be RED while the indication for pedestrian phases shall be DARK.

If used, right-turn overlaps should be hard-wired in the controller cabinet.