SCDOT TRAFFIC SIGNAL DESIGN GUIDELINES 2021

TRAFFIC ENGINEERING

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Chapter One - Introduction

The purpose of the South Carolina Department of Transportation (SCDOT) Traffic Signal Design Guidelines is to establish guidance, procedures and specifications that promote uniformity in the design of traffic signals. It is intended to clarify expectations and expedite the production and review of signal plans. These design guidelines include signal plan drafting guidance and specialized signal designs to ensure that plans properly convey the extent and character of the work to be performed, as well as the operation of the signal upon completion of the project. However, it is not represented to be comprehensive or sufficient in every respect. Sound traffic engineering judgment should be exercised in applying these guidelines.

Newer or different design techniques presented in this document do not imply that existing signal designs are unsafe, nor does it mandate the initiation of improvement projects to create compliance. The extent to which these guidelines are applied to maintenance and rehabilitation projects may vary depending on the scope of the improvements and site specific investigations, history, and analysis.

The documents listed below provide more detail concerning specific traffic signal design elements. These references are current at the time of publication. The designer is responsible to consult the source for updates and or modifications. The most current version should be used.

References

Manual on Uniform Traffic Control Devices (MUTCD)

Traffic Signal Timing Manual, NCHRP Report 812

Guidelines for Timing Yellow and All-Red Intervals at Signalized Locations, NCHRP Report 731

SCDOT References

SCDOT Maintenance Manual

Access & Roadside Management Standards

Roadway Design Manual

FHWA Highway Rail Crossing Handbook 3rd Edition

SCDOT Qualified Product List

SCDOT Material Specifications for Traffic Signal Equipment

SCDOT Traffic Signal Supplemental Technical Specifications

SCDOT Traffic Signal Standard Drawings

SCDOT Directives and Guidelines

SCDOT Engineering Directive 2 “Fiscal Responsibility for Traffic Signals on State Highway System”

SCDOT Engineering Directive 33 “Mast Arm Policy”

SCDOT Traffic Guideline 1 “Street Name Signs on Signal Span Wires on Mast Arms”

SCDOT Traffic Guideline 29 “Late Night Flash Operation of Traffic Signals”

SCDOT Traffic Guideline 33 “Rectangular Rapid Flash Beacon”

SCDOT Traffic Guideline 34 “Aesthetic Treatment of Traffic Signal Cabinets”

SCDOT Traffic Guideline 35 “Business Rules for Signal Shops”

Chapter Two – Border, Charts, and Signal Timings

Traffic signal plans should provide an accurate depiction of the roadway elements and the proposed signal equipment at the time of installation. These include but are not limited to:

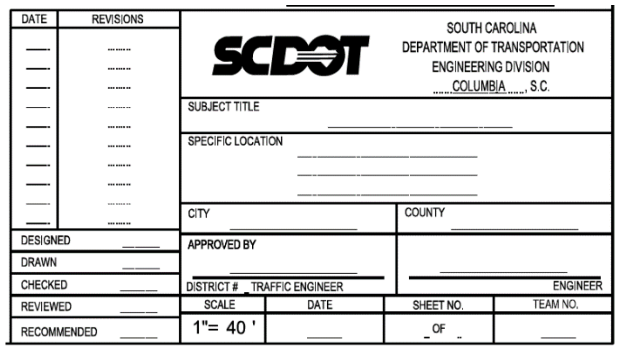
- Intersection geometry
- Pavement markings
- Pertinent signs
- Sidewalk and curb ramps
- Channelized islands
- Intersecting roadway/driveway on the mainline within 400 feet of the intersection
- Intersecting roadway/driveway on the side street within 200 feet of the intersection
- Relevant Utilities
- Rights-of-way
- Conduits
- Splice boxes
- Signal support poles
- Detection
- Signal head orientation
- Span wire
- Messenger wire/Interconnection
- Signal cabinet
- Pedestrian treatment
- Special features (adjacent development, railroad crossings, etc.)

All signal equipment shown on the plan is schematic and the actual location will be determined in the field. Signal plans are the property of the SCDOT District Office and/or the local municipality. Other signal information related to timings, phasing, intersection characteristics, etc. is displayed in the charts located on the SCDOT standard border shown in Appendix A and discussed later in this section.

2.1 General Signal Plan Presentation

The full size signal plan sheet will match SCDOT normal construction plans. Traffic signal plan sheets should be designed to be clear and legible while showing as much existing and/or proposed roadway information as possible. Signal plans shall be prepared under the supervision of a South Carolina registered engineer who will date, sign, and seal the plan. The date, signature, and seal must be legible on the plan.

The preferred scale for traffic signal plans is 1’=30’ or 1”=40’ and is shown in the Title Block which is located on the lower right corner of the Traffic Signal Border. The Title Block also specifies the location of the intersection and the plans revision history.



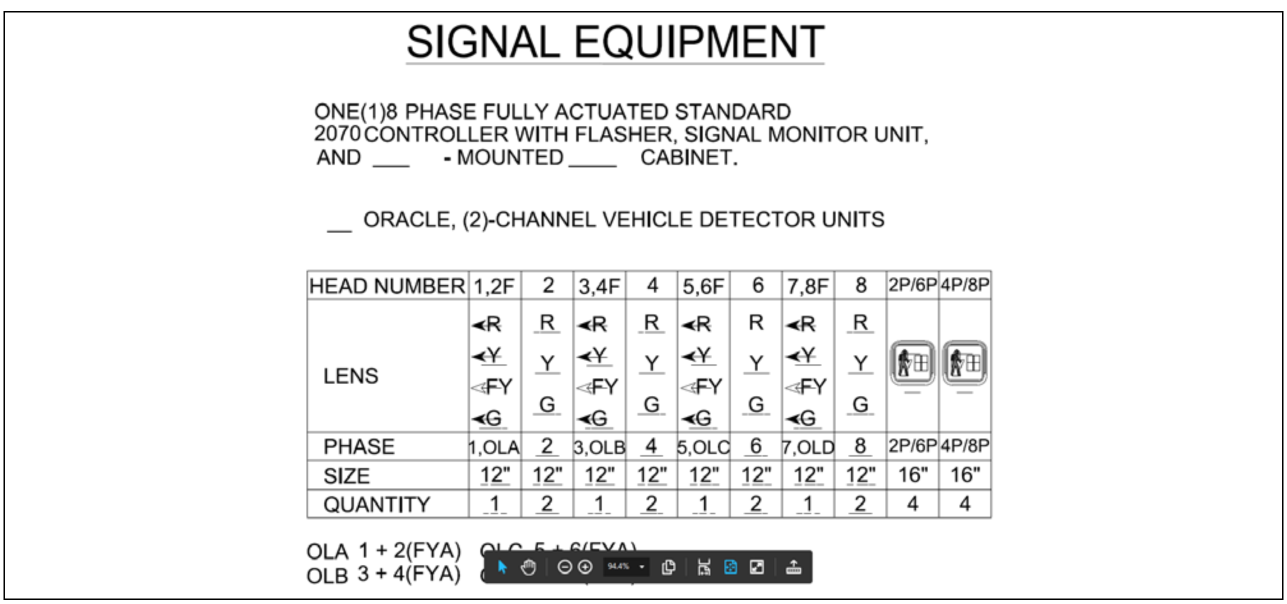
Generally, the traffic signal plans should be formatted with the main street orientated left to right across the page. All text and fonts should be large enough to read and understand. A north arrow is required to indicate direction on the signal plan.

2.2 Traffic Signal Border Charts

The charts contained in SCDOT's standard Traffic Signal Border provide specific information regarding the type of signal equipment and phasing associated with the signal.

2.2.1 Signal Equipment Chart

The Signal Equipment Chart is located in the upper left corner of the signal plan. It provides details on the controller, cabinet, detector units, the quantity and size of signal heads and pedestrian heads. Overlap function information is also shown in this chart.



SIGNAL EQUIPMENT

ONE(1)8 PHASE FULLY ACTUATED STANDARD
2070 CONTROLLER WITH FLASHER, SIGNAL MONITOR UNIT,
AND ___ - MOUNTED ____ CABINET.

__ ORACLE, (2)-CHANNEL VEHICLE DETECTOR UNITS

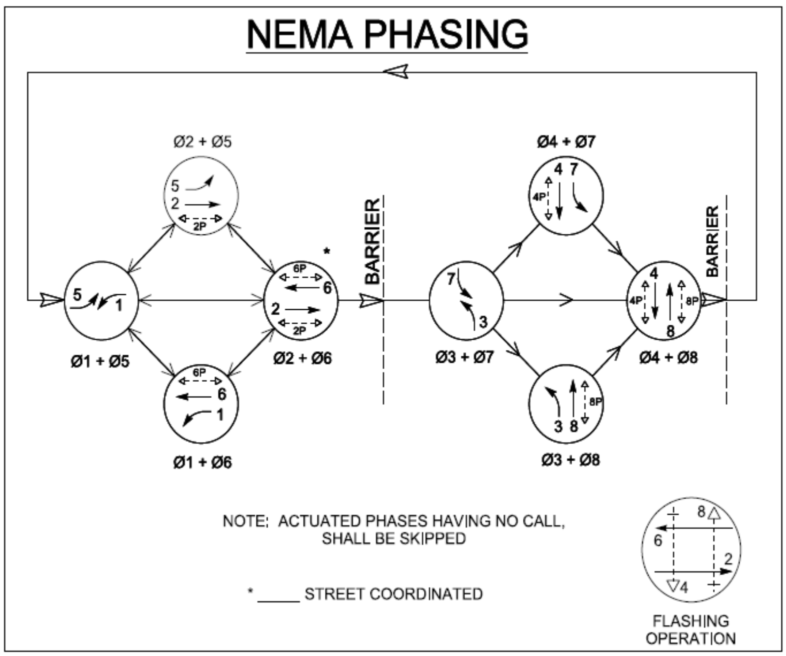
HEAD NUMBER	1,2F	2	3,4F	4	5,6F	6	7,8F	8	2P/6P	4P/8P
LENS	R Y FY G	R Y G	R Y FY G	R Y G	R Y FY G	R Y G	R Y FY G	R Y G		
PHASE	1,OLA	2	3,OLB	4	5,OLC	6	7,OLD	8	2P/6P	4P/8P
SIZE	12"	12"	12"	12"	12"	12"	12"	12"	16"	16"
QUANTITY	1	2	1	2	1	2	1	2	4	4

OLA 1 + 2(FYA)
OLB 3 + 4(FYA)

2.2.2 NEMA Phasing Chart

The NEMA Phasing chart details the phase and movement numbering convention. Signal heads on arterial streets (i.e. main street) are shown as phase 2 and phase 6. Phase 2 signal heads are either displayed in the direction of the eastbound or southbound approach. Intersection movements are numbered clockwise. Even phase numbers are for through movements and odd phase numbers are for left turn movements. Phasing may vary depending on intersection layout.

The arrows between the phasing circles indicate the sequence of phasing. The below NEMA Phasing chart indicates that phase 1 and phase 5 are allowed to lead and lag, while phase 3 and phase 7 are lead only.



2.2.3 Plan Information Chart

The Plan Information Chart is located in the upper right corner of the signal plan. It details project information when the signal work is funded as part of a project. The chart is omitted when the signal plan is not included in an SCDOT Let project.

FED. ROAD DIV. NO.	STATE	COUNTY	PROJECT ID	ROUTE NO.	SHEET NO.
-	-	-	-	-	-

TABLE OF OPERATION	PHASE IN OPERATION								
SIGNAL HEAD #	Ø1 + Ø5	Ø1 + Ø6	Ø2 + Ø5	Ø2 + Ø6	Ø3 + Ø7	Ø3 + Ø8	Ø4 + Ø7	Ø4 + Ø8	FLASH
1,2F	◄G	◄G	◄FY	◄FY	◄R	◄R	◄R	◄R	◄Y
2	R	R	G	G	R	R	R	R	Y
2,3CON	R	R	G	G	R / G►	R / G►	R	R	Y
3,4F	◄R	◄R	◄R	◄R	◄G	◄G	◄FY	◄FY	◄R
4	R	R	R	R	R	R	G	G	R
5,6F	◄G	◄FY	◄G	◄FY	◄R	◄R	◄R	◄R	◄Y
6	R	G	R	G	R	R	R	R	Y
7,8F	◄R	◄R	◄R	◄R	◄G	◄FY	◄G	◄FY	◄R
8	R	R	R	R	R	G	R	G	R
2P	DW	DW	W	W	DW	DW	DW	DW	DRK
4P	DW	DW	DW	DW	DW	DW	W	W	DRK
6P	DW	W	DW	W	DW	DW	DW	DW	DRK
8P	DW	DW	DW	DW	DW	W	DW	W	DRK

2.2.4 Table of Operation Chart

The signal head indication is displayed in the Table of Operations Chart for each phase.

2.2.5 Map/Grade/Speed Chart

The intersections location, as well as approach grades and speeds are shown in the Map/Grade/Speed Chart. The information is used to calculate the Yellow and Red Clearance times.

Map Here

ROUTE NUMBER	S-1 Main St.		S-2 Side St.	
APPROACH DIRECTION	E	W	N	S
SIGNAL DESIGN SPEED	45	45	45	45
GRADE (%)	0	1	0	1

2.2.6 Vehicle Detection Chart

The Vehicle Detection Chart describes the detection parameters at the intersection for each phase. These detection settings will influence the intersection operation. **Figure 2-1** displays the appropriate location for set back detection. Guidance on each column for the Vehicle Detection Chart is discussed in the following sections.

LOOP DETECTOR INSTALLATION CHART

PHASE/	DETECTOR		WIRED TO					OPERATION		SPECIAL FEATURES	LOOP DESIGN		
LOOP LTR#	AMP NO.	CHAN NO.	PHASE(S)	X LOCK	X NON-LOCK	X PULSE	X PRES	DELAY SEC	EXT SEC	TIME OF DAY-TOD SWITCHING, etc.	SIZE X	NO.OF TURNS	DIST. FROM ℄
1A			1		X		X			QUADRUPOLE	6' X 30'	2-4-2	0'
2A			2	X						LOOP	6' X 6'	4	330'

2.2.6.1 Phase/Loop LTR #

The first column of the Vehicle Detection Chart identifies the individual detection zone. Numbering convention is associated with the signal phase for the approach the detection zone occupies. Multiple detections zones on one approach are designated by letters starting with the detection closest to the stop line and/or closest to the center line.

2.2.6.2 Detector: Amplifier Number/Channel Number

The Detector columns identify the Amplifier and Channel the vehicle detector is connected with on the vehicle detector unit. These values come from the SCDOT signal shops.

2.2.6.3 Wired to Phase

Identifies the phase the vehicle detector activates.

2.2.6.4 Lock

The Lock column designates the detector memory setting to remember or 'lock' the call placed by a vehicle after it moves over the detector. The traffic signal controller places a continuous call for service upon the first actuation received by a vehicle detector set to lock. This call is retained until the assigned phase is serviced, regardless of whether or not any vehicles are waiting to be served. **This setting will also extend the green time when activated by a vehicle. Set back detectors are set to lock.**

2.2.6.5 Non-Lock

The Non-Lock column designates the detector memory setting to only place a call on the signal phase when a vehicle is present on the detector. Once the car passes over or leaves the detector, the call is removed from the signal phase. Stop bar detectors are set to non-lock.

2.2.6.6 Pulse

Pulse is a detector mode setting that generates a short pulse (or temporary output) each time a vehicle enters a detection zone. SCDOT does not typically use this setting.

2.2.6.7 Presence

Presence is a detector mode setting that provides a constant output while a vehicle is over the detection area. SCDOT standard practice is to set all detectors to Presence mode.

2.2.6.8 Operations

The Operations columns displays detector modifiers that have the ability to alter the actuations received by the traffic signal controller in order to improve intersection operations.

Delay is used to temporarily disable the detector output for a phase which prevents the vehicle actuation from being recognized immediately by the signal controller. An actuation is not recognized unless the delay timer has expired and the detection zone is still occupied. The delay parameter should be considered for right turn on red scenarios or to prevent erroneous calls from being received in the traffic signal controller when vehicles traverse over another phase's detection zone. The delay setting typically is between 8 and 12 seconds.

Extend is used to temporarily increase the duration of a detection actuation. The actuation is held in the traffic signal controller as the detection zone becomes unoccupied and the call is retained until the extension timer expires. The extend parameter is typically applied to advance detectors when slower moving traffic is expected and require time to reach the next downstream detector. Values may range up to two seconds.

2.2.6.9 Special Features

The Special Features column describes type of vehicle detection equipment to be installed (i.e. quadrupole loop, wireless detection, radar, etc.).

2.2.6.10 Loop Design

The Loop Design column details the size and location of the vehicle detector, as well as the number of turns when inductance loops are installed.

Size - SCDOT standard size for stop bar detection is 6' x 30' and placed five feet in advance of the stop line. SCDOT standard size for set back detection is 6' x 6' for each approach lane and the distance from the stop line is based on speeds as shown in **Figure 2-1**.

Sensitivity - Increased for inductance loop detection by the number of times the loop wire is turned. *SCDOT Traffic Signal Supplemental Specification, SC-M-678-1* details the standard number of turns for various loop detection sizes. In general, the number of turns for a 6' x 30' quadrupole loop is designated as 2-4-2 and for a 6' x 6' loop it is 4 turns.

2.3 Signal Timings

The Signal Timing Chart details signal timing settings for each phase. Signal settings are determined based on roadway conditions that include speed, grade, traffic volumes, presence of pedestrians, detection zones, and intersection geometry.

SIGNAL TIMINGS

	PHASE							
	1	2	3	4	5	6	7	8
WALK		7		7		7		7
DON'T WALK		31		33		31		32
MIN INITIAL	8	15	8	8	8	15	8	8
MAX INITIAL		37				37		
ADD/VEH		2.5				2.5		
VEH EXT	3.0	6.0	3.0	3.0	3.0	6.0	3.0	3.0
TIM BFR REDUC		15				15		
TIME TO REDUC		30				30		
MIN GAP		3.0				3.0		
MAX LIMIT	15	50	15	30	15	50	15	30
MAXIMUM 2								
YELLOW	4.4	4.4	5.1	5.1	4.4	4.4	5.1	5.1
RED CLEAR	3.4	3.4	3.5	3.5	3.4	3.4	3.5	3.5

Figure 2-1 provides signal timing settings for approaches with set back detection. It is important to note that set back detection is required to provide Type II Dilemma Zone protection. An indecision zone or Type II dilemma zone is created when a driver

decides to stop or go as a signal is transitioning to serve the next phase. Studies suggest this zone occurs between 2.0-2.5 seconds and 4.5-5.5 seconds from the intersection. However, set back detection utilized for volume-density timings will limit Type II dilemma zone protection. Volume-density timings are discussed further in section 2.3.7.

Speed (mph)	Detection Setback (ft)	Min Initial (sec)	Max Initial (sec)	Vehicle Extension	Min Gap (sec)	Notes
30	80	12	12	2.5	2.5	**Low Speeds - Urban** Detection is primarily to gap out signal. Decision zone protections not provided.
35	200	15	24	3.0	2.5	**Urban and Suburban Arterials** Detection is primarily used to determine min green times and gap out signal. Limited decision zone protection. Min Gap provided to extend vehicles through decision zone.
40	300	15	34	6.0	2.5	
45	330	15	37	6.0	2.5	
50	370	15	41	6.0	2.5	
55	445	15	49	6.0	3.0	**High Speed Rural or Controlled Access** Detection is primarily used to determine min green times and gap out signal. Limited decision zone protection. Min Gap provided to extend vehicles through decision zone.
60	485	15	53	6.0	3.0	

Figure 2-1 Signal Settings for Set Back Detection Chart

Guidance on each signal timing setting shown in the Signal Timing Chart is discussed in the following sections.

2.3.1 Walk Time

The Walk Time is typically either 4 or 7 seconds. The presence of pedestrian heads results in a minimum walk time of 7 seconds per MUTCD 4E.06.11. Higher values are considered when large groups of pedestrians are observed crossing at one interval. A walk time of 4 seconds is reserved for intersections that only have push buttons as allowed in section 4E.06.12 of the MUTCD.

2.3.2 Don't Walk Time

The pedestrian clearance setting is typically calculated based on a 3.5 feet per second walking speed to cross from the edge of the travel lane to the far side of the travel way or to a median of sufficient width to accommodate pedestrians. **Figure 2-8** shows the area to be measured when calculating the Don't Walk Time. The calculated value should be rounded up to the nearest second.

***The Max Limit time should minimally equal the sum of the Walk and Don't Walk time.**

2.3.3 Min Initial

The Min Initial setting, also referred to as the Minimum Green, is the minimum amount of time the green indication will be provided to a phase. **Figure 2-1** shows the time setting for the phases that have set back detection (typically phase 2 and 6). Phase time settings that have detection at the stop line (typically the side street and left turn phase) are 8 seconds.

2.3.4 Max Initial

The Max Initial Setting is a dynamic minimum (initial) green time that ensure vehicles queuing at the stop bar are able to dissipate without additional detection activation. The setting values are shown in **Figure 2-1** and are only for phases with set back detection.

2.3.5 Add/Veh

The Add/Veh setting is also referred to as the Added Initial time. Set back detection counts the vehicles arriving at the intersection while the conflicting phase is being served. The number of vehicles counted is multiplied by the Added Initial setting which results in a dynamic 'initial green' value, up to the Max Initial setting.

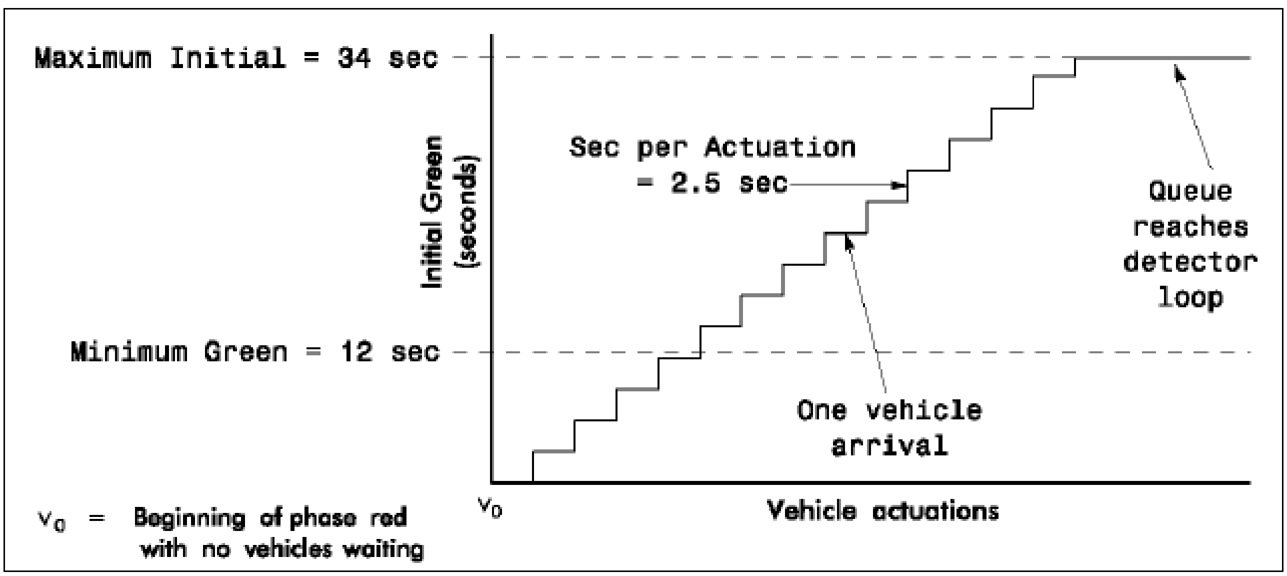


Figure 2-2 Added Initial Time Example

Figure 2-2 is a visual representation of the signal controller's process for calculating the initial green time.

Figure 2-3 provides guidance for Add/Veh timing values. Lower values should be used for traffic conditions that are evenly distributed over multiple lanes. Added Initial time should be increased for high truck traffic.

Approach Lanes	1 loop per lane (sec)	2 loops per lane (sec)
Single through lane	2.0 - 3.0	1.0 - 1.5
Two through lanes	1.5 - 2.0	0.5 - 1.0
Three (or more) through lanes	1.0 - 1.5	0.5 - 0.7

Figure 2-3 Added Initial Settings

*The Minimum Green time served is the greater of the Min Initial setting or the dynamic 'initial green' value.

2.3.6 Vehicle Extension

After the Min Green is served, the Vehicle Extension setting extends the green interval for each vehicle actuation up to the Max Limit (maximum green) as shown in **Figure 2-4**. Values are dependent on location of vehicle detectors. Vehicle Extension for phases with stop bar detection is between 2 and 3 seconds. **Figures 2-1** shows the setting values for phases with set back detection.

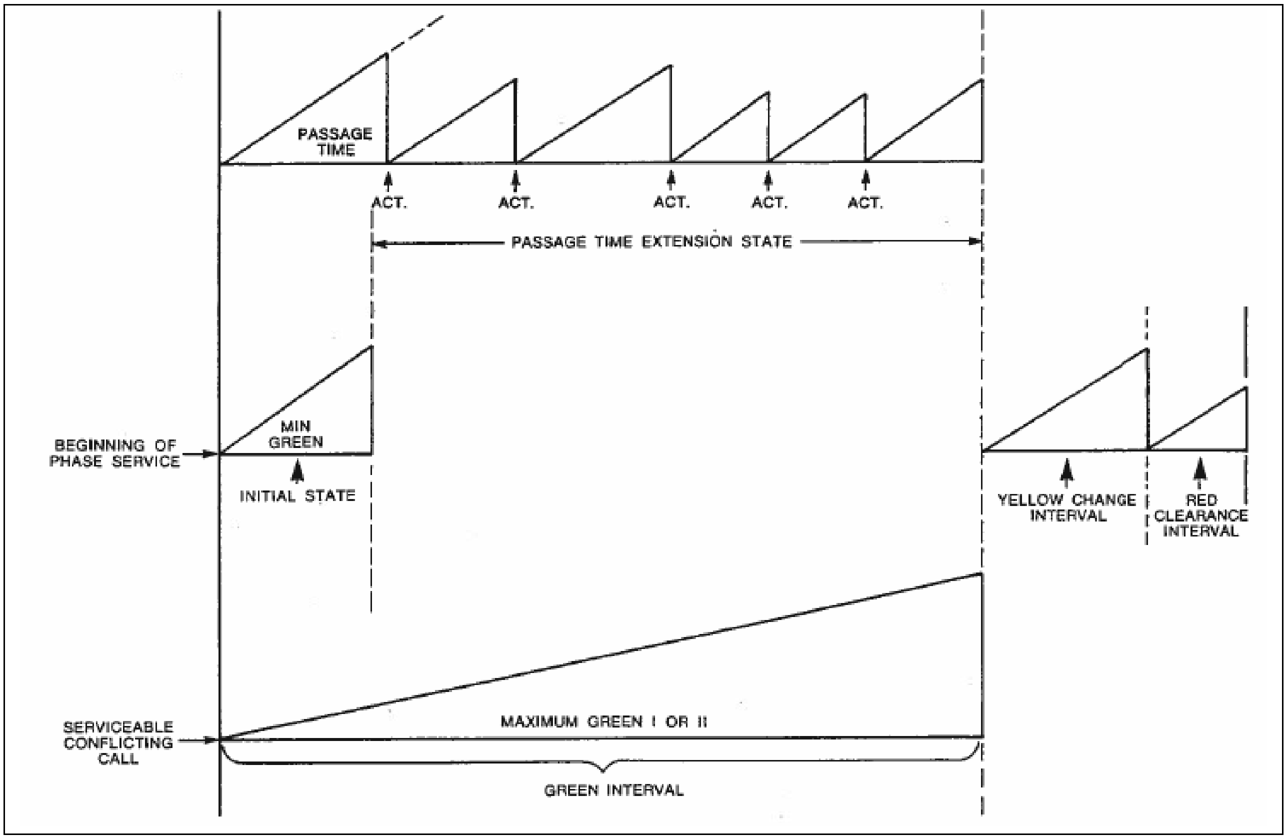


Figure 2-4 Typical Standard Timing Diagram

2.3.7 Volume Density

Volume – Density timings should be utilized for all intersections with speed limits that equal or exceeds 40 MPH. Signal efficiency is increased when utilizing volume-density timings by beginning the phase with a higher gap time to accommodate approaching platoons. The gap time may be reduced once the platoon is served, which increases the chances of the signal “gapping out” rather than “maxing out”. This prevents vehicles arriving after the platoon from unnecessarily extending the phase and ensures that vehicles waiting on the other approaches promptly receive the green indication.

2.3.7.1 Time Before Reduction

The Time Before Reduction is a volume-density setting that allows time for the queue at the stop line to dissolve and vehicles to begin to arrive with uniform headway. Typical values are between 10 and 20 seconds, but higher than the Min Initial setting.

2.3.7.2 Time to Reduce

The Time to Reduce is a volume-density setting that provides time to reduce the vehicle extension setting to the minimum gap setting. This setting should allow the Min Gap to operate for at least 15 seconds. The Time to Reduce setting is calculated from the difference between the Min Initial Setting, the Time Before Reduction Setting, and the Max Limit (maximum green). Typical values are between 10 and 15 seconds.

Example: Min Initial = 12 seconds

Time Before Reduce = 15 seconds

Max Limit = 90 seconds

Then Time to Reduce could = 45 seconds to allow Min Gap to operate for 30 seconds

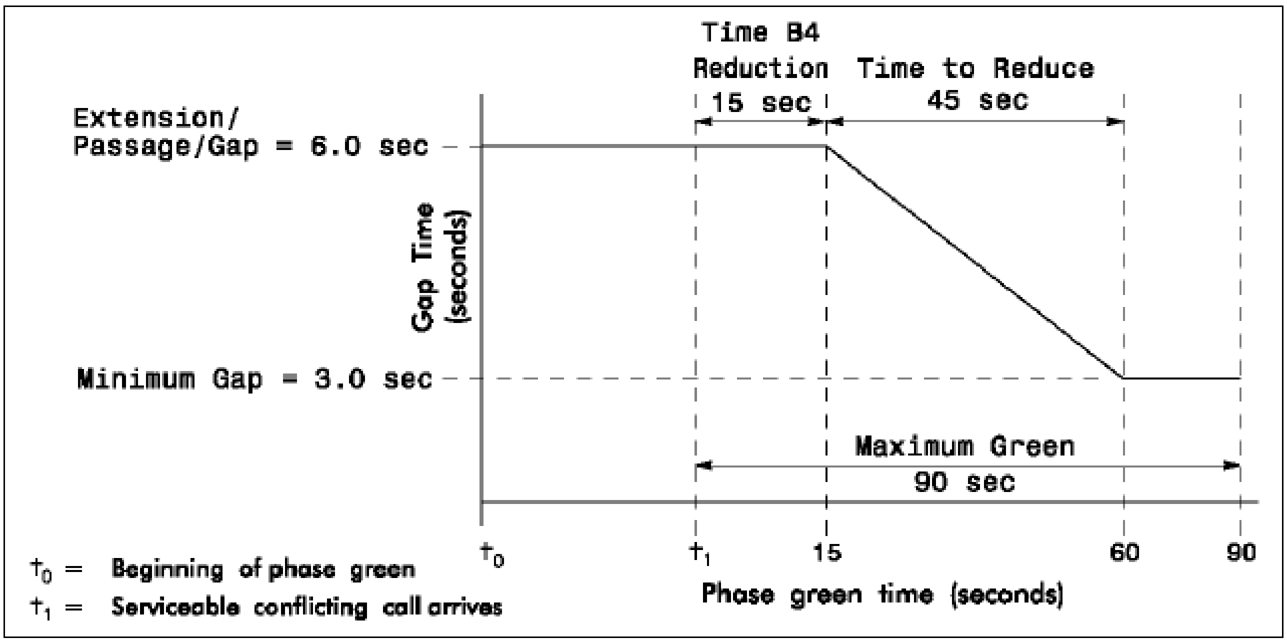


Figure 2-5 Time to Reduce Example

2.3.7.3 Min Gap

The Min Gap operates while its phase is being served and is the reduced timing for Vehicle Extension on approaches with set back detection. It extends the green interval for each vehicle actuation up to the Max Limit (maximum green). Values are typically 2.5 seconds. When volume density timings are not being used, the Min Gap must equal the Vehicle Extension to prevent sudden gap outs.

2.3.8 Max Limit

The Max Limit is the maximum green time provided for a signal phase. These settings can be calculated based on existing or projected traffic volumes, lane capacity, and phasing relationships as determined by widely accepted methods of engineering analysis. Synchro is the preferred program by SCDOT when performing a capacity analysis to determine the Max Limit. However, the minimum value for this setting would be the greater of either the sum of the Walk and Don't Walk time or the sum of the Time Before Reduce and Time to Reduce plus 15 seconds. Generally, values range from 40 to 60 seconds.

2.3.9 Maximum 2

The Maximum 2 settings is for special times of the day when traffic volumes are expected to increase and the signal will operate in congested or saturated conditions. It is usually a higher value than the Max Limit.

2.3.10 Yellow and Red Clearance Time

The kinematic equation is used to calculate the Yellow and Red Clearance intervals in order to provide enough time for vehicles to either stop or proceed safely through the intersection prior to the release of opposing traffic. During the yellow clearance interval, vehicles that cannot comfortable stop are given time to reach the intersection. The red clearance interval allows time for vehicles that entered the intersection during the yellow indication to clear the intersection before the display of a conflicting green signal indication.

Figures 2-6 and **2-7** charts the yellow and red clearance settings based on the ITE formula that adheres to current professional standards. The following guidelines should be applied when calculating the yellow and red clearance intervals.

- The minimum yellow clearance interval is 3 seconds as specified in the MUTCD.
- The minimum red clearance interval is 1.5 seconds.
- Use the posted speed for through movements.
- Use 20 mph speed for left turn movements. Adjusts for skews and other conditions.
- The calculated clearance intervals that encompasses both the left turn and through movements should be used during the permissive portion of the protected/permissive left turn phase.

  For example:
  Phase 1 (left turn) clearance intervals are calculated as Y=3.0 and R=3.0
  Phase 2 (through) clearance intervals are calculated as Y=4.0 and R=2.5
  Then show:
  Phase 1 (left turn) clearance intervals as Y=3.0 and R=3.0

Phase 2 (through) clearance intervals as Y=4.0 and R=3.0

- Opposing through movements that operate concurrently shall have matching clearance intervals.
- Conduct an engineering study to justify yellow clearnce intervals in excess of 6 seconds.
- Mitigate red clearance intervals in excess of 3 seconds using the following formula:

  Mitigated Red = ½*[(Calculated Red Clearance) – 3] + 3

Figure 2-8 and **2-9** shows the method used to calculate the intersection clearance length. SCDOT uses a Clearance Time Calculation worksheet shown in Appendix B to aid in clearance time calculations and mitigating excessive clearance times. While not verified by SCDOT, the worksheet should be included in any signal submittal.

Measured approach grade	Posted Speed	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph
	v- velocity =>	29.33	36.67	44.00	51.33	58.67	66.00	73.33	80.67	88.00
g	Formula Y = t + v/2(a+32.174g) where t=1 sec; a=10ft/sec/sec	Y - Yellow Clearance								
5%		3.0	3.0	3.0	3.2	3.5	3.8	4.2	4.5	4.8
4%		3.0	3.0	3.0	3.3	3.6	3.9	4.2	4.6	4.9
3%		3.0	3.0	3.0	3.3	3.7	4.0	4.3	4.7	5.0
2%		3.0	3.0	3.1	3.4	3.8	4.1	4.4	4.8	5.1
1%		3.0	3.0	3.1	3.5	3.8	4.2	4.6	4.9	5.3
0		3.0	3.0	3.2	3.6	3.9	4.3	4.7	5.0	5.4
-1%		3.0	3.0	3.3	3.7	4.0	4.4	4.8	5.2	5.5
-2%		3.0	3.0	3.4	3.7	4.1	4.5	4.9	5.3	5.7
-3%		3.0	3.0	3.4	3.8	4.2	4.7	5.1	5.5	5.9
-4%		3.0	3.1	3.5	3.9	4.4	4.8	5.2	5.6	6.0
-5%		3.0	3.2	3.6	4.1	4.5	4.9	5.4	5.8	6.2
		Minimum Yellow Clearance is 3 seconds								
		Mitigate Yellow Clearance exceeding 6 seconds								

Figure 2-6 Yellow Clearance Chart

Measured Intersection Clearance Length (ft)	Posted Speed	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph
	v- velocity =>	29.33	36.67	44.00	51.33	58.67	66.00	73.33	80.67	88.00
W	Formula R = (W+L)/v where L=20 ft	R - Red Clearance								
20		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
30		1.7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
40		2.0	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.5
50		2.4	1.9	1.6	1.5	1.5	1.5	1.5	1.5	1.5
60		2.7	2.2	1.8	1.6	1.5	1.5	1.5	1.5	1.5
70		3.1	2.5	2.0	1.8	1.5	1.5	1.5	1.5	1.5
80		3.4	2.7	2.3	1.9	1.7	1.5	1.5	1.5	1.5
90		3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.5	1.5
100		4.1	3.3	2.7	2.3	2.0	1.8	1.6	1.5	1.5
110		4.4	3.5	3.0	2.5	2.2	2.0	1.8	1.6	1.5
120		4.8	3.8	3.2	2.7	2.4	2.1	1.9	1.7	1.6
130		5.1	4.1	3.4	2.9	2.6	2.3	2.0	1.9	1.7
140		5.5	4.4	3.6	3.1	2.7	2.4	2.2	2.0	1.8
150		5.8	4.6	3.9	3.3	2.9	2.6	2.3	2.1	1.9
160		6.1	4.9	4.1	3.5	3.1	2.7	2.5	2.2	2.0
170		6.5	5.2	4.3	3.7	3.2	2.9	2.6	2.4	2.2
180		6.8	5.5	4.5	3.9	3.4	3.0	2.7	2.5	2.3
190		7.2	5.7	4.8	4.1	3.6	3.2	2.9	2.6	2.4
200		7.5	6.0	5.0	4.3	3.7	3.3	3.0	2.7	2.5
		Minimum Red Clearance is 1.5 seconds								
		Mitigate Red Clearance exceeding 3 seconds								

Figure 2-7 Red Clearance Chart

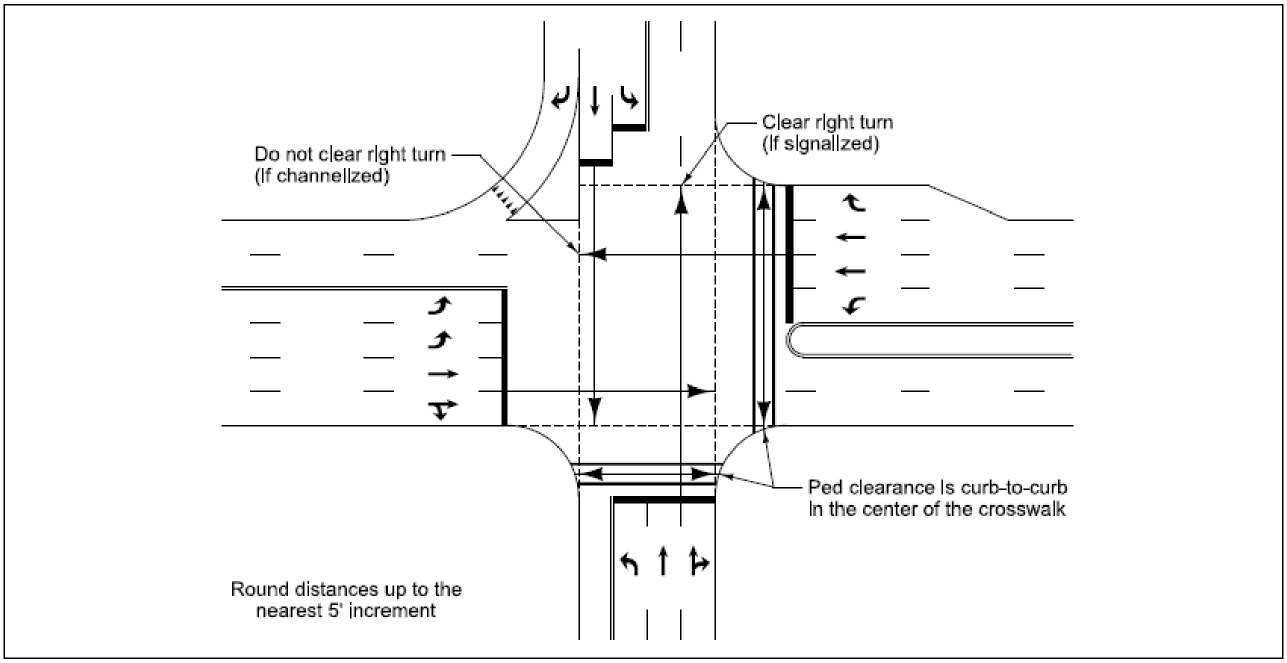


Figure 2-8 Through Movement Clearance Distances

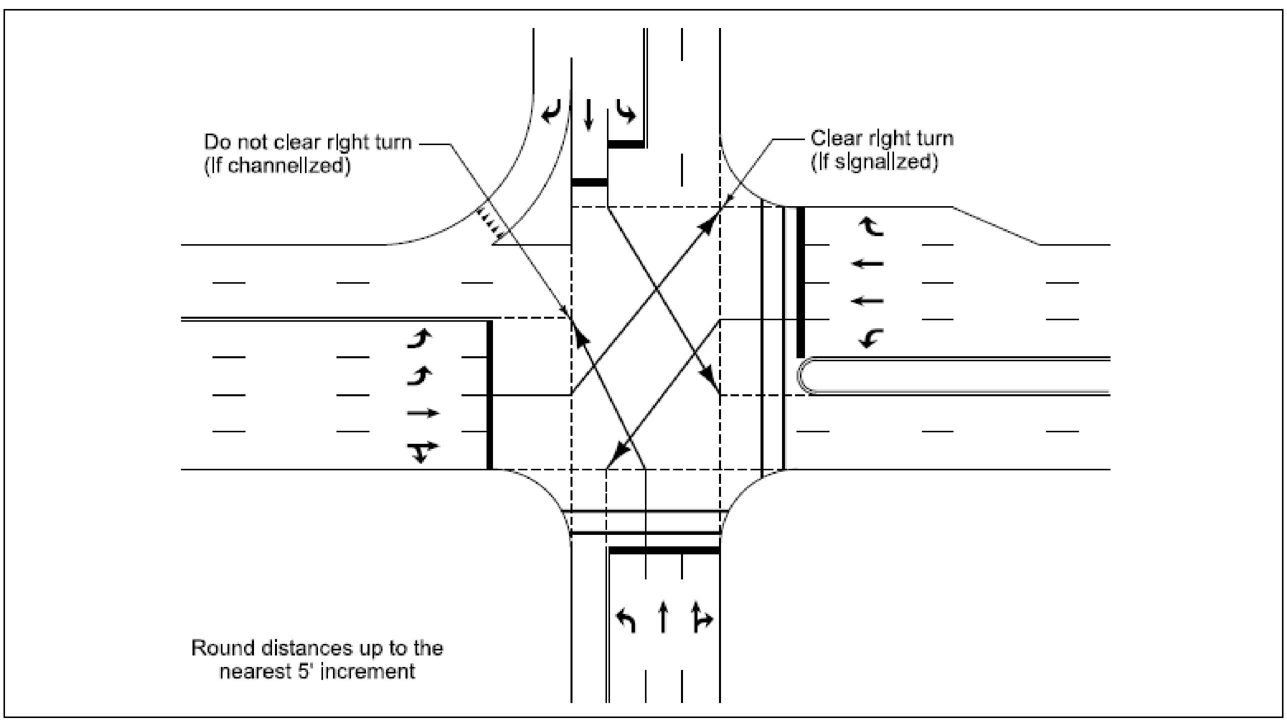


Figure 2-9 Left Turn Movement Clearance Distances

Chapter Three - Phasing

Signal phases are designated to an individual or a combination of traffic movements at an intersection in order to assign the right-of-way during the traffic signal cycle. The minimum number of phases for a signal is two, which consists of the mainline and the side street. The capacity of an intersection is affected by additional phasing due to the required signal phase clearance times and the reduced percent of time serving the mainline through traffic. A review of traffic volumes, roadway capacity, and field conditions should be conducted to determine the need for left turn phases, concurrent phases, split phases, and overlaps.

3.1 Left Turn Phase

Left turning movements encounter potential conflicts from several sources including opposing through traffic, crossing vehicular traffic, and pedestrians. A common request to facilitate this movement is a left turn phase. **A dedicated left turn lane must be present, as well as sufficient justification for a left turn phase to be installed at an intersection.** In rare instances, a left turn phase with no left turn lane may be considered.

3.1.1 Left Turn Study

The primary factors to consider in the need for a left turn phase are the volume and the degree of difficulty in executing the left turn through the opposing traffic. It is important to note that although the volume criteria may be met, a left turn phase may not be warranted when adequate left turn storage is available, sight distance is acceptable, and crash history is low.

Additional criteria for considering left turn signal phasing includes but is not limited to sight distance restrictions, speed of opposing traffic, number of left turn lanes, number of opposing through lanes, vehicle delay, angle of the left turn, and if the signal is part of a coordinated signal system. The following guidelines should be applied when determining whether a left turn phase should be considered. **A left turn analysis worksheet is provided in Appendix C**.

A protected/permissive left turn phase provides a combination of a left turn signal phase for the left turn movement and a permissive phase where the left turn vehicles must yield to oncoming through traffic. One or more of the following criteria should be met to consider this type of phasing.

- The cross-product of the same one hour volumes for the left turn traffic and the opposing through traffic divided by the number of lanes for the opposing through movement is greater than or equal to 50,000.

$$(V_{lt} \times V_o)/N_o \geq 50,000$$

Where: V_{lt} = left turn flow rate, vehicles/hour

V_o = opposing through movement flow rate, vehicles/hour

N_o = number of lanes for the opposing through movement

*Opposing right turn movement flow rate should be included as necessary

- The left turn volume exceeds 125 vehicles per hour.
- Correctable crashes equals or exceeds 4 crashes in one year or 6 crashes in two years.
- More than 2 left turn vehicles per cycle still waiting at the end of green.

A protected only left turn phase is an exclusive signal phase provided to left turning traffic. This phasing should be considered when one or more of the following conditions is satisfied.

- The cross-product of the same one hour volumes for the left turn traffic and the opposing through traffic divided by the number of lanes for the opposing through movement is greater than or equal to 150,000.

$$(V_{lt} \times V_o)/N_o \geq 150{,}000$$

Where: V_{lt} = left turn flow rate, vehicles/hour

V_o = opposing through movement flow rate, vehicles/hour

N_o = number of lanes for the opposing through movement

*Opposing right turn movement flow rate should be included as necessary

- Left turn crashes for protected/permissive phasing equals or exceeds 5 crashes in two years.
- Dual left turns.
- Limited sight distance will prohibit permissive turns.
- Conflicting left turning paths
- Opposing traffic is approaching in three or more lanes at speeds greater than or equal to 45 MPH.
- Unusual intersection geometry.
- High pedestrian volumes.

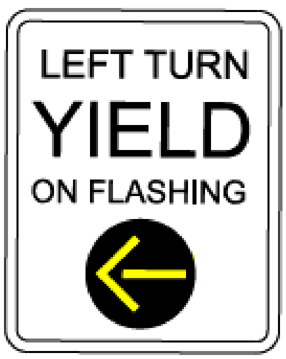
3.1.2 Left Turn Signal Heads and Phase Options

Special consideration is necessary for the selection of left turn phases and treatments. The four options for left turn phasing at an intersection are permissive only, protected/permissive, protected only, and prohibiting left turns.

3.1.2.1 Flashing Yellow Arrow (FYA)

Sections 4D.18 and 4D.20 of the MUTCD establishes the proper signal indications for permissive only and protected/permissive left turn movements. The MUTCD allows for multiple signal face arrangements and indications to be used for permissive only or protected/permissive left turn signal heads.

When new signals are installed or signals are substantially upgraded, a 4-section flashing yellow arrow (FYA) left turn signal head should be installed where a separate left turn lane is present and protected/permitted left turn operation is warranted unless geometric issues or lateral signal spacing issues reduce the effectiveness of a separate FYA signal face over the left turn lane. Where an offset left turn lane is present and protected/permitted left turn operation is warranted, a 4-section FYA left turn signal head shall be installed.



R10-12A-30

SCDOT sign R10-12A-30 explains the flashing yellow arrow operation to approaching motorists and should be placed adjacent to the FYA signal head.

In conditions where the minimum signal head height (17') cannot be provided due to utilities or other issues, it is allowable to install a 3-section flashing yellow arrow signal face that uses the bottom section to show both the steady green arrow (GA) and the flashing yellow arrow (FYA). This dual mode signal head is approved for use in Section 4D.20 of the MUTCD.

Where protected/permitted left turns are provided with a 4-section FYA and lagging operation of the protected left turn phase is anticipated, a FYA signal head (3-section for permitted only lefts or 4-section for protected/permitted lefts) must be installed for the opposite approach to eliminate the yellow trap.

A 3-section flashing yellow arrow (FYA) signal head shall be installed for permitted only left turn movements from offset left turn lanes or where the geometry of the intersection indicates a separate signal head would be beneficial over the left turn lane.

For permitted left turns opposite an approach with a 4-section FYA for protected/permitted left turn movements, installation of a 3-section FYA should be considered.

When the intersection is in flash due to a malfunction, the FYA head shall flash the same as the adjacent through movement (typically yellow on the main street and red on the side street). Red flash can be utilized on the mainline approach if indicated by engineering judgement. When yellow flash is utilized, the steady yellow section shall flash.

In some cases a five-section (doghouse) signal head may be used for a protected/permissive left turn phase. However, this style of signal head is not permissible at intersections with FYA signal heads. The 'doghouse' signal head should be aligned with the lane lines between the left turn lane and the through lane. A "Left Turn Yield on Green ball" (R10-12) sign must be installed adjacent to the signal head.

3.1.2.2 Protected Only Left Turn Phase

Protected only left turn phase shall have a separate signal head consisting of a RA RA YA GA signal head for a single left turn lane or two RA YA GA signal heads for two left turn lanes.

SCDOT Image

Left Turn Signal Head for Single Left Turn Lane

SCDOT Image

Left Turn Signal Heads for Dual Left Turn Lanes

The use of the red arrow in the left turn signal heads eliminates the need for the "Left Turn Signal" sign. Both the single and left turn signal phase heads should be placed directly over the center of the left turn lane. All signal heads should be placed within the 20-degree cone of vision as shown in **Figure 4-1**.

3.1.2.3 Left Turn Phase Sequence

It is necessary to select a protected left turn phasing sequence relative to the adjacent through movement. Left turn phases can operate either before or after the opposing through phase. However, special attention is necessary when selecting the left turn sequence phasing regarding the potential for the left turn yellow trap. Although there is no standardized method to select the sequence of left turn phasing, **Figure 3-1** describes the operational characteristics that will aid in the choice.

Left Turn Phase Sequence	Advantages	Disadvantages
Leading	1. Drivers tend to react more quickly to a leading green arrow indication than to a lagging left turn. 2. Minimizes conflicts between left turns and opposing through movements by clearing left turning vehicles first and reducing the need of left turn drivers to find safe gaps. 3. Minimizes conflicts between left turners and through movements on the same approach when the left turn volume exceeds the available storage bay length.	1. Potential for the left turn yellow trap. 2. Left turning vehicles may continue to turn after the green arrow display ends. 3. Through vehicles in the adjacent lane may make false starts in an attempt to move with turning vehicles. 4. Potential pedestrian conflicts at the beginning of the left turn phase due to pedestrian expectation of a Walk signal display.
Lagging	1. Provides operational benefits when the through movement queue blocks access to the left turning bay and the left turn is "starved" of traffic. 2. Increase efficiency by allowing left turning vehicles to clear the intersection during the permissive phase (if operating under protected/permissive left turn phasing) and, therefore, not call the protected phase. 3. Less pedestrian conflicts.	1. Potential for the left turn yellow trap. 2. Drivers usually react slower to a lagging left turn than to a leading left turn. 3. Through drivers may not stop due to the continued movement of the opposing through driver.
Lead-Lag	1. Beneficial in accommodating through movement progression in a coordinated system by providing a larger bandwidth.	1. Potential for the left turn yellow trap.

Figure 3-1 Left Turn Phase Sequence Operation Characteristics

3.1.3 Variable Left Turn Mode

Variable left turn mode is a traffic operation that changes the left turn phase from protected only, protected/permissive, and permissive by time of day or other selection criteria. Variable turn modes at traffic signals is **not** a standard practice in South Carolina. An engineering study evaluating the impact of this operation should be submitted to the Director of Traffic Engineering for review and must be approved prior to installation.

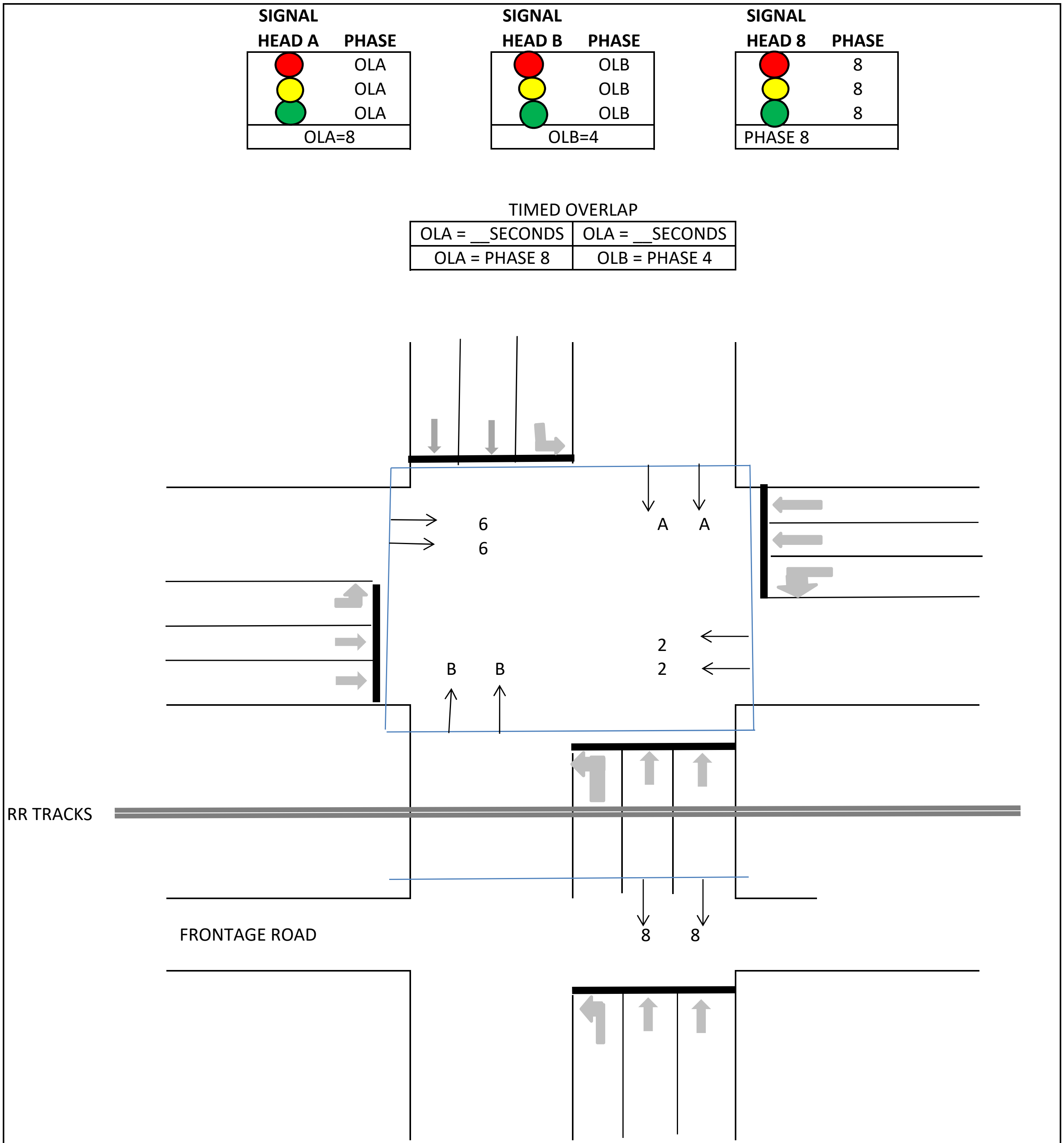
3.2 Overlaps

An overlap improves intersection operations by combining two or more phases for any non-conflicting movement. **Figure 3-2** shows the phase numbering convention when overlaps are used to operate the flashing yellow arrow section.

1,2F		3,4F		5,6F		7,8F	
RA	OLA	RA	OLB	RA	OLC	RA	OLD
YA	OLA	YA	OLB	YA	OLC	YA	OLD
FYA	OLA	FYA	OLB	FYA	OLC	FYA	OLD
GA	PHASE 1	GA	PHASE 3	GA	PHASE 5	GA	PHASE 7
OLA=1+2		OLB=3+4		OLC=5+6		OLD=7+8	
2F		4F		6F		8F	
RA	OLA	RA	OLB	RA	OLC	RA	OLD
YA	OLA	YA	OLB	YA	OLC	YA	OLD
FYA	OLA	FYA	OLB	FYA	OLC	FYA	OLD
OLA = 2		OLB = 4		OLC = 6		OCD = 8	

Figure 3-2 FYA Overlaps

Overlaps are also used to extend a green indication on certain signal heads to 'clear' a designated area. Additional signing and markings should be considered when designing timed overlaps. Examples of timed and complex overlaps are shown in **Figure 3-3** and **3-4**, respectively.



A TIMED OVERLAP WILL EXTEND THE GREEN TIME FOR OVERLAP SIGNAL HEADS (A AND B AS SHOWN IN THIS EXAMPLE) FOR THE TIME SPECIFIED IN THE CHART. TIMED OVERLAPS ARE COMMONLY USED TO PREVENT VEHICLES FROM GETTING CAUGHT IN THE SHORT STORAGE AREA BETWEEN THE FRONTAGE ROAD AND INTERSECTION. NOTE THAT BOTH APPROACHES UTILIZE TIMED OVERLAPS TO ENSURE HEADS A AND B GO TO YELLOW AND RED SIMULTANEOUSLY.

Figure 3-3 Timed Overlap

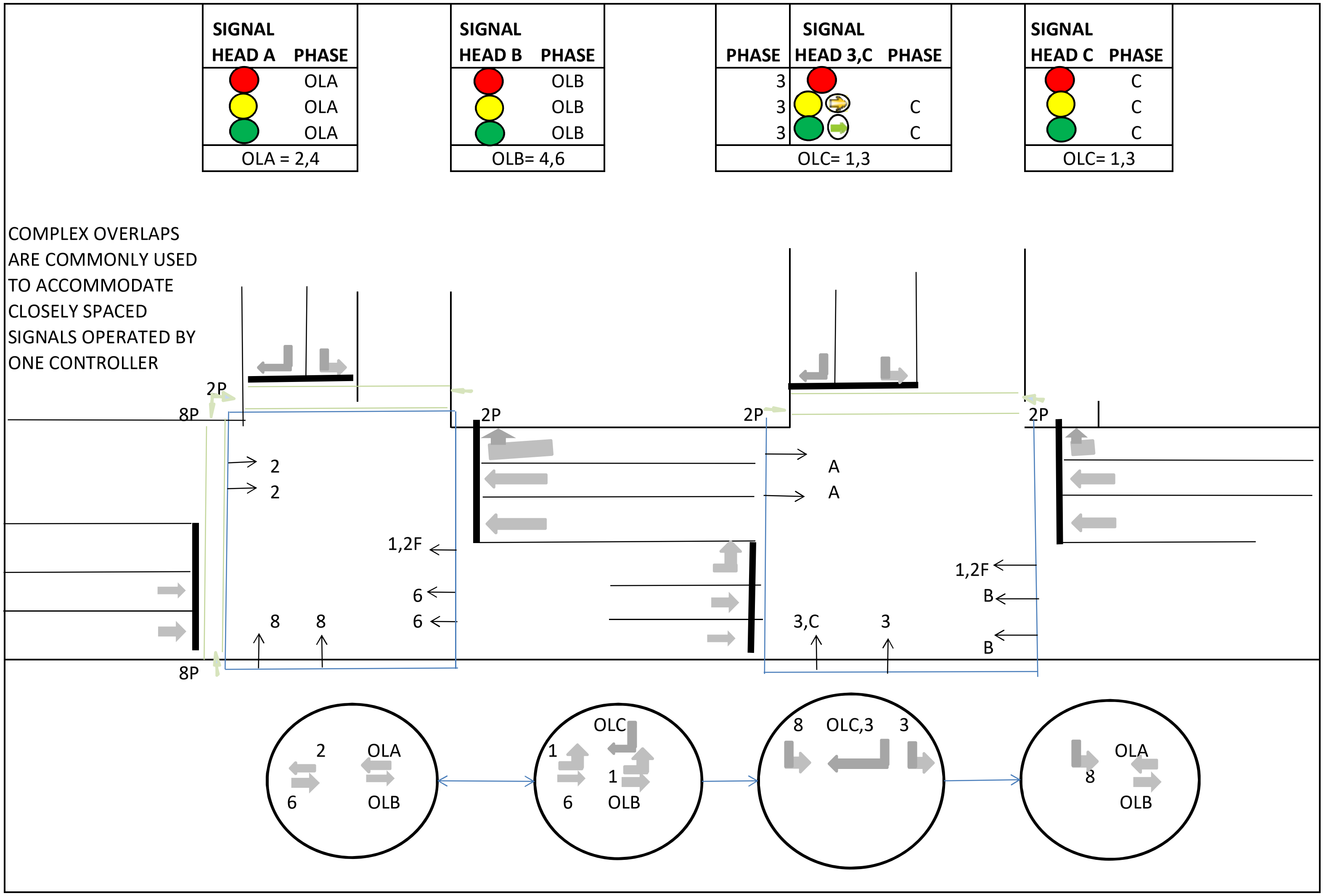


Figure 3-4 Complex Overlap

3.3 Concurrent Phase

Concurrent phases serve right turn movement during the appropriate left turn phase. An exclusive right turn lane is required to operate this type of phasing. The concurrent phase is displayed in a five section right turn signal head. An example is shown in **Figure 3-5**.

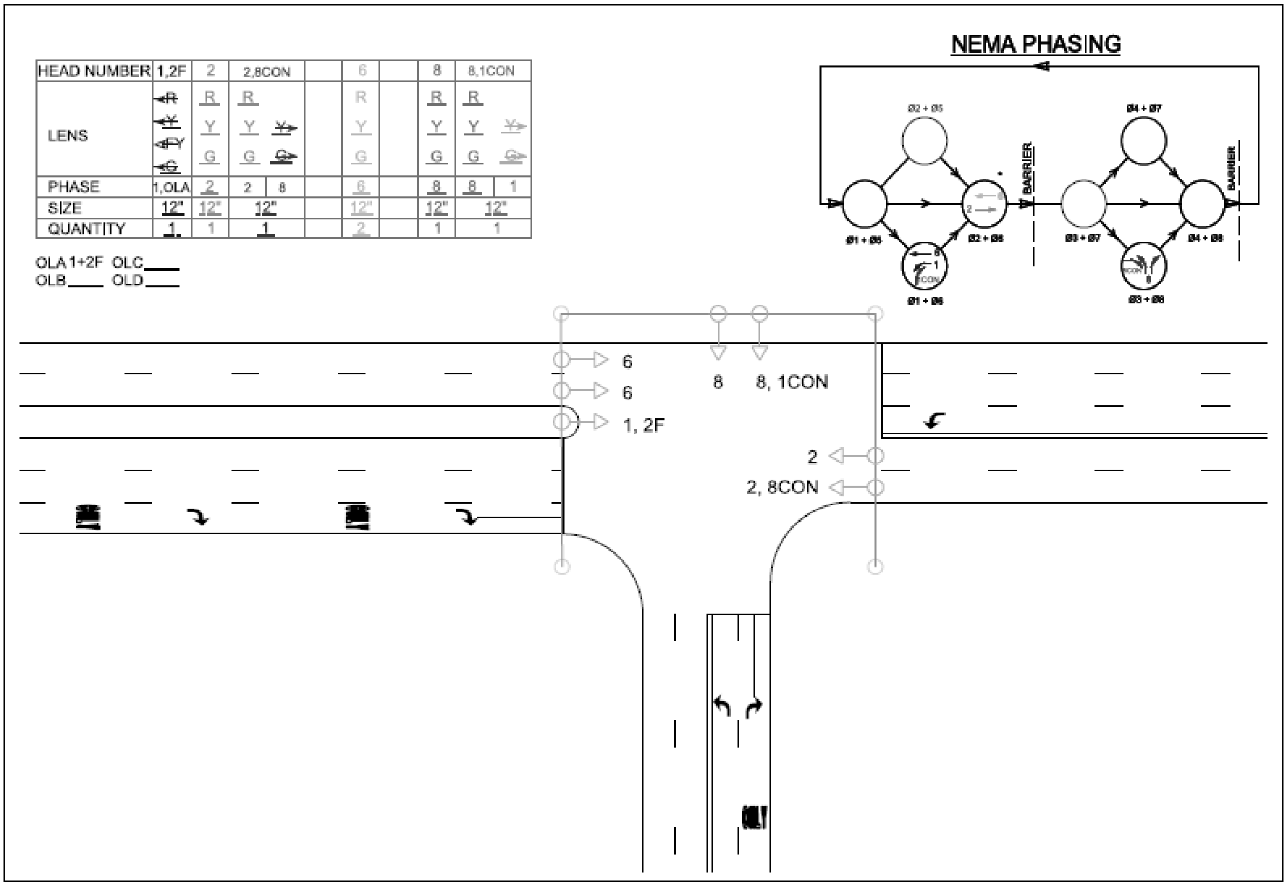


Figure 3-5 Concurrent Phasing Example

3.4 Split Phase

The signal phase sequence for an intersection (typically the side streets) is sequential rather than simultaneous during split phase operation. This design is commonly used where simultaneous through movements are impossible due to the geometric configuration of the intersection (i.e. offset side streets) or where heavy left turn/through movements oppose low volume movements. An analysis should be performed to determine the need for split phasing a signal, but geometry may dictate its use. An example split phase design is shown in **Figure 3-6**. It is important to note that while the below figure displays phase 4 and 8 as split phase, it is also acceptable to assign phases that typically operate sequential (ex. Phases 3 and 4) for the split phase approaches. Although odd phase numbers are generally reserved for left turn phases, assigning the split phase approaches sequential phases will ensure that these approaches operate sequential.

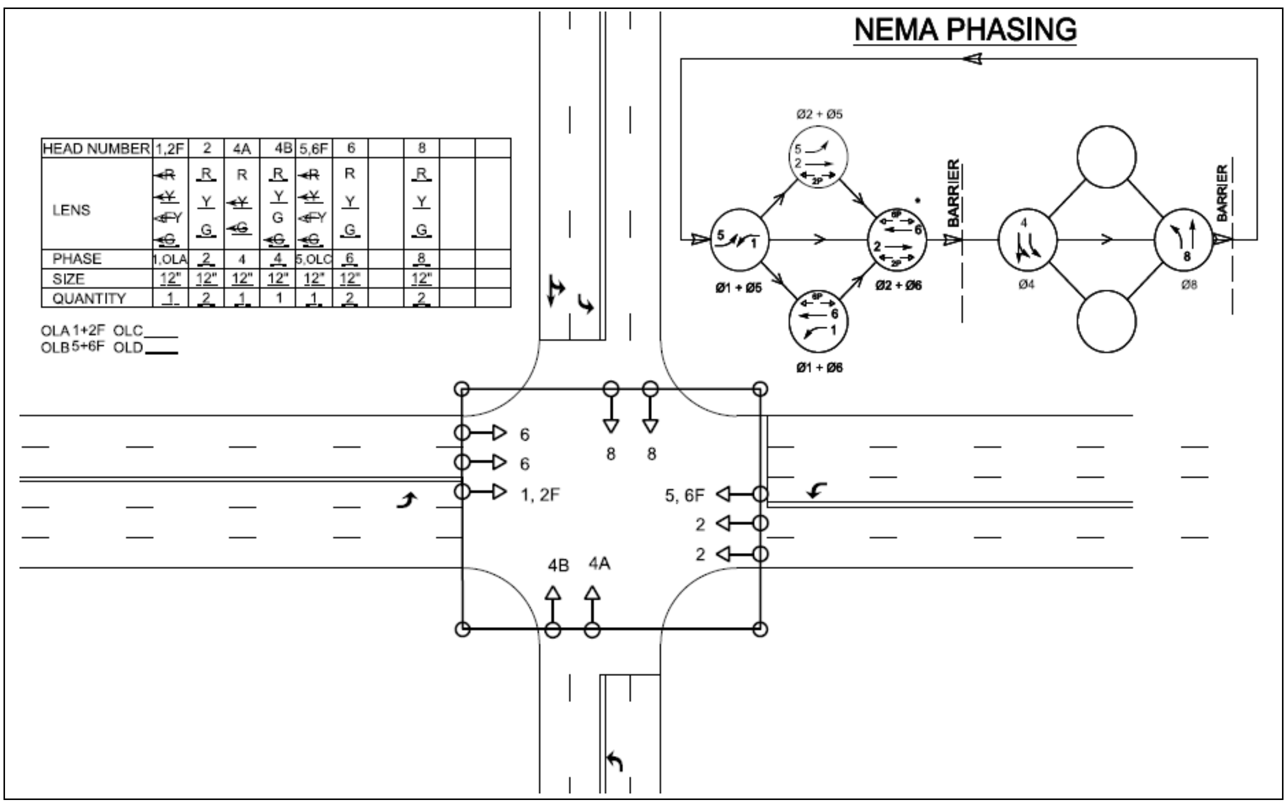


Figure 3-6 Split Phasing Example

3.5 Pedestrian Phasing

SCDOT's typical signal design serves pedestrian movements concurrently with the adjacent parallel vehicular phase at an intersection. However, potential pedestrian conflicts may occur with right-turning vehicles and vehicles turning left permissively. An exclusive pedestrian phase mitigates some of the potential conflicts during vehicular turning movements and provides additional safety to pedestrians. This treatment is reserved for special conditions that include intersections where heavy left or right turn movements conflict with pedestrian movements.

Pedestrian phasing consists of countdown pedestrian heads, push buttons, signing, and crosswalk markings. Application of one or more of these treatment types is based on the intersection characteristics. **Figure 3-7** gives guidance in determining the appropriate pedestrian treatment.

Figure 3-7 MINIMUM PEDESTRIAN TREATEMENT

CONDITION	MIN. TREATMENT
Curb and Gutter Section with Sidewalk and Existing Ramps	Install Pedestrian Heads, Push Buttons and Crosswalk. Ramp does not need to be modified.
Curb and Gutter Section with Sidewalk or Worn Path	Install Pedestrian Heads, Push Buttons and Crosswalk. Remove Barriers by installing Curb Ramps.
Curb and Gutter Section without Sidewalk or Worn Path	Install Push Button to cross main street
Curb and Gutter Section in CBD	Install Pedestrian Heads, Crosswalks, and Curb Ramps where none exist. Install Push Buttons based on signal actuation.
Shoulder Section without Sidewalk or worn path	Install Push Button to cross main street

A pedestrian phase is initiated by demand on activation of a pedestrian push button or by setting a traffic signal controller to automatically recall selected pedestrian phases. **In order to reduce the impact on signal capacity from providing pedestrian timings every cycle, SCDOT's minimum pedestrian treatment is push buttons to facilitate pedestrians crossing the main street approach.** The characteristic of the intersection for minimum pedestrian treatment involves the absence of sidewalk or a worn path. Sign R10-4a should be installed with push buttons when this is the only pedestrian treatment designed for the intersection. Sign R10-3e should be installed with push buttons when pedestrian treatment includes countdown pedestrian heads.

SCDOT standard is to use countdown pedestrian heads. Consideration should be given to installing pedestrian heads when the following conditions exists at a signal:

- The presence of a pedestrian path (crosswalk, sidewalk, worn path).
- The signal meets the Pedestrian Signal Warrant described in section 4E.03 of the MUTCD.
- The crossing at the signal is an established school crossing.
- An exclusive protected phase is available for pedestrians in one or more directions.
- At locations where the signal phasing is confusing for the pedestrian to determine when to cross.
- At locations where the traffic signal heads are not visible for the pedestrians to make crossing decisions.

Pedestrian signal heads may be installed without push buttons when sufficient Min Initial time is provided to serve the Walk and Don't Walk time. In these cases, the pedestrian phase would need to be set to recall each cycle.

For signalized intersections that have channelized right turns, the pedestrian treatment should be placed in the channelized island and a crosswalk marked on the uncontrolled channelized lane. The island should be large enough to accommodate ADA standards for access to the push button. Channelized islands that cannot meet these standards should be removed from the design and the right turn movement included in the signal.

Two stage pedestrian crossings are not preferred. However, it may be necessary when the timing required to cross pedestrians in one stage is detrimental to the signal operations by producing sever delays and queues. A two stage crossing requires a median that is wide enough to store pedestrians and has additional push buttons for detection. Signing should clearly direct pedestrians in safely navigating this type of crossing.

Intersections that present a serious and consistent safety concern for pedestrians should prohibit crossings using sign R9-3-12 (No Pedestrian Crossing). Also, signal phasing may require pedestrians to only cross along a single approach. Restricting pedestrians at an intersection can be accomplished through appropriate signing that provides guidance to preferred crossing locations.

Chapter Four - Equipment

The SCDOT Traffic Signal Material Specifications and Traffic Signal Supplemental Technical Specifications describes the physical features and installation methodology for traffic signal equipment. SCDOT established a Qualified Product List for equipment that meets these specifications. The type of equipment installed at an intersection depends on the characteristics of the location and the discretion of the District Traffic Engineer. It is essential to perform field reviews at the intersection with a representative from the District Traffic Engineering staff when designing a traffic signal plan.

4.1 Poles

Signal support pole details are shown in the Traffic Signal Standard Drawings. The minimum pole placement is two feet from the face of curb. However, this distance does not accommodate future sidewalk or pedestrian treatments. It is recommended that signal support poles be placed five to ten feet from the edge of the roadway when curbing is present. In the absence of curbing, the signal poles should be placed ten to fifteen feet from the edge of the roadway. The signal poles should be located so that signal heads are between 40 to 180 feet from the approach stop line.

The type of signal poles used in the construction of traffic signals include steel poles (Standard Drawing 688-500-01), wood poles (Standard Drawing 682-300-01), concrete poles (Standard Drawing 688-600-01), shared use utility poles, and mast arms (Standard Drawing 690-100-02). SCDOT standard signal support pole is a steel strain pole due to the cost savings associated with its durability and functionality.

4.1.1 Steel Pole

The typical steel pole height is 28’ for a two to three lane road section. Wider roadway sections may require the taller 32’ steel poles. Other factors, such as the number of signs on the span wire, installation of four section FYA, or overhead utilities may require the taller steel poles. In some cases 26’ and 30’ steel poles are acceptable. Electrical cable for the traffic signal is installed inside the steel poles. Powder coating is an available aesthetic treatment for these poles.

4.1.2 Wood Pole

SCDOT does not design new traffic signals with wood poles. However, existing wood poles may remain in place on a signal design for a variety of reasons. Back guys attached to wood poles require additional right-of-way. The height of a wood pole is either 35’ or 45’. All electrical cables must be installed in risers attached to the outside of the pole.

4.1.3 Concrete Pole

Concrete support poles are installed at very wide intersections due to their ability to prevent sag in long span wire lengths. The height of a concrete pole is either 35' or 45'. Concrete poles contain internal conduit for electrical cables.

4.1.4 Utility (Shared Use) Pole

Signal span wire may be installed on existing utility poles when right-of-way is insufficient to place a steel pole. Permission from the utility company must be obtained prior to attaching the span wire, back guys, and riser (conduit) to the shared use pole.

4.1.5 Mast Arm Pole

Mast Arms are nonstandard SCDOT signal support poles. Mast arm poles and foundation designs require a PE stamp. The costs for mast arms typically far exceeds by two to three times the costs for the standard signal with steel poles and span wire. However, there are circumstances that may justify mast arms over the standard signal design and include the following cases.

- Right-of-way limitation that will excessively delay the project and/or purchasing costs will exceed the installation of cost of a mast arm in an accessible quadrant.
- Overhead utility conflicts that restrict the installation of steel poles in each quadrant.
- Underground utility conflicts that restrict the installation of steel poles in each quadrant.
- Unique lane arrangements that require rigidly mounted signal heads for safety.

A local municipality's preference for mast arms due to aesthetic purposes does not qualify as an exception to the standard signal design.

Engineering Directive 33, 'SCDOT Mast Arm Standards' outlines the procedures for installing mast arms on the state highway system. It is important to note that mast arms may be installed for several types of projects using a variety of different funds. Further clarification on specific situations are addressed below.

> *Agreement for mast arms installed by non-SCDOT funding (developer installed or city/county funding)* – A special mast arm agreement is not needed since an encroachment permit will be required for this work to occur. An encroachment permit is an agreement and will satisfy the requirements of the directive. The local government will be required to attach Engineering Directive 33 as part of the encroachment permit package, along with a completed Mast Arm Information Form (page 3 of Mast Arm Standards), a traffic signal plan, and the current copy of the SCDOT Mast Arm Specifications. Any special issues may be addressed in the special provisions portion of the encroachment permit.

Agreements for mast arms as part of an enhancement project – For enhancement projects, coordination with the Enhancements office will be needed to include language to cover the mast arms portion within the Enhancement Agreement. The Mast Arm Policy and Mast Arm Specifications should be included in the Enhancement Agreement as an attachment. The District's contribution (if any) to the signal work should be detailed in this agreement. It should be noted that Enhancement Agreements have a requirement for an encroachment permit. The District should verify that the two documents do not conflict. If a conflict does exist the Enhancement office will need to be contacted so that a contract modification can be developed and executed.

Agreements for mast arms where SCDOT funding is involved in signal work – For projects that SCDOT funding is involved, such as widening, safety, or intersection improvement projects, a special mast arm agreement must be prepared. These are typically coordinated through the Program Development office, in conjunction with Traffic Engineering (Headquarters and District) and the financial participation agreements are prepared by the Contract Services office. These special agreements are needed to detail the specific work, the financial obligations of the local governments, and the schedule of the project.

Agreements for existing mast arm locations – The Districts should identify locations where mast arms are in place. If mast arms were installed under an encroachment permit, the District should approach the local government, in pursuit of an addendum to the permit, to include Engineering Directive 33, along with a completed Mast Arm Information Form (page 3 of Mast Arm Standards). If no encroachment permit is in place, but a letter from the local government indicating their intent to maintain the mast arm is in place, the District may approach the town to attempt to develop a formal encroachment permit or a formal contract can be developed by contacting the Contract Services office at Headquarters.

Signal Maintenance Agreement – Mast Arm Agreements are not needed for signals within those local governments that maintain signals for SCDOT under an existing Signal Maintenance Agreement.

4.2 Pole Placement and Span Wire

Span wire is 3/8" galvanized steel cable. SCDOT's standard placement for signal support poles is one pole per quadrant, which results in a box span wire configuration. The advantages of this configuration include allowing a good alignment of signal heads, shorter span wire lengths and sag than diagonal spans, and provides a location for pedestrian signals. However, field conditions may require modifications to spans to ensure optimal locations for signal heads. Span wire allows signal support pole placement to be flexible to accommodate these modifications.

4.3 Messenger Cable

Messenger cable is ¼” galvanized cable that provides overhead cable connections as communications cable (fiber) or detection home run cable.

4.4 Signal Heads

SCDOT standard signal head size is 12” sections. In special situations 8” signal head sections may be used for the bottom yellow section of an emergency flasher. Backplates with two inch yellow retroreflective border (Type XI) are installed on all signal heads at intersections with approach speed equal to or greater than 45 MPH. The signal heads must be within a 20-degree cone of vision as shown in **Figure 4-1**. The vertical clearance range from the roadway to the bottom of the signal head is 17’ to 19’. The minimum and maximum spacing between signal heads is 8’ and 16’, respectively.

The minimum number of signal heads per approach is two. For multilane approaches, one signal head should be installed for each through lane. Signal heads should be located between 40’ and 180’ from the stop line for each approach. Near-side signal heads need to be installed for approaches with signal heads further than 180’ from the stop line and where the minimum visible distance to the signal head as specified in the Chapter 4 of the MUTCD cannot be achieved. **Figure 4-1** details the requirements for signal head visibility. This is also shown in Standard Drawing 686-100-03.

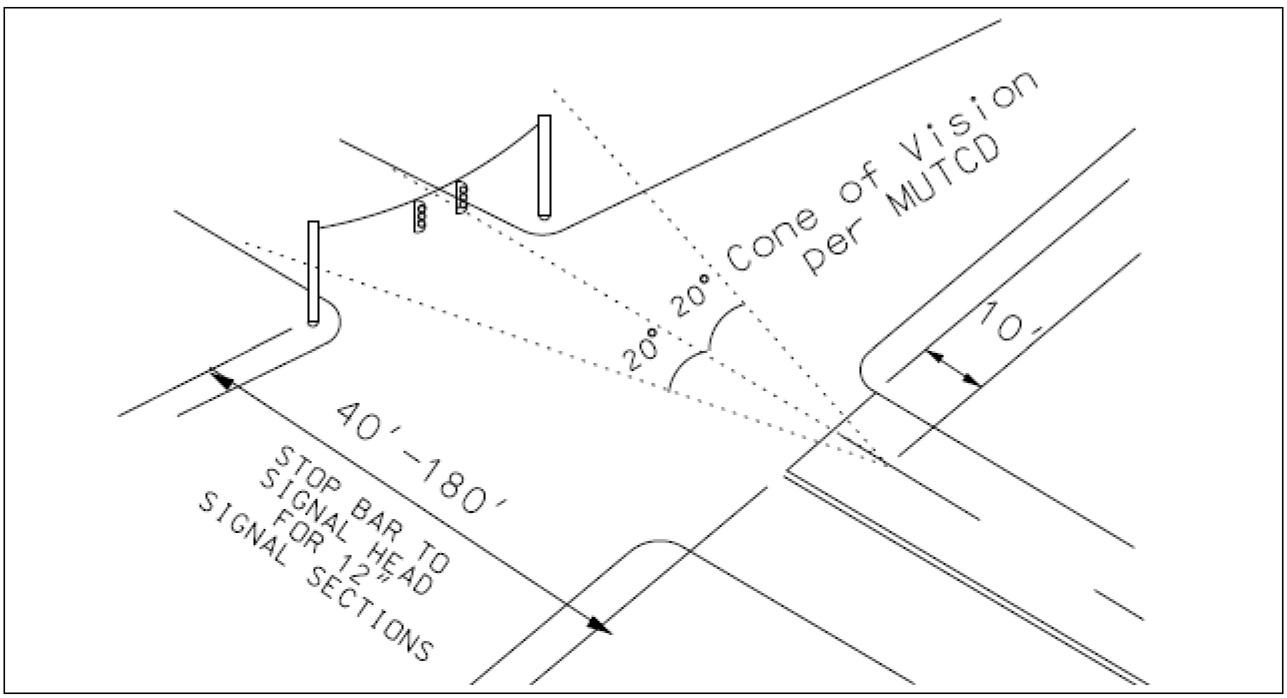


Figure 4-1 Signal Head Visibility

4.5 Signal Cabinet

The traffic signal cabinet houses the control equipment at an individual intersection. SCDOT standard cabinet is a base mounted 332A. The smaller 336S cabinet can be installed on a signal support pole at intersections where right-of-way and space are limited. The signal cabinet should be located adjacent to the signal support structure in the same quadrant and as far as possible from the edge of the roadway to prevent sight distance restrictions for motorists making a right turn on red. Also, the cabinet should be oriented to allow a signal technician to view the intersection when working on the cabinet. The far right corners in each direction of the main street are considered high-impact locations for signal cabinets as shown in **Figure 4-2**. Care should be taken in avoiding these locations when installing signal cabinets.

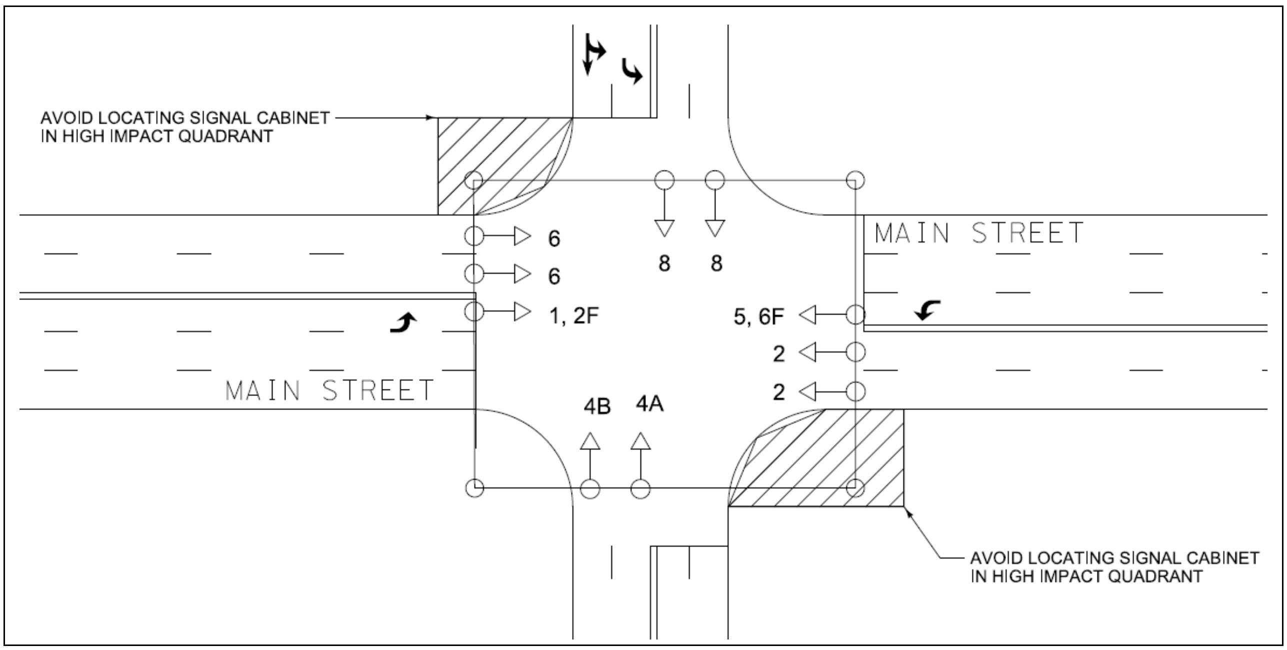


Figure 4-2 High Impact Signal Cabinet Locations

4.6 Battery Backup System (BBS)

Battery backup systems provide a stable supply of power to the signal for four to eight hours during power outages. In addition, BBS conditions power during surges and other power disruptions. A BBS should be included in the design of the following intersections.

- Traffic signals that are interconnected with railroad devices.
- Signals with Ethernet communications.
- Large intersections with complex phasing that are difficult for emergency personnel to control.

- Signalized intersections that are critical along evacuation routes.
- Signals with traffic monitoring cameras.
- Interchanges

4.7 Vehicle Detection

Vehicle detection is a critical component of signal design. It aids in efficiently operating traffic signals by recognizing the presence of vehicles at the intersection. The signal controller processes the information received from the detector to determine when to extend or terminate a phase. Several technologies are widely accepted and include inductance loops, video, microwave, and radar. Detection may be located at the stop line or upstream from an intersection. See **Figure 2-1** for placement of set back detection. Stop line detection is typically used on the minor street and left turn lanes.

Advance detection is located on the major street and provides information on vehicles approaching the intersection that can be used to safely terminate a phase on the onset of the yellow indication. Advanced signal systems that include traffic adaptive and traffic responsive require additional detection. This provides the controller with vehicle data in order to adjust signal timings in response to changing traffic conditions. **Figures 4-3** through **4-6** show typical examples of vehicle detection placement for advance signal system designs using the different options described below and the appropriate way to note it on the signal plan.

4.7.1 Inductance Loops

The most common type of vehicle detection is inductance loops. Loop wire is sawcut into the roadway. The sensitivity of the loop is increased by the number of turns of the loop wire. Once the loop has been completed, the remaining wire is twisted (pigtailed) and sawcut to the edge of the roadway where it is installed in a 1” schedule 80 PVC conduit. Depending on SCDOT District Office preference the ‘pigtailed’ loop wire for setback loops may be sawcut to the intersection before being installed in conduit.

4.7.2 Video

Video detection is installed at intersections with unusual pavement conditions that include rutting and concrete bridge decks. It is preferred during construction projects where lane shifts will occur or repeated damage to loop detection is expected. This technology works best for stop bar detection. The cameras are installed overhead at the intersection and connected to the cabinet where single or dual channel processing units are located. Each camera requires one channel.

4.7.3 Microwave Flush Mounted Wireless Detection

Microwave flush mounted wireless detection is similar to loop detection without the variables of size and type. The device is installed in the roadway and does not have any wires or lead-in cabling. Antennas or receivers are installed on poles at the intersection. Some wireless detection systems require repeaters to be installed for setback detection. A 15’ pedestrian pole can be used for mounting the repeaters.

4.7.4 Radar

Radar is capable of detecting vehicles in all approach lanes without occlusion by transmitting electromagnetic radar signals through the air. The radar is installed overhead on all signal support poles for both stop bar and set back detection. Depending on field conditions, one radar may be able to detect two approaches.

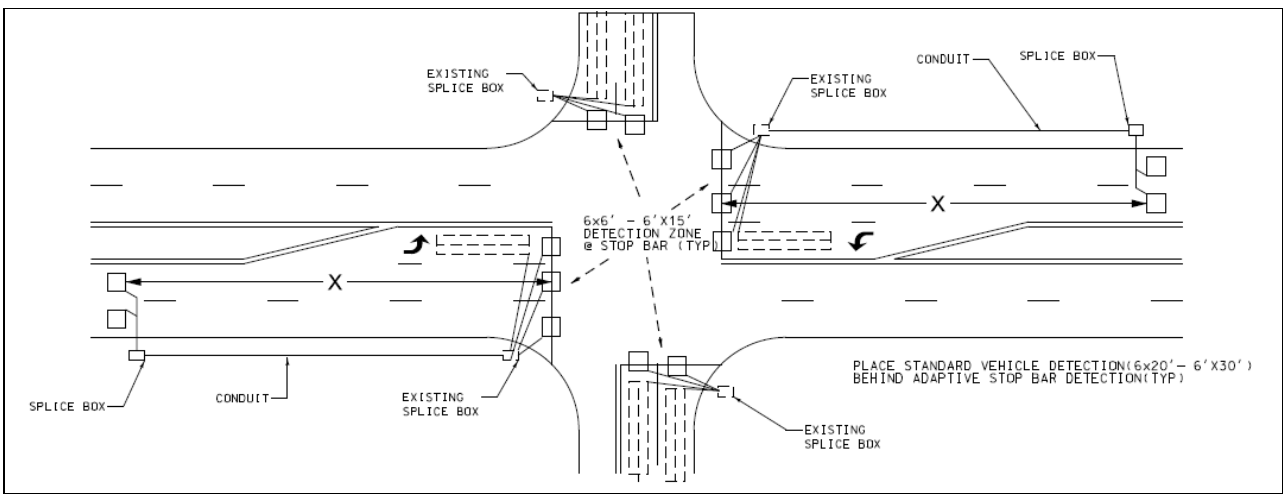


Figure 4-3 Inductive Loops for Traffic Adaptive

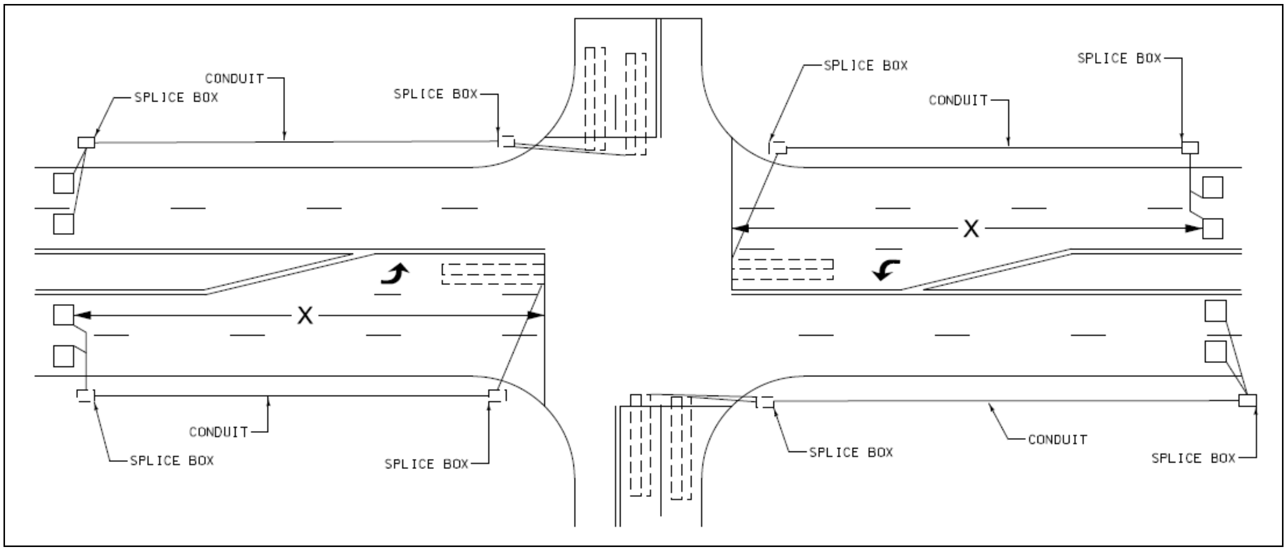


Figure 4-4 Inductive Loops for Traffic Responsive

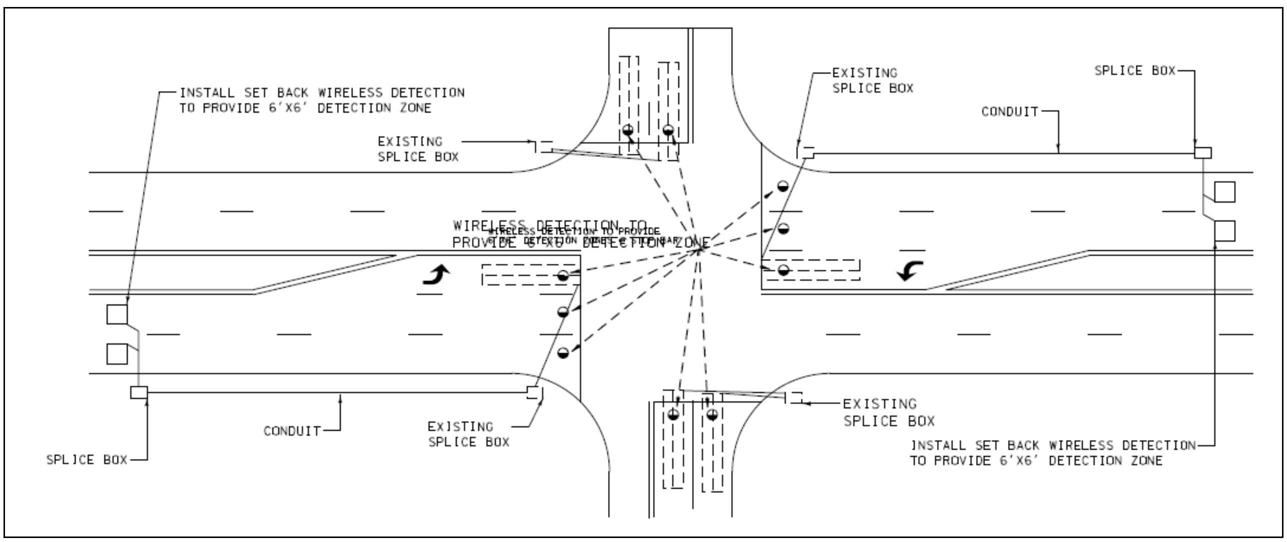


Figure 4-5 Wireless Detection with Inductive Loops for Traffic Adaptive

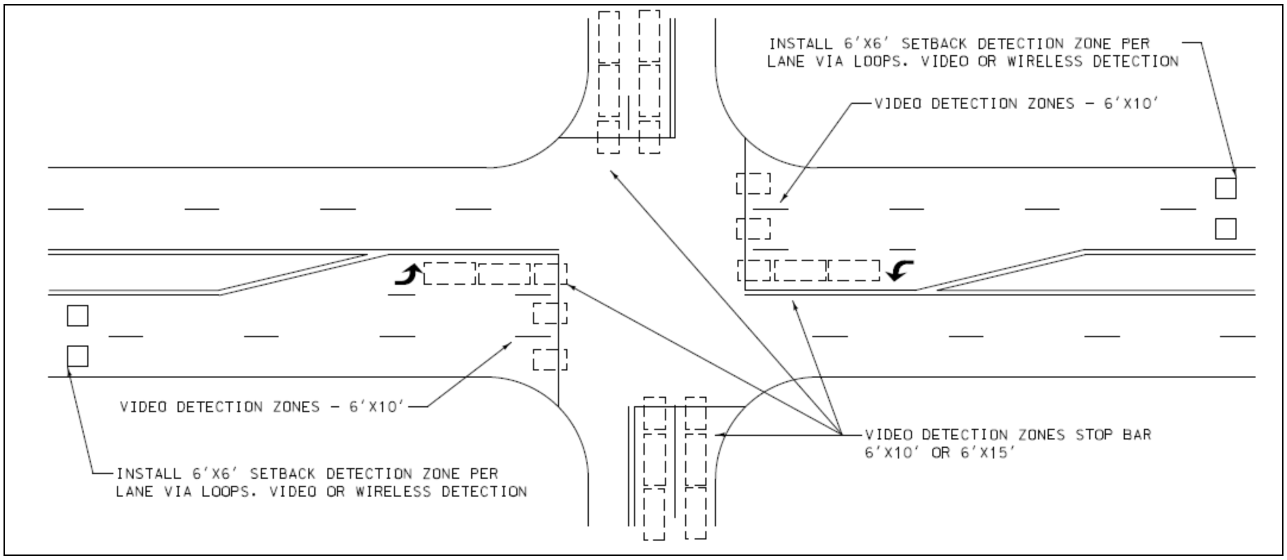


Figure 4-6 Video Detection Zones for Traffic Adaptive

4.8 Splice Box

Splice boxes accommodate conduit connections for electrical cable and should be shown on the signal plan. Splice boxes should be installed at each signal support pole, conduit runs at 150' spacing, and at the signal cabinet. There are several sizes for splice boxes. The large 17"x30"x24" splice box is reserved for use adjacent to the signal cabinet and for underground fiber communication. Sizes for all other splice boxes are specified by the District Signal Shops.

4.9 Conduit

All underground signal wiring shall be encased in conduit to protect the electrical cable. All signal wiring above ground shall be installed in conduit (i.e. risers), unless the wiring is inside of a pole, attached to a span wire, or a messenger cable. The most common conduit used is schedule 80 PVC. However, High Density Polyethylene (HDPE) Rolled conduit is used when installing conduit under a roadway or driveway by directional bore. The size of the conduit depends on the amount and size of wire being run inside. Loop wire is run in 1" conduit. The 2" conduit is used for one 4 conductor wire or one 8 conductor wire. The 3" conduit can accommodate several cables. Low voltage and high voltage cable need to be in separate conduits.

4.10 Accessible Pedestrian Signals (APS)

Accessible pedestrian signals are pedestrian equipment that is audible and/or vibro-tactile to provide additional guidance for visually impaired pedestrians. Installation is site specific.

4.11 Blank out Sign

Blank out signs are 24" LED No Left Turn or No Right Turn electronic symbol sign which restricts traffic movement during signal operation. These electronic signs only display an indication when activated.

4.12 Emergency Preemption System

Emergency preemption systems are operated by a local municipality to preempt signal systems for emergency vehicles. Receivers installed at traffic signals are activated by transmitters in the emergency vehicle to preempt the normal signal operation and activate a designated preemption hold interval to provide a green indication in the direction of the oncoming emergency vehicle. The local municipality is solely responsible for the cost and operation of the emergency preemption system. An Emergency Preemption System may be installed under encroachment permit or as part of a project with a financial participation agreement. DTE approval is required prior to the installation of this system. SCDOT will contact the local municipality when malfunctioning equipment associated with the Emergency Preemption System is removed. It is the local municipality's responsibility to notify emergency personnel.

4.13 Luminaires

Luminaires may be mounted on signal support poles. This is nonstandard SCDOT equipment that is primarily desired by local municipalities. Since the luminaire is unnecessary for signal operation, a separate power source and meter shall be specified in the signal design.

4.14 Wireless Detection Arrays and Travel Time Monitoring Devices

Local municipalities may desire to install an array of wireless detection that operates as an origin destination detection system. Travel time monitoring devices are installed for detecting vehicle travel patterns and travel times. Depending on the preferred data, the devices can be set up in one of two ways. Installing the devices at the beginning and end of a corridor will provide travel times and traffic speed. Traffic volumes, as well as trip origins and destinations can be collected using multiple devices throughout the traffic system.

Chapter Five – Railroad Preemption

Traffic signals within close proximity to railroad crossings often require special attention to prevent vehicles from stopping on the track. Preemption 'interrupts' normal signal operation to clear the track area prior to a train's arrival at the crossing. The start of preemption occurs when a message is received by the traffic signal controller that a train is approaching the railroad crossing. The traffic signal controller immediately enters into a special signal phase operating sequence that clears any vehicles on the roadway approach with the railroad crossing and restricts traffic movement that conflict with the railroad for the duration of the train. Further information can be found in the FHWA Highway Rail Crossing Handbook 3rd Edition.

Preemption of traffic signals by railroad equipment may be either:

Simultaneous – The traffic controller and the active railroad warning devices are simultaneously notified of an approaching train.

Or

Advance – The traffic controller receives notification of an approaching train before the active railroad warning devices.

Interconnecting the traffic signal with the railroad should be considered when the following conditions apply.

- Railroad crossing is within 200' of a signalized highway intersection. The distance may be greater than 200', but is rarely greater than 500'.
- Queueing regularly occurs within the Track Clearance Distance (TCD). Regularly is defined as the queuing that occurs within the TCD during normal peak traffic times.
- Active railroad warning devices are existing or planned.
- Train speed exceeds 20 MPH.

A signal plan needs to be submitted to the Director of Traffic Engineering for traffic signals that require interconnection. The plan will need to include a Railroad Preemption Note that states the below information.

Railroad Preemption Operation

Track Clearance Phase ___ = ___ Seconds

Preemption Hold Interval = Limited Services for phases ____ or Yellow Flash phases ____ Red Flash phases ___ or All Way Red Flash

Depending on the complexity of the intersection, this note may need to be replaced with the Railroad Preemption Sequence Chart shown in **Figure 5-1**.

RAILROAD PRE-EMPTION SEQUENCE

SIGNAL HEAD NUMBER	CONDITION 1							CONDITION 2							CONDITION 3							CONDITION 4							F.CLEAR		
	INTERVAL							INTERVAL							INTERVAL							INTERVAL							INTERVAL		
	R/W	1	2	9	10	11	12	R/W	3	4	9	10	11	12	R/W	5	6	9	10	11	12	R/W	7	8	9	10	11	12	13	14	N.O.
SIGN "X"	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON	ON	OFF
SIGN "Y"	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON	ON	OFF
TIMINGS	*						**	*						**	*						**	*						**			A

* NORMAL R/W OPERATION GO IMMEDIATELY TO NEXT INTERVAL.

** INTERVAL TO CONTINUE UNTIL PRE-EMPTION TERMINATES. THEN BEGIN FINAL CLEAR IN INTERVAL 13.

A NORMAL OPERATION WILL RESUME IN 04-08.

CONDITION 1 - PRE-EMPTION OCCURS DURING /02-05 GREEN.

CONDITION 2 - PRE-EMPTION OCCURS DURING /02-06 GREEN.

CONDITION 3 - PRE-EMPTION OCCURS DURING /03-08 GREEN.

CONDITION 4 - PRE-EMPTION OCCURS DURING /04-08 GREEN.

IF PRE-EMPTION OCCURS DURING ANY PHASE YELLOW OR ALL RED CLEARANCE, BEGIN CONDITION 1 SEQUENCE, STARTING WITH INTERVAL 9, ONCE YELLOW AND RED HAVE TIMED OUT.

Figure 5-1 Railroad Preemption Sequence Chart

The signal plan should also include the location of a common splice box used to physically interconnect the signal cabinet with the railroad devices. Typically, this is placed near the railroad property.

The signal plan will be included in the preemption agreement submitted to the railroad company by the Director of Traffic Engineering. There are several railroad companies in South Carolina. Each has a different process for implementing and installing interconnection, as well as permitting requirement when working on the railroad property. Insurance, right of entry permit fees, and flagging operations should be included in the cost estimate when developing a signal project adjacent to the railroad.

5.1 Pre-signals

Pre-signals supplemental traffic control equipment that reinforces the railroad's active warning devices. Pre-signals should display two red indications per traffic approach and be installed with a stop line on the approach side of the crossing. The stop line should be marked as far back as possible from the railroad's active warning devices while maintaining an appropriate stopping point for vehicles waiting on a train to clear the track. Typically, this distance is between 15’ and 40’ from the railroad’s active warning devices. The pre-signals should be oriented to prevent their placement from blocking the visibility of any overhead railroad warning devices. The following conditions should be considered when determining the need for pre-signals.

- Railroad gates are not present or planned and the geometric design of the intersection allows vehicles to store between the intersection and the at-grade crossing.
- Location with advanced preemption in order to prevent vehicles from proceeding onto the track during the preemption clear sequence.
- Intersections with timed overlaps.

Two types of pre-signals may be used in advance of the railroad crossing. The typical 3-section RYG signal head is used to operate a timed overlap that clears the area of the track during normal and preempted signal operation. The timed overlap extends the green time for the intersection signal heads on the crossing approach while the pre-signal serves the yellow and red clearance time. See **Figure 3-2**. Overlaps are often used when the distance between the crossing and the intersection is inadequate to store vehicles, but where it is not practical to stop all vehicles in advance of the crossing. They are also used to prevent a frontage road that is in close proximity of the intersection and in advance of the crossing from being blocked.

The other type of pre-signal is the RYY signal head with 12” top red and middle yellow sections. The bottom section is an 8” yellow that flashes all the time during normal signal operation. Once preemption is activated, the signal display changes to a solid yellow in the middle section and then a solid red in the top section. The pre-signal will show the red indication until preemption terminates. This type of pre-signal should be installed when railroad gates are not present and a track clearance phase will operate during the preemption signal operation sequence.

5.2 Essential Design Criteria

There are two distinct areas that should be measured to determine the appropriate design of the preemption operation and track clearance time.

- Track Clearance Distance (TCD) – Measured from 6’ downstream of the nearside rail to 12’ upstream from the center line of the track. There are a number of other areas that could be the measuring point upstream of the rail that include the stop line on the crossing approach or the railroad warning device. However, SCDOT uses the 6’ and 12’ measurements.
- Clear Storage Distance (CSD) – Measured from the edge of the TCD (6’ from the nearside rail) to the stop line or the normal stopping point of the adjacent signalized intersection. A stop line should be installed with a detection device in advance of the crossing at

locations where vehicles are unable to store in the CSD without overhanging into the TCD. At locations with severely limited CSD, consideration should be given to stopping all vehicles in advance of the track using the "Stop Here on Red" sign.

When the railroad track is not perpendicular to the roadway, the longest TCD and shortest CSD should be measured. Depending on the skew, this would either be along the edge of the pavement or the center line of the roadway. **Figure 5-2** is provided to assist in determining the appropriate measuring points for the TCD and CSD.

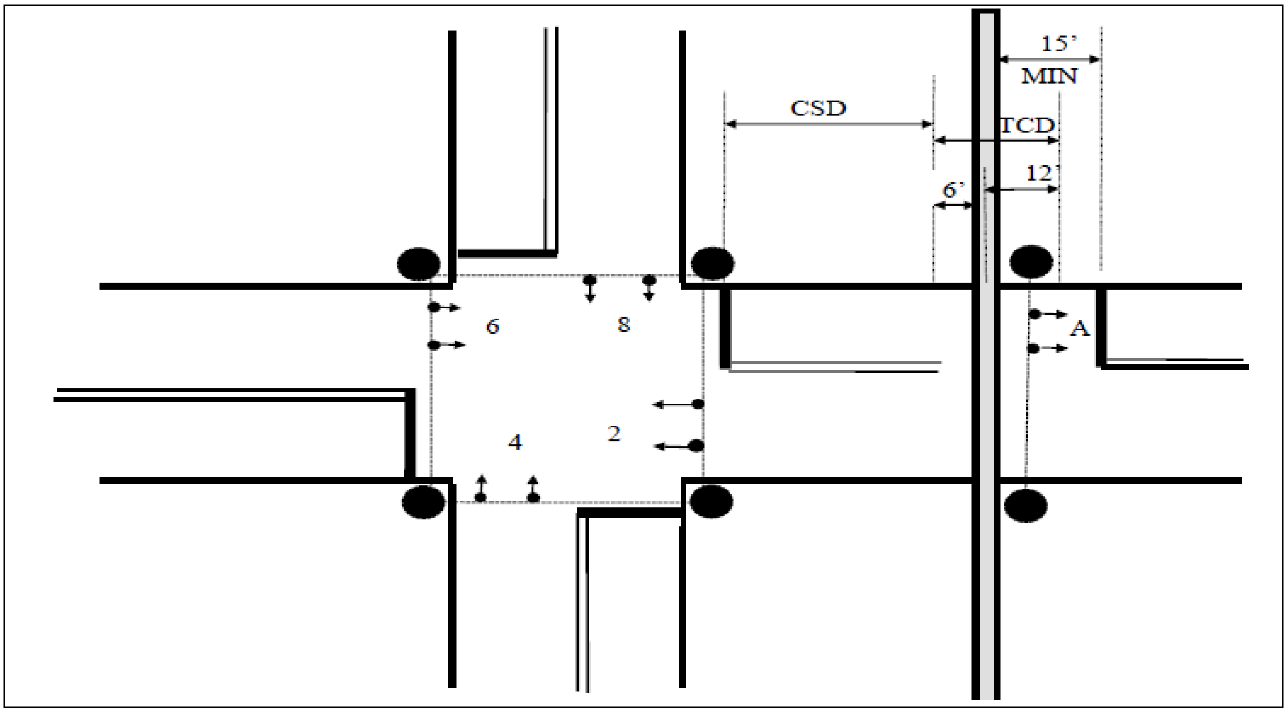


Figure 5-2 TCD and CSD Measurement Guide

5.3 Maximum Signal Preemption Time (MSPT)

The maximum amount of time required to exit normal signal operation and enter into the Preemption Hold Interval is the Maximum Signal Preemption Time. The MSPT is limited to the time provided from when the traffic signal controller receives notice that a train is approaching the crossing to the presence of the train in the crossing. Although it is acceptable at locations with railroad gates for a train to arrive at the crossing while the track clearance green, yellow clearance time, or red clearance time is operating, every effort should be made to serve the entire MSPT before the train is in the crossing. The MSPT is calculated by summing the Right of Way Transfer Time, Queue Clearance Time, and Separation Time.

5.3.1 Right of Way Transfer Time (RTT)

The Right of Way Transfer Time is the maximum time required to clear the existing vehicular or pedestrian movements prior to serving the track clearance green interval or pedestrian hold interval. The maximum value for all phase combinations including pedestrian clearances, minimum green time, yellow and red clearance times should be used to determine RTT.

The pedestrian clearance interval may be significantly shortened during the railroad preemption operation. At signalized locations that only use push buttons for pedestrian treatment, the controller may be programmed to immediately leave the pedestrian clearance phase and only serve the yellow and red clearances of the corresponding signal phase. Pedestrian treatment that includes the use of pedestrian heads and that conflicts with the track clearance approach must have sufficient clearance time. However, the Walk phase may be immediately terminated and the Don't Walk time may be reduced by dividing the crossing distance by 5 feet/second and subtracting the yellow and red clearance time for normal signal operation.

A minimum green time should only be served when an engineering study indicates it is vital to the safety of the intersection and there is adequate railroad warning time available. The clearance times for the yellow and red interval must remain the same as during normal signal operation.

5.3.2 Queue Clearance Time (QCT)

The Queue Clearance Time is provided to clear the railroad track. This value is calculated by summing the Track Clearance Green Time with the normal operating Yellow and Red Clearance Time of the same phase. The Track Clearance Green Time is calculated using Greenshields formula and/or field observations. The following guidance provides direction on applying Greenshields formula when selecting the appropriate storage length to clear.

- CSD < Design Vehicle Length – Clear the CSD and TCD storage length. This allows the design vehicle stopped within the TCD to clear the area.

  Track Clearance Green = 4 + 2 x [(CSD+TCD)/Design Vehicle Length]
  4 = Startup Time
  2 = Headway Factor
  Design Vehicle Length = 20' (typical)
- CSD > Design Vehicle Length – Clear the TCD storage length.

  Track Clearance Green = 4 + 2 x [TCD/Design Vehicle Length]
  4 = Startup Time
  2 = Headway Factor
  Design Vehicle Length = 20' (typical)

Field observations should include noting the operational characteristics of vehicles crossing and moving through the CSD and TCD, as well as, measuring the queue clearance times during peak and off peak traffic periods.

5.3.3 Separation Time (ST)

The Separation Time is the time between the clearance of the last vehicle and the arrival of the train. A minimum value of 2 seconds is desired, but not always possible.

5.4 Total Railroad Warning Time (TRWT)

The Total Railroad Warning Time is the amount of time provided by the railroad company to the traffic signal controller for the operation of the preemption phase sequence. This value is calculated by the railroad and is based on the type of warning device, width of the crossing, and train speed. Simultaneous preemption is acceptable when the TRWT is greater than or equal to MSPT. When the TRWT is less than the MSPT, the signal operation should be reviewed to determine if the MSPT can be reduced. Advance preemption may be appropriate when the MSPT cannot be reduced. Coordination with the railroad company is necessary to determine if the additional time required to operate the traffic signal preemption phase sequence is acceptable.

5.5 Preemption Hold Interval

The Preemption Hold Interval is the traffic signal phase operation that begins immediately after the track clearance and remains in effect while a train is detected in the crossing. Selecting the appropriate operation during the preemption hold interval is provided in the guidance below.

- Limited Service permits the normal operation of phases that do not direct traffic to the crossing. Intersection with multiple through lane approaches where the mainline traffic is parallel to the railroad track work best with limited service operation. The traffic signal will exit limited service operation by continuing to serve the current phase for the duration of time provided during normal operation.
- Flashing operations displays a flashing yellow or red indication on each intersection approach. Intersections with single through lane approaches or locations where the track crosses the mainline work best with flashing operation. Typically, the signal heads for the roadway that is perpendicular to the track flash red and the signal heads on the roadway parallel to the track flash yellow. Exiting a yellow-red flashing operation should comply with MUTCD Section 4D.31 which states that the flashing yellow signal heads proceed directly to steady green while the flashing red signal heads proceed to a steady

red indication. All way red flash is appropriate in some cases. These include locations where the track crosses the mainline approach and a side street approach or where the track crosses the mainline approach in close proximity to the side street. Exiting an all way red flashing operation requires the intersection to serve a six second all-way steady red. The major street through movement will be the first to receive a green indication.

Chapter Six- Beacons

Beacons increase safety by alerting motorists to special roadway conditions. They are composed of one or more traffic signal sections operating in a flashing mode. Engineering studies should be conducted in accordance with the MUTCD Chapters 4L, 4G, and 7 to determine the need for a flashing beacon. SCDOT considers these devices traffic signal equipment and usually a traffic signal plan is not required. In most cases a P.E. seal is not required on these types of plans.

6.1 Intersection Control Beacon

Intersection control beacons supplement other traffic control at an intersection when a safety study indicates the possibility of a special need. The most common application for these beacons is at intersections with minor approach stop control. Normally, the flashing yellow signal indication will be displayed on the major street and the flashing red signal indication to the minor street. At the intersection of two streets of equal importance, flashing red signal indications may be displayed to both streets. A Stop sign shall be present on approaches with flashing red signal indications. **Figures 6-1** and **6-2** shows examples of intersection control beacons.

6.2 Warning Beacons

Warning beacons supplement an appropriate warning or regulatory sign where crash experience or field observations reveal that warning signs alone are not effective. Warning beacons consist of one or more signal sections that flash alternately. With the exception of the stop beacon which has a red signal indication to supplement a stop sign, all other warning beacon signal indications are yellow. **Figure 6-3** shows an example plan for a warning beacon.

6.3 School Zone Speed Limit Sign Beacons

School speed limit signs may be supplemented with beacons that are activated using a timer or with a switch operated by the school. This beacon consists of two signal sections that flash yellow signal indications alternately. The flashing operation indicates that the school zone speed limit is in effect. An example plan is shown in **Figure 6-4**.

Equipment for school zone speed limit sign beacons is paid for by the requesting entity and installed under an encroachment permit. SCDOT will maintain the equipment installed in the right of way unless it is within the limits of a local government participating in the signal maintenance agreement program. The school pays the electrical costs for all beacons receiving power from their facility. The electrical costs for school zone speed limit sign beacons not receiving power from the school facility will be paid for by SCDOT. Solar flashers are typically preferred for these types of beacons.

6.4 Pedestrian Hybrid Beacon

A pedestrian hybrid beacon is a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist with heavy pedestrian flow at a marked crosswalk. Pedestrian Hybrid Beacons should primarily be considered at locations where accommodations need to be made for pedestrian traffic at special events, intermittent times or at midblock crossings.

A pedestrian hybrid beacon may be considered an option to increase pedestrian safety at locations where a signal is not warranted. Chapter 4F of the 2009 MUTCD establishes provisions for pedestrian hybrid beacons. The below guidance establishes a consistent and uniform plan for implementing a pedestrian hybrid beacon in South Carolina.

6.4.1 Warrants

At locations where a traffic signal is not justified, an engineering study should be conducted for a pedestrian hybrid beacon to indicate if at least one of the following conditions exits:

- Insufficient gaps in traffic
- High speed of vehicles approaching on major street
- Excessive pedestrian delay
- Excessive pedestrian collisions
- Distance from existing signalized intersection

The engineering study should, at a minimum evaluate the following key factors:

- Major street volumes
- Pedestrian volumes
- Vehicle speeds
- Gaps in traffic
- Pedestrian Delay
- Pedestrian Collisions (See MUTCD 4C.05 Warrant 4 and 4C.08 Warrant 7)

The engineering study may also consider walking speeds and the width of the intersection. Figures 4F-1 and 4F-2 of the MUTCD provide guidelines for determining installation. A minimum of 20 pedestrians per hour is needed

Approval for installation should only occur if an engineering study indicates significant improvements upon installation. The District Engineering Administrator will be responsible for final determination of installation.

6.4.2 Design

Although this treatment is classified as a beacon, a traffic signal controller is required to operate the Pedestrian Hybrid Beacon. Therefore, a traffic signal plan that is stamped by a P.E. must be submitted for approval.

6.4.2.1 Timing

The ability to balance the needs of the pedestrian and the delay of the driver is a valuable component of the pedestrian hybrid beacon. Extensive red light time when pedestrians no longer need it to cross safely can encourage violations. The flashing yellow interval typically lasts for five seconds. The duration of the solid yellow light should be calculated based on existing field conditions and these Traffic Signal Design Guidelines. The solid red light displayed to drivers is equal to the pedestrian walk indication. The flashing red indication is the same as the flashing hand indication for the pedestrian countdown head and is determined by the width of the crossing.

6.4.2.2 Signing and Marking

A pedestrian hybrid beacon shall be used in conjunction with signs and pavement markings to warn and control traffic at locations where pedestrians enter or cross a street or highway. A Crosswalk Stop on Red (symbolic circular red) (R10-23) sign shall be mounted adjacent to a pedestrian hybrid beacon face on each major street approach. If an overhead pedestrian hybrid beacon face is provided, the sign shall be mounted adjacent to the overhead signal face.

A Pedestrian (W11-2) warning sign with an AHEAD (W16-9P) supplemental plaque shall be placed in advance of a pedestrian hybrid beacon. A warning beacon may be installed to supplement the W11-2 sign, which, if installed, should be programmed to flash only when the pedestrian hybrid beacon is not in the dark mode.

A pedestrian hybrid beacon shall only be installed at a marked crosswalk. A stop line shall be installed for each approach of the major street. Pedestrian hybrid beacons should be installed at least 100 feet from an intersection or driveway unless determined acceptable by engineering judgement. Pedestrian hybrid beacons should not be placed in proximity to signalized locations. See **Figure 6-5**.

6.5 Intersection Conflict Warning System (ICWS)

An Intersection Conflict Warning System provides motorists at stop-controlled intersections with a dynamic warning of other vehicles approaching the intersection. Several research studies have been conducted that provide design and evaluation guidance for implementing ICWS. These include:

- FHWA-HRT-15-076 Safety Evaluation of Intersection Conflict Warning Systems (ICWS)
- Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS) Version 1: December 2011

Since a traffic signal controller is required to provide real time warning, a P.E. seal is necessary on ICWS plans.

6.6 Emergency Signal

An emergency signal may either be a flashing beacons or a traffic signal installed at fire/EMS stations that stops vehicles on the mainline to provide emergency vehicles immediate access to the roadway. These may be installed under encroachment permit. SCDOT Engineering Directive 2 specifies that the fire/EMS department or their funding agency will pay all installation costs. SCDOT or the local government participating the signal maintenance program will maintain the emergency signals. An emergency signal plan does not require a P.E. seal since the beacon or signal is typically activated by a push button inside the station. **Figures 6-6** shows an example plan.

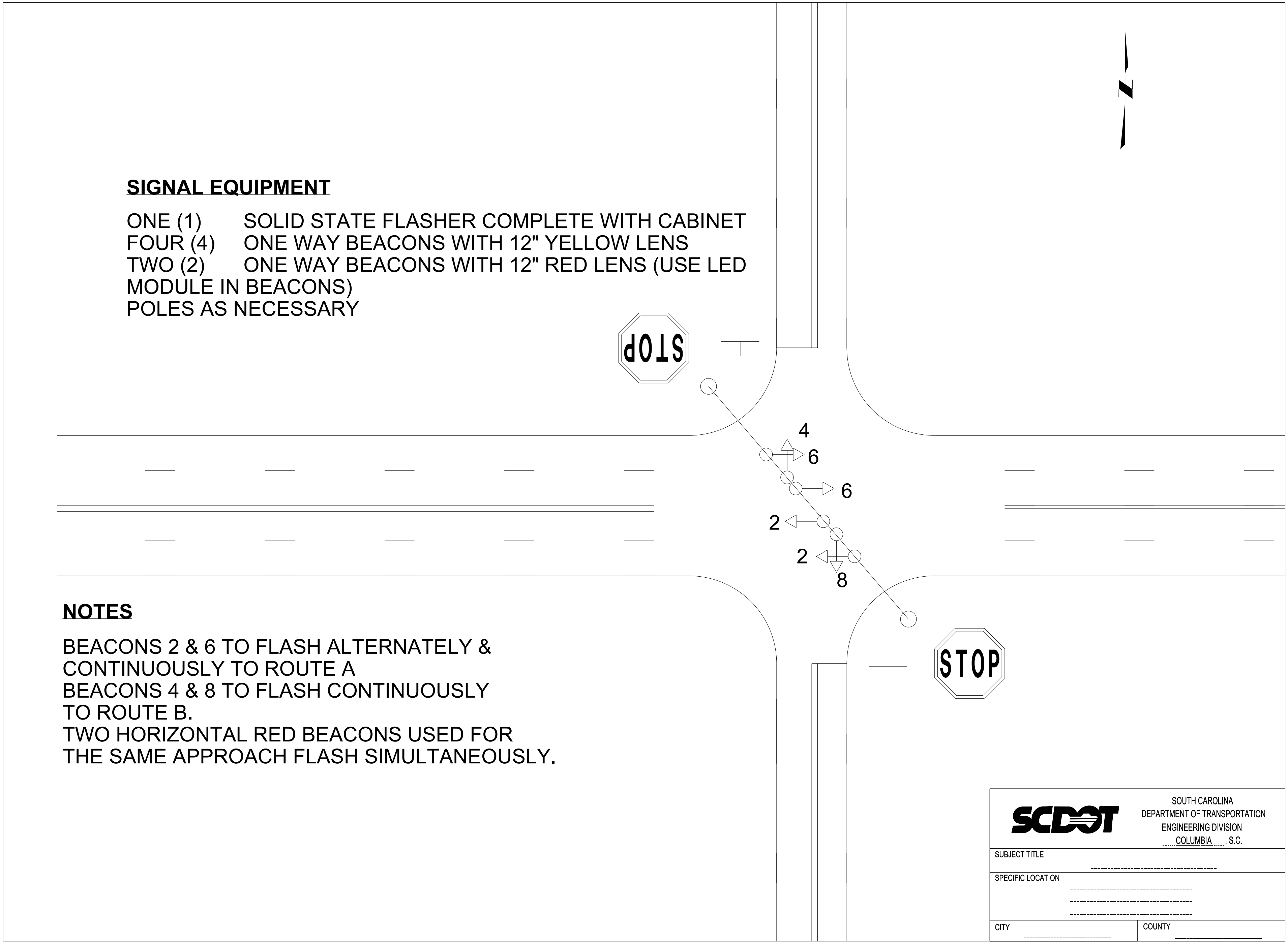


Figure 6-1 Overhead Intersection Beacon

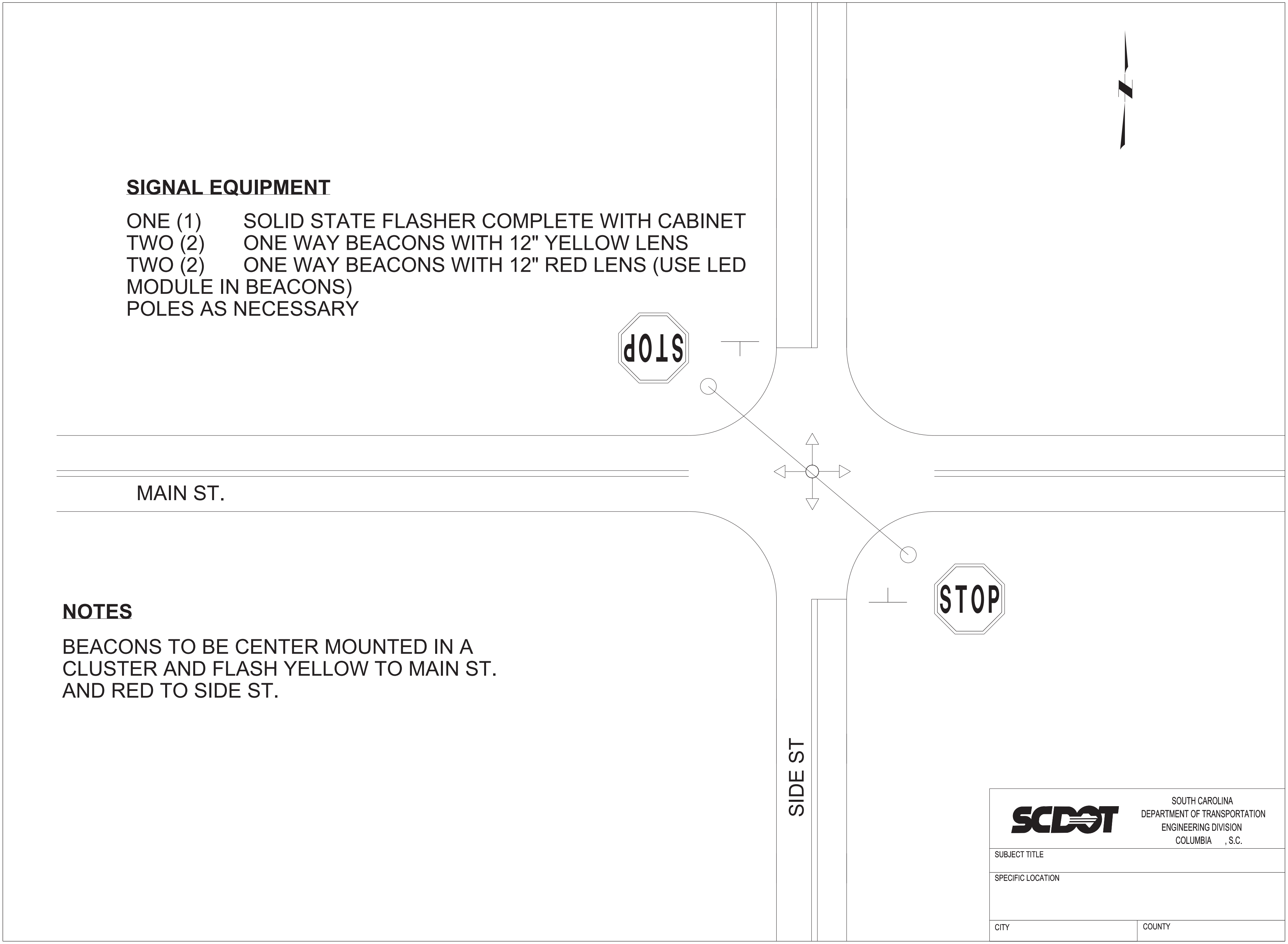
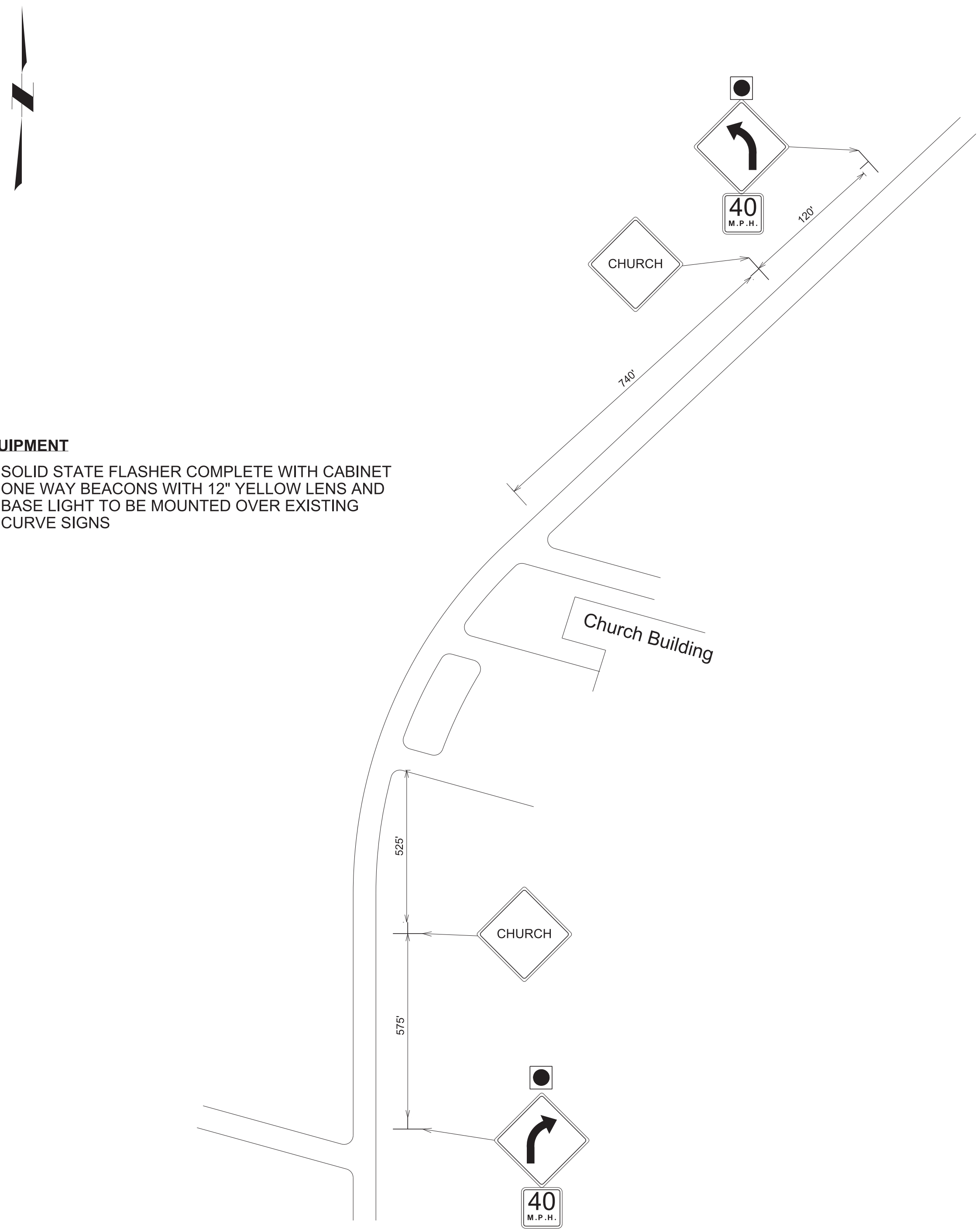


Figure 6-2 Cluster Overhead Intersection Beacon

SIGNAL EQUIPMENT

TWO (2) SOLID STATE FLASHER COMPLETE WITH CABINET

TWO (2) ONE WAY BEACONS WITH 12" YELLOW LENS AND BASE LIGHT TO BE MOUNTED OVER EXISTING CURVE SIGNS



SCDOT	SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION ENGINEERING DIVISION COLUMBIA , S.C.
SUBJECT TITLE	
SPECIFIC LOCATION	
CITY	COUNTY

Figure 6-3 Warning Beacon

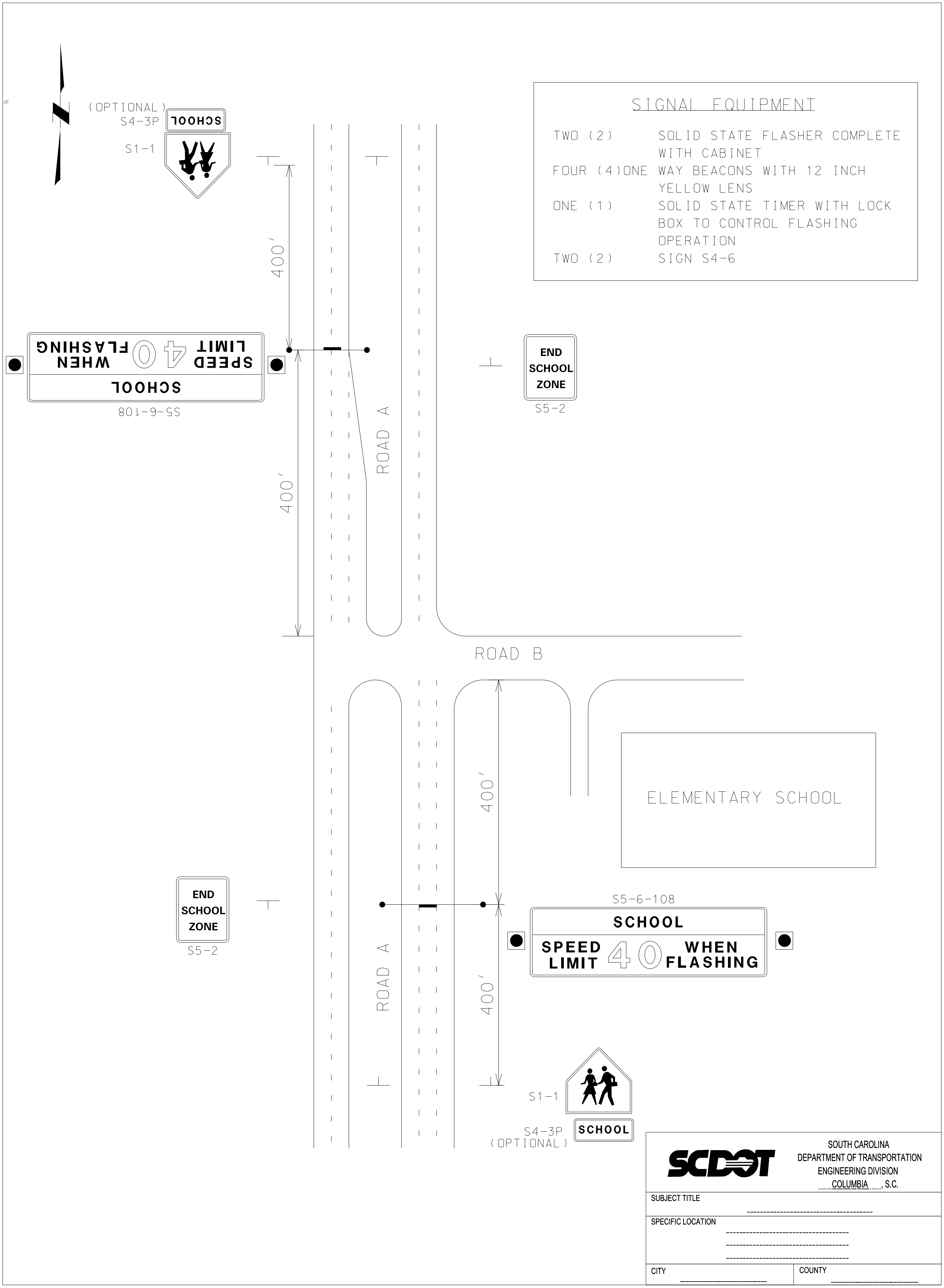


FIGURE 6-4 Overhead School Flashing Beacon

SIGNAL EQUIPMENT

______ PHASE FULLY ACTUATED STANDARD
___ CONTROLLER WITH FLASHER, SIGNAL MONITOR UNIT,
AND ___ - MOUNTED ___ CABINET.

HEAD NUMBER		2				6			4P	
LENS		RR Y				RR Y			---	--- --- ---
PHASE		2				6			4	---
SIZE		12"				12"			16"	---
QUANTITY		2				2			2	---

OLA _____ OLC ____
OLB _____ OLD _____

NOTE:

SIGN "A" - PEDESTRIAN WARNING SIGN (W11-2)

SIGN "B" - "AHEAD" SIGN (W16-9P)

SIGN "C" - "CROSSWALK STOP ON RED" SIGN (R10-23)

SIGN "D" - "PEDESTRIAN CROSSWALK" SIGN (R9-8)

CALCULATE YELLOW, RED, WALK, AND FLASHING DON'T WALK TIMES BASED ON EXISTING CONDITIONS AND SCDOT TRAFFIC SIGNAL DESIGN GUIDELINES

SIGNAL DISPLAY SEQUENCE CHART

G-GREEN
Y-YELLOW
R-RED
G-G, ARROW
Y-Y, ARROW
W-WALK **
DW-DON'T WALK

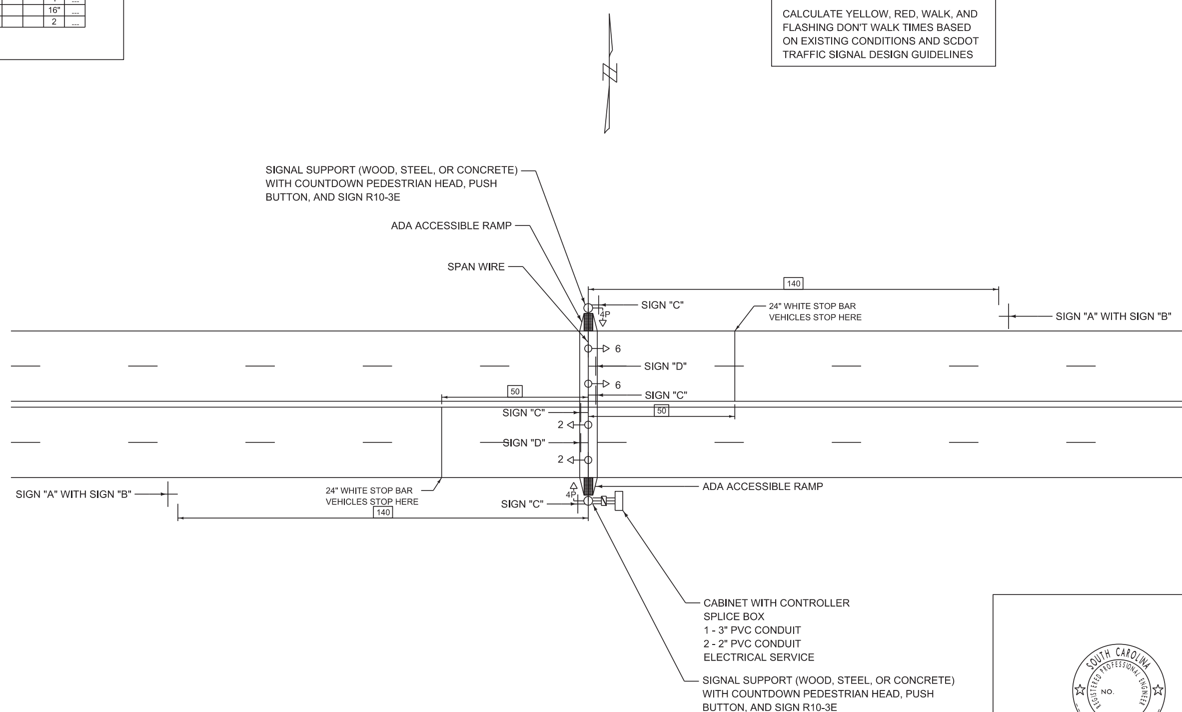
NOTE A: ANY ACTUATED PHASE FOR WHICH THERE IS NO CALL SHALL BE OMITTED.
NOTE B: WHEN ONE PHASE IS ON ALONE, ANY/NON-CONFLICTING PHASE MAY START TIMING CONCURRENTLY WITHOUT A CLEARANCE INTERVAL (SEE CHART).
* CONFLICTING PHASES REQUIRE A CLEARANCE INTERVAL.

** WHEN CALLED, DISPLAY SOLID 'WALKING PERSON' AND TIMES OUT WALK TIMING; THEN DISPLAYS FLASHING 'UPRAISED HAND' AND TIMES WALK CLEARANCE (DON'T WALK TIMING), THEN DISPLAYS A SOLID 'UPRAISED HAND'.

SIGNAL DISPLAY SEQUENCE
(PREFERENTIAL PHASING)

FLASH	SIGNAL HEAD NUMBER	Ø1 — Ø5 R/W	CLEAR TO Ø1-Ø6	Ø2-Ø5	Ø2-Ø6	BARR.	Ø2 — Ø6 R/W	CLEAR TO ACTIVATION	BARR.		BARRIER	Ø3 — Ø7 R/W	CLEAR TO Ø3-Ø8	Ø4-Ø7	Ø4-Ø8	BARR.	Ø2 — Ø6 R/W	CLEAR TO PED CLEAR	BARR.	
	2						--	FY	Y	R							R	FR*	--	--
	6						--	FY	Y	R							R	FR*	--	–
–																				
--	4P						DW	DW	DW	DW							* *	DW	DW	DW
–																				

*ALTERNATING FLASH



Map Here

ROUTE NUMBER	____		______	
APPROACH DIRECTION	--	_	--	_
SIGNAL DESIGN SPEED	--	_	--	_
GRADE (%)	--	_	--	_

* ESTIMATED FILE # : SHEET # :

SOUTH CAROLINA REGISTERED PROFESSIONAL ENGINEER
NO.

FOR / CONSTRUCTION : ________ ____ DATE

DATE	REVISIONS
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DESIGNED ____
DRAWN ____
CHECKED ____
REVIEWED ____
RECOMMENDED ____

SCDOT
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ENGINEERING DIVISION
COLUMBIA, S.C.

SUBJECT TITLE **PEDESTRIAN HYBRID BEACON PLAN**

SPECIFIC LOCATION

CITY ________________ COUNTY ________________

APPROVED BY
________________ DISTRICT # __ TRAFFIC ENGINEER
________________ ENGINEER

SCALE	DATE	SHEET NO.	INDEX NO.
1"= 20 '	____	__ OF __	____

SCDOT
South Carolina Department of Transportation
Post Office Box 191
Columbia, South Carolina 29202
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This intersection border drawing including the information blocks contained within, is intended only for the specific purpose and client for which it was prepared. Reuse of and improper reliance on the sheet without written authorization from the SCDOT Traffic Engineering office is prohibited.

NOTE:
Coordinate with Existing Utilities for Placement of Conduit and Pole Foundations.
Return All Existing Traffic Signal Equipment, Poles and Stop Signs to SCDOT

SIGNAL TIMINGS

		PHASE					
		2	4	6			
INTERVAL	WALK	___	___	___			
	DON'T WALK	___	___	___			
	FLS YELLOW	5	___	5			
	YELLOW	___	___	___			
	RED	___	___	___			
	FLS RED	___	___	___			

Figure 6-5

SIGNAL EQUIPMENT

ONE(1)8 PHASE FULLY ACTUATED STANDARD 2070 CONTROLLER WITH FLASHER, SIGNAL MONITOR UNIT, AND ___ - MOUNTED ____ CABINET.

__ ORACLE, (2)-CHANNEL VEHICLE DETECTOR UNITS

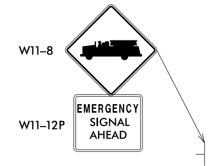
HEAD NUMBER		2				6		8		
LENS		R Y Y				R Y Y		R Y G		
PHASE		2				6		8		
SIZE		12"				12"		12"		
QUANTITY		2				2		2		

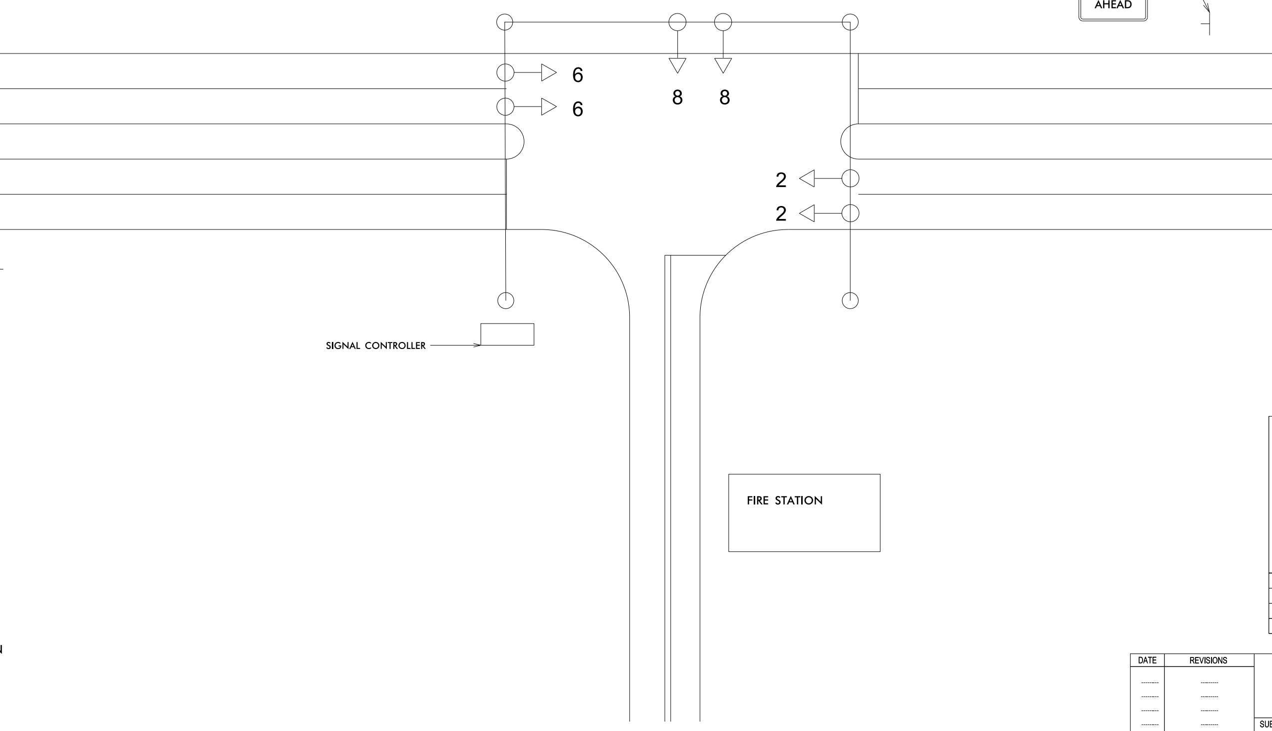
OLA ____ OLC ____
OLB ____ OLD ____

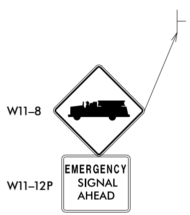
EMERGENCY SEQUENCE

SIGNAL HEAD NUMBER	CONDITION 1				F.CLEAR		
	INTERVAL				INTERVAL		
	R/W	1	2	3	4	5	N.O.
2	YF	Y	R	R	R	R	YF
6	YF	Y	R	R	R	R	YF
____							
8	R	R	R	G	Y	R	R
____							
____							
____							
TIMINGS	*	____	____	**	____	____	A

TABLE OF OPERATION	PHASE IN OPERATION								
SIGNAL HEAD #	Ø1 + Ø5	Ø1 + Ø6	Ø2 + Ø5	Ø2 + Ø6	Ø3 + Ø7	Ø3 + Ø8	Ø4 + Ø7	Ø4 + Ø8	FLASH
1,2F									
2				G				R	Y
3,4F									
4									
5,6F									
6				G				R	Y
7,8F									
8				R				G	Y
8,1									







SIGNAL NOTES

SIGNALS WILL FLASH YELLOW (8 INCH SECTION) TO ARTERY AND RED TO SIDE STREET OR DRIVE DURING ALL PERIODS EXCEPT DURING A SPECIFIED INTERVAL FOLLOWING ACTUATION FROM FIRE STATION.

ON ACTUATION FROM FIRE STATION, THE FLASHING SEQUENCE WILL BE PRE–EMPTED BY A FIXED TIME SEQUENCE SHOWING THE INDICATIONS AS LISTED IN THE EMERGENCY SEQUENCE.

FIRE STATION INTERCONNECT PUSH BUTTON ACTUATION

Map Here

ROUTE NUMBER	____		____	
APPROACH DIRECTION	--	--	--	--
SIGNAL DESIGN SPEED	--	--	--	--
GRADE (%)	--	--	--	--

* ESTIMATED FILE # : SHEET # :

NOTE:

All work to be performed within SCDOT Right of Way.

Coordinate with Existing Utilities for Placement of Conduit and Pole Foundations.

Return All Existing Traffic Signal Equipment, Poles and Stop Signs to SCDOT

SCDOT
South Carolina Department of Transportation
Post Office Box 191
Columbia, South Carolina 29202

DATE	REVISIONS
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DESIGNED ___
DRAWN ___
CHECKED ___
REVIEWED ___
RECOMMENDED ___

SCDOT
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
ENGINEERING DIVISION
COLUMBIA, S.C.

SUBJECT TITLE ____

SPECIFIC LOCATION ____

CITY ____ COUNTY ____

APPROVED BY

DISTRICT # TRAFFIC ENGINEER ____ ENGINEER

SCALE	DATE	SHEET NO.	TEAM NO.
1"= 40 '	____	-- OF --	____

FIGURE 6–6 Emergency Beacon

Appendix A

SCDOT Standard Border Plan Sheet

SIGNAL EQUIPMENT

ONE(1)8 PHASE FULLY ACTUATED STANDARD
2070 CONTROLLER WITH FLASHER, SIGNAL MONITOR UNIT,
AND BASE - MOUNTED 332A CABINET.
EXT. PROP.

8 ORACLE, (2)-CHANNEL VEHICLE DETECTOR UNITS

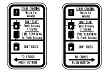
PEDESTRIAN SIGNALS: EXT. P PROP. P W/ACT. & SIGN

VEHICLE SIGNALS: EXT. PROP.

HEAD NUMBER	1,2F	2	3,4F	4	5,6F	6	7,8F	8	2P/6P	4P/8P
LENS	←R ←Y ←FY ←G	R Y G	←R ←Y ←FY ←G	R Y G	←R ←Y ←FY ←G	R Y G	←R ←Y ←FY ←G	R Y G		
PHASE	1,OLA	2	3,OLB	4	5,OLC	6	7,OLD	8	2P/6P	4P/8P
SIZE	12"	12"	12"	12"	12"	12"	12"	12"	16"	16"
QUANTITY	1	2	1	2	1	2	1	2	4	4

OLA 1 + 2(FYA) OLC 5 + 6(FYA)
OLB 3 + 4(FYA) OLD 7 + 8(FYA)
METAL POLES AS NECESSARY: EXT. PROP. M
WOOD POLES AS NECESSARY: EXT. PROP. W
BACKPLATE WITH RETROREFLECTIVE BORDER: *

INSTALL PEDESTRIAN PUSH BUTTON SIGNS



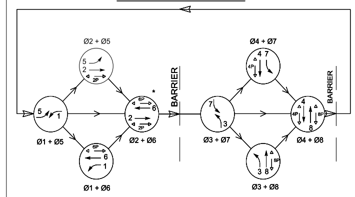
R10-3eL 9" X 15"

R10-3eR 9" X 15"

INSTALL SIGN FOR FLASHING YELLOW ARROW

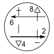
R10-12A-30

NEMA PHASING



NOTE: ACTUATED PHASES HAVING NO CALL, SHALL BE SKIPPED

* _____ STREET COORDINATED



FLASHING OPERATION

TABLE OF OPERATION	PHASE IN OPERATION								
SIGNAL HEAD #	Ø1 + Ø5	Ø1 + Ø6	Ø2 + Ø5	Ø2 + Ø6	Ø3 + Ø7	Ø3 + Ø8	Ø4 + Ø7	Ø4 + Ø8	FLASH
1,2F	←G	←G	←FY	←FY	←R	←R	←R	←R	←Y
2	R	R	G	G	R	R	R	R	Y
3,4F	←R	←R	←R	←R	←G	←G	←FY	←FY	←R
4	R	R	R	R	R	R	G	G	Y
5,6F	←G	←FY	←G	←FY	←R	←R	←R	←R	←Y
6	R	G	R	G	R	R	R	R	Y
7,8F	←R	←R	←R	←R	←G	←FY	←G	←FY	←R
8	R	R	R	R	R	G	R	G	Y
8,1	R/G	R/G	R	R	R	G	R	G	Y
2P	DW	DW	W	W	DW	DW	DW	DW	DRK
4P	DW	DW	DW	DW	DW	DW	W	W	DRK
6P	DW	W	DW	W	DW	DW	DW	DW	DRK
8P	DW	DW	DW	DW	DW	W	DW	W	DRK

Map Here

ROUTE NUMBER	----		------	
APPROACH DIRECTION	--	-	--	--
SIGNAL DESIGN SPEED	--	-	--	--
GRADE (%)	--	-	--	--

* ESTIMATED FILE # : SHEET # :

LOOP DETECTOR INSTALLATION CHART

PHASE/ LOOP LTR#	DETECTOR AMP NO.	DETECTOR CHAN NO.	WIRED TO PHASE(S)	X LOCK	X NON-LOCK	X PULSE	X PRES	OPERATION DELAY SEC	OPERATION EXT SEC	SPECIAL FEATURES TIME OF DAY-TOD, SWITCHING, etc.	LOOP DESIGN SIZE __X__	NO.OF TURNS	DIST. FROM ℄
--	-	-	-	-	-	-	-	--	---	-------------	----	-	---
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SIGNAL TIMINGS

INTERVAL	PHASE 1	2	3	4	5	6	7	8
WALK	--	--	--	--	--	--	--	--
DON'T WALK	--	--	--	--	--	--	--	--
MIN INITIAL	--	--	--	--	--	--	--	--
MAX INITIAL	--	--	--	--	--	--	--	--
ADD/VEH	--	--	--	--	--	--	--	--
VEH EXT	--	--	--	--	--	--	--	--
TIM BFR REDUC	--	--	--	--	--	--	--	--
TIME TO REDUC	--	--	--	--	--	--	--	--
MIN GAP	--	--	--	--	--	--	--	--
MAX LIMIT	--	--	--	--	--	--	--	--
MAXIMUM 2	--	--	--	--	--	--	--	--
YELLOW	--	--	--	--	--	--	--	--
RED CLEAR	--	--	--	--	--	--	--	--

NOTE:

All work to be performed within SCDOT Right of Way.

Coordinate with Existing Utilities for Placement of Conduit and Pole Foundations.

Return All Existing Traffic Signal Equipment, Poles and Stop Signs to SCDOT

FOR / CONSTRUCTION : ________ DATE

South Carolina Department of Transportation
Post Office Box 191
Columbia, South Carolina 29202

FED. ROAD DIV. NO.	STATE	COUNTY	PROJECT ID	ROUTE NO.	SHEET NO.
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DATE	REVISIONS
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DESIGNED ___
DRAWN ___
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SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ENGINEERING DIVISION
COLUMBIA, S.C.

SUBJECT TITLE ----------------------------------

SPECIFIC LOCATION ----------------------------------

CITY ________ COUNTY ________

APPROVED BY ________

DISTRICT # -- TRAFFIC ENGINEER ________ ENGINEER

SCALE	DATE	SHEET NO.	TEAM NO.
1"= 40 '	____	-- OF --	____

Appendix B

Clearance Time Calculation Worksheet

Clearance Time Calculations

Rev 2020-10-23

City:		District:	
County:		Sig. ID #	
NB Street:		Project #:	
SB Street:		Computed by:	
EB Street:		Checked by:	
WB Street:		Approved by:	

Movement	Street Name								
	Orientation	Northbound		Southbound		Eastbound		Westbound	
	Turn movement	Left	Thru	Left	Thru	Left	Thru	Left	Thru
NEMA Phase #	Protected								
	Permissive								
FYA									
Speed	mph	20	45	20	45	20	45	20	45
	ft/sec	29.33	66.00	29.33	66.00	29.33	66.00	29.33	66.00
Grade	%	0		0		0		0	
	Elevation at Stopbar, ft								
	Elevation at Setback, ft								
	Dist to Setback, ft								
	-OR- Enter Grade, %								
Clear Distance	feet								
Ped Cross Dist	feet								
Parameters	Percept-React Time, sec	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Decel Rate, ft/sec^2	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	Walk Speed, fps	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Recommended:	Phase #								
Yellow	sec								
All Red	sec								
Flashing Don't Walk	sec								

NOTES:

Compute times only as needed for plan.
Yellow change interval should be between 3 and 6 seconds.
Red clearance intervals less than 1.5 and more than 4.0 seconds require special circumstances.
Grades are rounded to the conservative whole percent.
Yellow and All Red times are rounded up to the next tenth of a second.
Ped clearance time is rounded up to the next whole second.

Appendix C

Left Turn Phase Study Worksheet

Left Turn Analysis
SCDOT- Traffic Engineering

Intersection: ______________________ Street: ______________________
Count Date: ________________ Left-turn Movement: __________
Counted By: ________________ Number Opposing Lanes: __________

Speed Limit or 85th Percentile of Opposing Traffic __________
Is the current left turn Protected/Permitted ? (Y/N) __________
Peak Hour Delay/Left Turn Vehicle __________

Count Data

Time	Left Turn Volume	Opp Thru Volume	Cycle Length	Max Green	Cross Product	Left Turns Per Cycle
Average						
Peak Hour						
Peak Time						

Accident History

Year	Left Turn Accidents

Guidelines for Left Turn Phase Installation

Summary of Guidelines	**Guidline Met?**	**Hours/Years**
Minimum Left-turn Colume		
Minimum Cross Product of Opposing and Left-turns		
Minimum Number of Lefts/Cycle		
Minimum Left-turn Volume vs. Oposing Speed Limit		
Accident History Analysis		
Minimum Left-turn Delay		