



Ministry of
Transportation
and Infrastructure

ELECTRICAL AND TRAFFIC ENGINEERING MANUAL

Section 400
Signal Design

Electrical and ITS Engineering

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TABLE OF CONTENTS

400 SIGNAL DESIGN

401	INTRODUCTION.....	1
401.1	ABOUT SECTION 400	1
401.2	BEFORE YOU BEGIN	1
402	TRAFFIC SIGNALS.....	3
402.1	GENERAL	3
402.2	DATA REQUIREMENTS	3
402.3	WARRANTS.....	5
402.3.1	Requirements of the Warrant Analysis	5
402.3.2	Warrant 1: Minimum Vehicular Volume	7
402.3.3	Warrant 2: Interruption of Continuous Traffic	8
402.3.4	Warrant 3: Progressive Movement	9
402.3.5	Warrant 4: Collision Experience	9
402.3.6	Warrant 5: System Warrant	9
402.3.7	Warrant 6: Combination Warrant.....	10
402.3.8	Warrant 7: Four Hour Volume Warrant.....	10
402.3.9	Warrant 8: Peak Hour Delay.....	12
402.3.10	Warrant 9: Peak Hour Volume.....	13
402.4	PHASING	15
402.4.2	Direction Assignments	16
402.4.3	Use of Separate Left Turn Movements.....	18
402.4.4	Protected/Permissive Versus Protected Left Turn Phasing	20
402.4.5	Phase Sequencing.....	23
402.4.6	Leading, Lagging and Lead-Lag Left Turn Phasing	37
402.5	TIMING.....	39
402.5.1	Minimum Green Time	40
402.5.2	Passage Time.....	40
402.5.3	Vehicular Clearance Periods.....	41
402.5.4	Yellow - All-Red Split	46
402.5.5	Maximum Green Times	48
402.5.6	Pedestrian Walk Intervals.....	49
402.5.7	Pedestrian Clearance Times	49
402.5.8	Recall	51
402.5.9	Detector Memory	52
402.5.10	Intersection Flash	52
402.5.11	Delay/Extension Detection	53
402.5.12	Coordination	54
402.5.13	Coordination Cycle Length and Splits	55
402.5.14	Coordination Offsets.....	56
402.5.15	Coordination Force-Offs and Permissives.....	57

TABLE OF CONTENTS

402.5.16	Pre-emption	63
402.5.17	Emergency Pre-emption	63
402.5.18	Railway Pre-emption	64
402.5.19	First Green Display	71
402.5.20	Time Clock Settings	71
402.6	SIGNAL DESIGN	71
402.6.1	General	71
402.6.2	Traffic Signal Indications and Signal Heads	72
402.6.3	Signal Head Light Sources	76
402.6.4	Signal Head Locations	76
402.6.5	Pedestrian Pushbuttons	87
402.6.6	Bicycle Signals & Detection	87
402.6.7	Audible Pedestrian Signals	87
402.6.8	Communications Services	89
402.6.9	Traffic Controller Assemblies	90
402.6.10	Advance Warning Flashers	91
402.6.11	Prepare to Stop at Railway Crossing Signs	97
402.6.12	Detectors	97
402.6.13	Detector Loop Applications	99
402.6.14	Wheelchair Ramps	103
402.6.15	Interconnection Signals	103
402.6.16	Signs on Signal Poles	103
402.6.17	Bicycle Signal Activation Guidelines	104
402.6.18	Countdown Pedestrian Signals	105
402.6.19	Uninterruptible Power Supplies (UPS)	107
402.7	PRE-EMPTION	107
402.7.1	General	107
402.7.2	Railway Pre-emption	108
402.7.3	Emergency Vehicle Pre-emption	109
402.7.4	Vehicle Queue Pre-emption	110
402.7.5	Transit Pre-emption (Low Priority)	110
402.7.6	Transit Priority	110
402.7.7	Railway, Emergency, or Transit Pre-emption Systems	110
402.7.8	Approval Process and Division of Responsibilities	116
403	PEDESTRIAN SIGNALS	119
403.1	GENERAL	119
403.2	DATA REQUIRMENTS	119
403.3	WARRANT	119
403.4	PHASING	119
403.4.1	Signal Operation	119
403.4.2	Phase Assignment	120
403.5	TIMING	122

TABLE OF CONTENTS

403.5.2	Pedestrian Walk Intervals	122
403.5.3	Pedestrian Clearance Times	122
403.5.4	Vehicle Phase Green	122
403.5.5	Vehicular Clearance and Yellow/Red Split	123
403.5.6	Coordination	123
403.6	DESIGN	125
403.6.1	General	125
403.6.2	Traffic Signal Indications and Signal Heads	125
403.6.3	Flashing Signal Indication	125
403.6.4	Signal Head Locations	125
403.6.5	Pedestrian Signal Equipment	126
404	ONE-WAY BRIDGE SIGNALS	127
404.1	GENERAL	127
404.2	FEATURES	127
404.3	OPERATION	127
404.4	FIXED TIME CONTROLLERS	127
404.5	ACTUATED CONTROLLERS	128
404.6	TIMING	128
404.7	SELECTABLE FLASHING OPERATION	130
404.8	DESIGN	130
405	DRAWBRIDGE/SWINGBRIDGE SIGNALS	132
405.1	GENERAL	132
405.2	OPERATION	132
405.3	TIMING	132
405.4	DESIGN	133
406	FIRE SIGNALS	134
406.1	GENERAL	134
406.2	OPERATION	134
406.3	TIMING	134
406.4	DESIGN	135
407	SPECIAL CROSSWALKS	137
407.1	GENERAL	137
407.2	DATA COLLECTION AND WARRANTS	137
407.3	DESIGN	137
408	INTERSECTION FLASHING BEACONS AND WARNING SIGNS	138
408.1	GENERAL	138
408.2	WARRANTS FOR INTERSECTION FLASHING BEACONS	138
408.3	OPERATION	138
408.4	DESIGN OF INTERSECTION FLASHING BEACONS	138
408.5	DESIGN OF FLASHING BEACONS ON OVERHEAD SIGNS ..	140

TABLE OF CONTENTS

409	LANE CONTROL SIGNALS.....	141
409.1	GENERAL	141
409.2	DESIGN.....	141
409.2.1	General	141
409.2.2	Signal Indications.....	141
409.2.3	Equipment.....	142
409.2.4	Standards	142
410	INSTALLATION OF MICELLANEOUS DEVICES	144
410.1	GENERAL	144
410.2	GENERAL POLICY	144
410.3	PROCEDURE.....	144
410.4	DEVICES.....	145
410.4.2	LED Chevron Signs	145
410.4.3	Speed Reader Signs.....	145
410.4.4	Rectangular Flashing Beacons.....	145
410.4.5	Illuminated Bollards	145
410.4.6	Microwave Radios	145
410.4.7	Bluetooth Readers	146
410.4.8	Radar Vehicle Detection Sensors.....	146

TABLE OF CONTENTS

LIST OF TABLES

Table 1. Warrant 1: Minimum vehicular volume for rural and large urban areas.	7
Table 2. Warrant 1: Minimum volumes for intersections in small urban areas ($\leq 10,000$ population).....	7
Table 3. Warrant 2: Minimum volumes for intersections in rural and large urban areas. ...	8
Table 4. Warrant 2: Minimum volumes for intersections in small urban areas ($\leq 10,000$ population).....	8
Table 5. Warrant 7: Four hour volumes - figures by location.....	10
Table 6. Warrant 9: Peak Hour Volume figures by location.....	13
Table 7. Minimum Green Times	40
Table 8. Passage Times.....	41
Table 9. Approach speeds for protected left turn phases.....	43
Table 10. Yellow/all-red splits for through movements.....	47
Table 11. Yellow/all-red splits for left turn movements.....	48
Table 12. Emergency pre-emption entry timing standards.....	64
Table 13. Railway pre-emption entry timing standards	66
Table 14. Signal head lenses	75
Table 15. Traffic Controller Assemblies and Applications.	90
Table 16. Friction factors for wet pavement.....	95
Table 17. Advance warning sign distances.....	96
Table 18. Pre-emption card capabilities of type M and S cabinets.....	113
Table 19. Pre-emption capabilities for P6 cabinets.....	113
Table 20. Railway activated pre-emption and advance warning sign responsibilities..	117
Table 21. Siren activated pre-emption responsibilities.....	118

TABLE OF CONTENTS

LIST OF FIGURES

Figure 1. Warrant 7: Four-hour volumes 1.....	11
Figure 2. Warrant 7: Four-hour volumes 2.....	12
Figure 3. Warrant 9: Peak hour volumes 1.	14
Figure 4. Warrant 9: Peak hour volumes 2.	15
Figure 5. Direction assignments for a north-south highway	17
Figure 6. Direction assignments for an east-west highway	17
Figure 7. Direction assignments for a north-south highway with split phase operation..	18
Figure 8. Protected/permissive sight distance requirement for passenger cars	21
Figure 9. Opposing vehicle visual obstruction.....	22
Figure 10. Protected/permissive sight distance requirement for WB-15 trucks	23
Figure 11. NEMA Dual Ring operation.....	26
Figure 12. NEMA Dual Ring operation with split phasing on the highway	27
Figure 13. NEMA Dual Ring operation with split phasing on the cross street.....	28
Figure 14. 2 Over 2 Plus 4 operation.....	29
Figure 15. 4 Plus 2 Over 2 operation.....	30
Figure 16. Sequential operation with split phasing and anticipated left turn signals	31
Figure 17. Sequential operation with no anticipated left turn signals.....	32
Figure 18. Sequential operation with split phasing and no anticipated left turn phases.	33
Figure 19. Sequential operation with one left turn signal.....	34
Figure 20. 2 Over 2 Plus 4 with geometric conflicts on the cross street.	35
Figure 21. 4 Plus 2 Over 2 with geometric conflicts on the main street (highway).....	36
Figure 22. Leading and lagging left turns in a <i>Signal Timing Sheet</i>	39
Figure 23. Clearance and conflict distances for protected/permissive left turns	44
Figure 24. Clearance and conflict distances	45
Figure 25. Examples of delay/extension detection.....	54
Figure 26. Force-offs and permissives for NEMA Dual Ring operation	59
Figure 27. Force-offs and permissives with lead/lag operation	61
Figure 28. Railway pre-emption.....	70
Figure 29. Typical signal indication positioning.....	74
Figure 30. Secondary head cone of vision.....	77
Figure 31. Signal and pedestrian head orientation	78
Figure 32. Full intersection with sequential operation and no left turn signals.....	80
Figure 33. "T" intersection with sequential operation and left turn signals.....	81
Figure 34. Channelized "T" intersection with sequential operation and left turn signals.	82
Figure 35. Full intersection with NEMA Dual Ring & protected/permissive left turn.....	83
Figure 36. Full intersection, Dual Ring, protected left turn & split phase cross street. ...	84
Figure 37. Full intersection, Dual Ring, protected left turn (two lane) on the highway. ...	85

TABLE OF CONTENTS

LIST OF FIGURES (*continued*)

Figure 38. Double left-turn primary signal head locations.	86
Figure 39. Audible Signal Orientation at Intersections	89
Figure 40. Loop detector numbering and layout	102
Figure 41. Pedestrian signal phasing	121
Figure 42. Pedestrian signal in coordination	124
Figure 43. Standard pole location for pedestrian signal.	126
Figure 44. Standard pole location for o/h flashing beacon at an intersection	139

LIST OF APPENDICES

- 400.1 Traffic Engineering Checklist
- 400.2 Traffic Signal Timing Sheets
- 400.3 Manual Traffic Count Template
- 400.4 Signal Warrant Analysis
- 400.5 Bicycle Pushbutton Post

Electronic versions of this manual and appendices available at:

http://www.th.gov.bc.ca/publications/eng_publications/electrical/electrical_and_traffic_eng/Electrical_Signing_Design_Manual/tableofcontents.htm

401 INTRODUCTION

401.1 ABOUT SECTION 400

- .1 Section 400 presents guidelines for the design of motor vehicle traffic signals within the British Columbia highway system. The ministry's primary goals are to provide safe, reliable, and efficient traffic signals.
- .2 The ministry uses standard signal equipment and standard methods of operation for all traffic signals throughout the Province of British Columbia.
- .3 This section also includes signals for pedestrian crossings, one-way bridge control, drawbridges or swing bridges, fire, special crosswalks, flashing beacons and warning signs, and lane control systems.

401.2 BEFORE YOU BEGIN

- .1 As noted above, the ministry has specific requirements for traffic signals designs. A signal typically involves electrical and traffic engineering.
- .2 Prior to submitting a signal design, the traffic engineer shall complete a Traffic Engineering Checklist and a Signal Timing Sheet and obtain sign-off by the ministry Senior Traffic Operations Engineer. To aid in the production of these documents, the ministry has produced guides titled Traffic Engineering Checklist - How to Complete the Form and Signal Timing Sheet - How to Complete the Form. The documents and the complete instructions are located in Appendix 400 of this manual. Prior to starting any design, the traffic engineer shall obtain the current documents and completion requirements.
- .3 The traffic engineer shall use the current ministry approved signal capacity software for the development of Signal Timing Sheets. Contact the Senior Traffic Operations Engineer for the current ministry approved software.
- .4 All traffic engineering shall be undertaken by a qualified traffic engineer registered with the EGBC. The traffic engineer shall have experience in preparing signal timings and using signal capacity software. The ministry may require proof of qualifications.
- .5 All signal design drawings shall be prepared by a qualified electrical engineer registered with the EGBC. The electrical engineer shall have experience with signal design and shall be knowledgeable in the hardware used for signals.
- .6 There are specific procedures are for obtaining development approval for a traffic signal design. Refer to Section 200 – Design Process and Quality Management of this manual for requirements.

INTRODUCTION

- .7 The following documents shall be read in conjunction with this manual and are referenced throughout. When using this document, a current copy of the following documents will be required:
 - .1 The B.C. Motor Vehicle Act Regulation Division (23) Traffic Control Devices, and the B.C. Motor Vehicle Act RSBC 1996 Chapter 318.
 - .2 It is assumed that the reader has a sound knowledge of signal design. Refer to Part B, Traffic Signals, of the latest edition of the Manual of Uniform Traffic Control Devices for Canada (MUTCD) for information on signal concepts and terminology.
 - .3 The Highway Capacity Manual and the Canadian Capacity Guide for Signalized Intersections will be required for calculating signal timings.
 - .4 Where conflicts exist between documents noted above and this document, this document shall take precedence.

402 TRAFFIC SIGNALS

402.1 GENERAL

- .1 Traffic signals have a strong influence on traffic flow and can operate to the advantage or disadvantage of the vehicles and pedestrians they control. The proper application, design, installation, operation and maintenance of traffic signals is critical to the orderly movement of traffic and can improve the safety and traffic handling capacity of an intersection.
- .2 Conversely, unnecessary, poorly designed, improperly operated or inadequately maintained traffic signals can cause excessive delay, reduce intersection capacity, and reduce safety.

402.2 DATA REQUIREMENTS

- .1 These data requirements are for warrant analysis and signal timings.
- .2 A comprehensive site investigation of the intersection should be conducted, documenting the physical characteristics and traffic volume data. Traffic volume data shall be no older than two years. Where applicable, this data should include:
 - .1 The number of vehicles entering the intersection from each approach in 15-minute intervals during the peak periods of a typical day. The duration of the count period shall be a minimum of 7 hours over one 24-hour day; the time periods need not be consecutive. Each allowable turning movement at the intersection shall be included in the count.
 - .2 The posted speed on the uncontrolled approaches to the location.
 - .3 Stopped delay (vehicle-hours) for each approach, if this is addressed in the warrant assessment.
 - .4 A condition sketch showing details of the physical layout, including:
 - .1 intersection geometry
 - .2 channelization
 - .3 grades
 - .4 sight-distance restrictions
 - .5 bus stops and routings
 - .6 parking conditions
 - .7 signs and pavement markings
 - .8 street lighting
 - .9 driveways
 - .10 location of nearby railroad crossings
 - .11 distance to nearest signals

TRAFFIC SIGNALS

- .12 utility poles and fixtures
 - .13 adjacent land use
- .5 A collision diagram showing at least three years of collision experience by:
 - .1 type
 - .2 location
 - .3 direction of movement
 - .4 severity
 - .5 time of day
 - .6 day of week
 - .7 time of year
- .3 The following data may be required on a site-specific basis using sound engineering judgment.
 - .1 Vehicular volumes for each traffic movement from each approach, classified by vehicle type including heavy trucks, passenger cars and light trucks, public-transit vehicles and, in some locations, bicycles, during 15-minute intervals of the two hour morning peak and the two hour afternoon peak.
 - .2 The number and distribution of gaps in major street traffic when minor street traffic finds it possible to use the intersection safely. This should be recorded during 15-minute intervals of the two-hour morning peak and the two-hour afternoon peak.
 - .3 The posted speeds or 85th percentile speeds of vehicles on controlled approaches at a point near to the intersection, but unaffected by the control. These should be recorded during 15-minute intervals during the morning and afternoon periods.
 - .4 Stopped pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or a Sunday.
 - .5 The number of right turn on red (RTOR) vehicles from each approach recorded during 15-minute intervals of the two-hour morning peak and the two-hour afternoon peak.
 - .6 Vehicle occupancy, which is the number of people in each vehicle. This should be recorded during 15-minute intervals of the two-hour morning peak and the two-hour afternoon peak.
 - .7 Queuing study, to be carried out as outlined in the latest ITE “Manual of Transportation Engineering Studies.”

402.3 WARRANTS

402.3.1 Requirements of the Warrant Analysis

- .1 All engineering study information, warrant analyses and decisions shall be documented for future reference. Refer to Appendix 400.5 for a blank traffic signal warrant sheet.
- .2 An engineering study shall be conducted to determine if the installation of a traffic signal will improve the overall safety and/or operation of the intersection. If these requirements are not met, a traffic signal should not be put into operation nor continued to operate, if already installed.
- .3 The engineering study should:
 - .1 Include an evaluation of the warrants in 402.3.2 through 402.3.10. These warrants are based on those promulgated by MUTCD. Traffic control signals should not be installed unless one or more of the signal warrants are met. However, satisfaction of a warrant or warrants is not in itself justification for a signal. Satisfaction of a warrant is an indicator that the engineer must conduct further analysis into the type of traffic control that is most applicable. Other factors noted in this section should be considered in determining whether a signal should also be installed.
 - .2 Roundabouts shall be considered as the first option for intersection designs where 4-way stop control or traffic signals are supported by traffic analysis. If an intersection treatment other than a roundabout is recommended, the project documentation should include a reason why a roundabout solution was not selected for that location. This roundabouts “first” policy supports the province’s Climate Action Program of 2007.
 - .3 Examine collisions and possible mitigating treatments, including but not limited to, traffic signals. The effect of a traffic signal varies considerably with the traffic pattern, road geometry, signal design and other local characteristics of intersections at which signals are installed. While the installation of traffic signals can reduce certain collisions, traffic signals cannot solve all intersection collision problems.
 - .4 Consider alternative solutions to traffic signals. Geometric improvements or regulatory and/or warning signing may provide a better solution to a safety or efficiency problem than the installation of a traffic signal.
 - .5 Include an analysis of traffic gaps for a more precise warrant evaluation. Eight of the nine signal warrants used in these guidelines are based primarily on traffic volumes or delay. Some studies have found that major-street gap availability, not solely volume, directly

affects the operational performance and determines the necessity of a traffic control signal. If the existing gaps in the major-street flow can accommodate all side-street vehicles and pedestrians, without conflict and with only minimal delay, then it is reasonable to assume that a traffic signal is not needed. Volume directly influences the major-street gap availability. Other factors, such as the traffic composition, platooning caused by nearby traffic signals, and platoon decay also has a significant effect on gap availability. As a result, for the same major-street volume, it is possible to have widely varying gap distribution.

- .6 Assess the system-wide impact and consequences of an intersection signalization in terms of optimizing network efficiency. Traffic control signals should be conceived and implemented on a systematic basis.
- .7 Assess the proposed signalization in accordance with the ministry's Access Management Plan and the corridor plan for that route.
- .8 Traffic counts for warrants are obtained from an "average" day. An "average" day is defined as: *"A weekday with traffic volumes found normally and repeatedly at the location"*.

TRAFFIC SIGNALS

402.3.2 Warrant 1: Minimum Vehicular Volume

- .1 This warrant applies when the average volume of intersecting traffic is the principal reason for considering signal installation.
- .2 The warrant is satisfied when, for any seven hours of an average day, traffic volumes equal or exceed those given in Table 1 or Table 2, as applicable. For major streets, the volume entering the intersection from both directions are combined. For minor streets, the higher volume of the two directions is used. The major street and minor street volumes shall be for the same seven hours.

NUMBER OF LANES		MAJOR STREET SPEED (POSTED OR 85TH PERCENTILE)			
		≤ 70 KM/H		> 70 KM/H	
Major Street	Minor Street	Major Street Combined Volume (vph)	Minor Street Higher Volume (vph)	Major Street Combined Volume (vph)	Minor Street Higher Volume (vph)
1	1	500	150	350	105
2 or more	1	600	150	420	105
2 or more	2 or more	600	200	420	140
1	2 or more	500	200	350	140

Table 1. Warrant 1: Minimum vehicular volume for rural and large urban areas.

NUMBER OF LANES		MAJOR STREET COMBINED VOLUME (VPH)	MINOR STREET HIGHER VOLUME (VPH)
MAJOR STREET	MINOR STREET		
1	1	350	105
2 or more	1	420	105
2 or more	2 or more	420	140
1	2 or more	350	140

Table 2. Warrant 1: Minimum volumes for intersections in small urban areas (≤10,000 population).

TRAFFIC SIGNALS

402.3.3 Warrant 2: Interruption of Continuous Traffic

- .1 This warrant applies to operating conditions where the traffic on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or hazard in entering or crossing the major street.
- .2 The warrant is satisfied when, for any seven hours of an average day, average traffic volumes equal or exceed those given in Table 3 or Table 4, as applicable, and the signal installation will not seriously disrupt progressive traffic flow on the major street. For major streets, the volumes entering the intersection from both directions are combined. For minor streets, the higher volume of the two directions is used.

NUMBER OF LANES		MAJOR STREET SPEED (POSTED OR 85TH PERCENTILE)			
		≤ 70 KM/H		> 70 KM/H	
Major Street	Minor Street	Major Street Combined Volume (vph)	Minor Street Higher Volume (vph)	Major Street Combined Volume (vph)	Minor Street Higher Volume (vph)
1	1	750	75	525	53
2 or more	1	900	75	630	53
2 or more	2 or more	900	100	630	70
1	2 or more	750	100	525	70

Table 3. Warrant 2: Minimum volumes for intersections in rural and large urban areas.

NUMBER OF LANES		MAJOR STREET COMBINED VOLUME (VPH)	MINOR STREET HIGHER VOLUME (VPH)
MAJOR STREET	MINOR STREET		
1	1	525	53
2 or more	1	630	53
2 or more	2 or more	630	70
1	2 or more	525	70

Table 4. Warrant 2: Minimum volumes for intersections in small urban areas (≤10,000 population).

402.3.4 Warrant 3: Progressive Movement

- .1 This warrant applies when traffic signal installation is necessary for progressive movement control, which maintains proper grouping of vehicles and effectively regulates group speed.
- .2 This warrant is satisfied when one of the following is true:
 - .1 Adjacent signals on a one-way street or a street with predominantly unidirectional traffic are so far apart that they do not provide the necessary degree of vehicle platooning and speed control.
 - .2 Adjacent signals on a two-way street do not provide the necessary degree of platooning and speed control. The proposed and existing adjacent signals could constitute a progressive signal system.
- .3 Using this warrant, signal installation should:
 - .1 Be based on the 85th percentile speed unless an engineering study indicates that another speed is more desirable.
 - .2 Not be considered where the resulting signal spacing would be less than 300 meters.

402.3.5 Warrant 4: Collision Experience

- .1 This warrant is satisfied when all the following are met:
 - .1 Adequate trials of less restrictive remedies with satisfactory observance and enforcement have failed to reduce the collision frequency.
 - .2 Five or more reported collisions, of types “susceptible” to correction by traffic signal control, have occurred within a 12-month period, with each collision involving personal injury or property damage of \$5000 or more.
 - .3 The installation of a signal would allow progressive traffic flow.

402.3.6 Warrant 5: System Warrant

- .1 Traffic signal installations may be warranted at some intersections to encourage the concentration and organization of traffic flow networks.
- .2 To be considered a major route, the road shall have at least one of the following characteristics. A major route:
 - .1 Is part of the street or highway system that serves as the principal network for through-traffic flow.
 - .2 It includes rural or urban highways outside, entering or traversing a city.

TRAFFIC SIGNALS

- .3 It appears as a major route on an official plan such as a major street plan in an urban area traffic and transportation study.
- .3 This warrant is met when the common intersection of two or more major routes has one of the following:
 - .1 An existing, or immediately projected, total entering volume of at least 1000 vehicles during the peak hour of a typical weekday and based on an engineering study, has five year projected traffic volumes, which meet one or more of the following warrants: Warrant 1 - Minimum Vehicular Volume, Warrant 2 - Interruption of Continuous Traffic, Warrant 6 - Combination, Warrant 7 - Four Hour Volume, Warrant 9 - Peak Hour Volume during an average weekday, or
 - .2 An existing, or immediately projected, total entering volume of at least 1000 vehicles for each of any five hours of a Saturday and/or Sunday.

402.3.7 Warrant 6: Combination Warrant

- .1 In exceptional cases, signals may be justified where no single warrant is satisfied, but where both the Minimum Vehicular Volume and Interruption of Continuous Traffic Warrants are satisfied to the extent of 80 percent or more of the stated values. Before installing signals under this warrant, other measures causing less delay and inconvenience to traffic should be attempted.

402.3.8 Warrant 7: Four Hour Volume Warrant

- .1 This warrant is satisfied where, for any four consecutive hours of an average day, the combination of major street volume using the total of both approaches and minor street volume in the peak direction only, exceeds the applicable threshold in Figure 1 or Figure 2, as applicable. 5 shows which figure should be used by location.

LOCATION TYPE	MAJOR STREET SPEED (POSTED OR 85TH PERCENTILE)	
	≤ 70 KM/H	> 70 KM/H
Rural	Figure 1	Figure 2
Large Urban (>10,000 pop)	Figure 1	Figure 2
Small Urban (≤10,000 pop)	Figure 2	Figure 2

Table 5. Warrant 7: Four hour volumes - figures by location

TRAFFIC SIGNALS

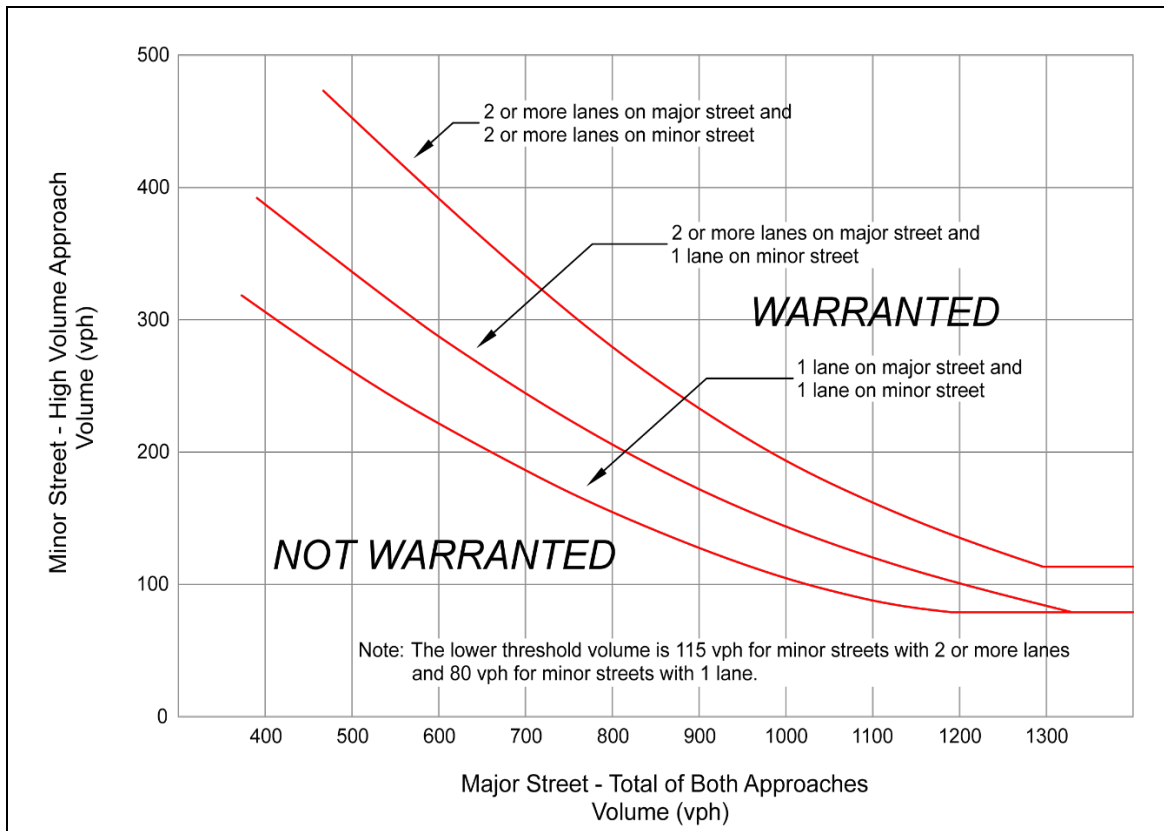


Figure 1. Warrant 7: Four-hour volumes 1.

TRAFFIC SIGNALS

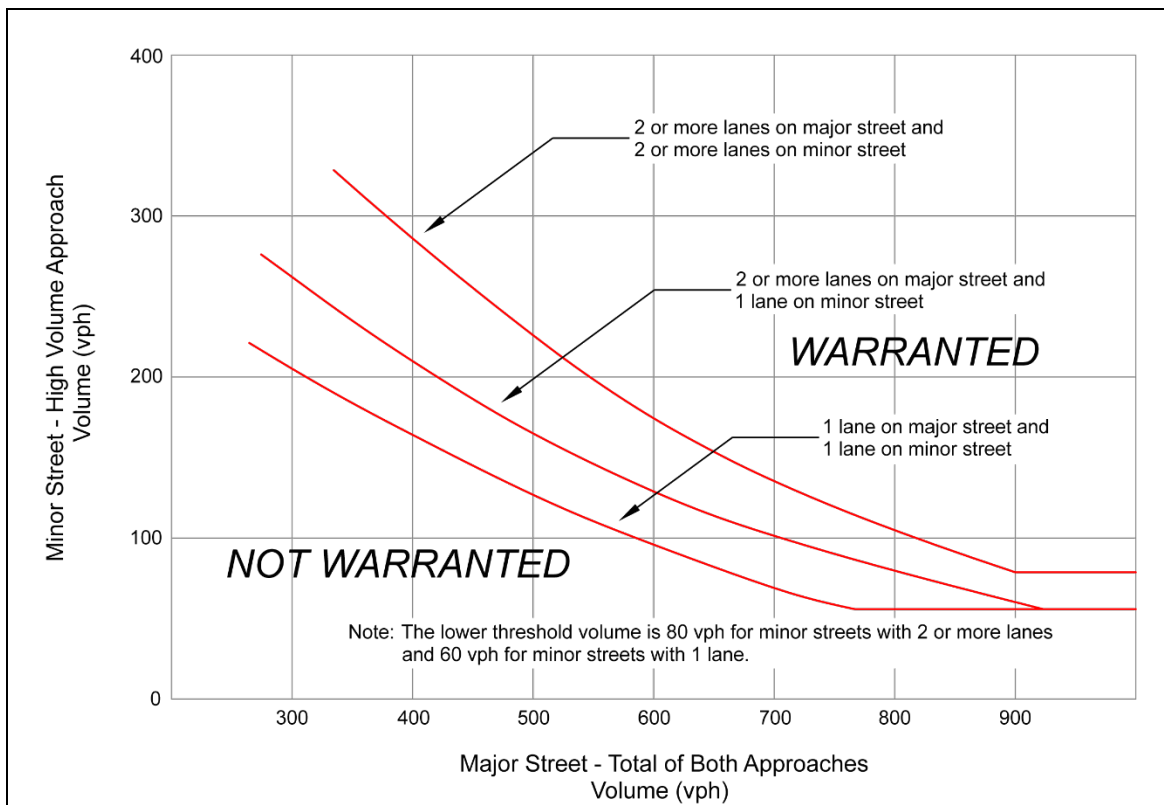


Figure 2: Warrant 7: Four-hour volumes 2.

402.3.9 Warrant 8: Peak Hour Delay

- .1 This warrant applies when minor street traffic suffers undue delay in entering or crossing the major street, during the peak hours of an average day.
- .2 This warrant is satisfied when all the following conditions are true for a one-hour period of an average day. The one-hour interval is defined as any four consecutive 15-minute periods.
 - .1 The total delay experienced by traffic on one minor street approach in one direction only and controlled by a STOP sign equals or exceeds four vehicle-hours for a one-lane approach and five vehicle hours for a two-lane approach.
 - .2 The volume of the same minor street approach in one direction only equals or exceeds 100 vph for one moving lane of traffic or 150 vph for two moving lanes.
 - .3 The total entering volume serviced during the hour equals or exceeds 800 vph for intersections with four or more approaches or 650 vph for intersections with three approaches.

402.3.10 Warrant 9: Peak Hour Volume

- .1 This warrant is intended for applications where the traffic is concentrated in the peak hours of an average day. Although the average volumes are not high enough to warrant a signal, the peak hour volumes may be relatively high causing an operational or safety problem at the intersection.
- .2 This warrant is satisfied where, for any single hour of an average day, the combination of major street volume using the total of both approaches and minor street volume in the peak direction only, exceeds the applicable threshold in Figure 3 or Figure 4, as applicable. 6 shows which figure should be used by location.

LOCATION TYPE	MAJOR STREET SPEED (POSTED OR 85TH PERCENTILE)	
	≤ 70 KM/H	> 70 KM/H
Rural	Figure 3	Figure 4
Large Urban (>10,000 pop)	Figure 3	Figure 4
Small Urban (≤10,000 pop)	Figure 4	Figure 4

Table 6. Warrant 9: Peak Hour Volume figures by location.

TRAFFIC SIGNALS

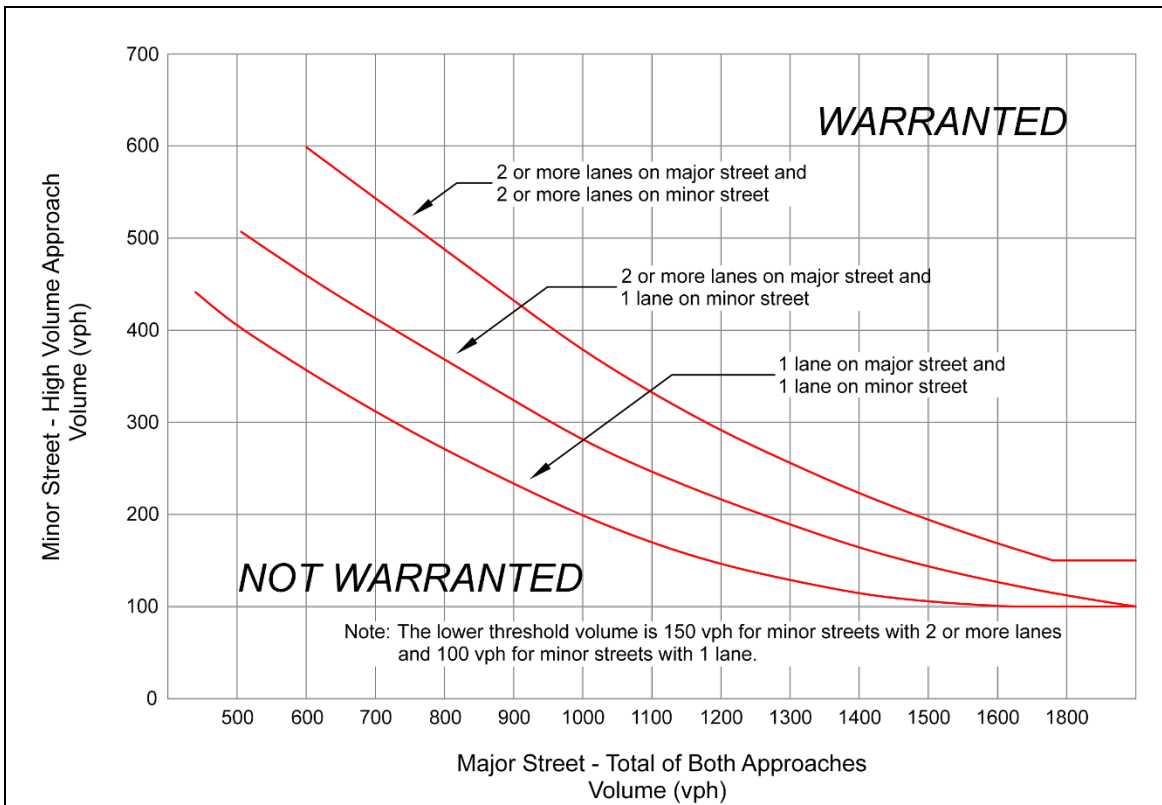


Figure 3. Warrant 9: Peak hour volumes 1.

TRAFFIC SIGNALS

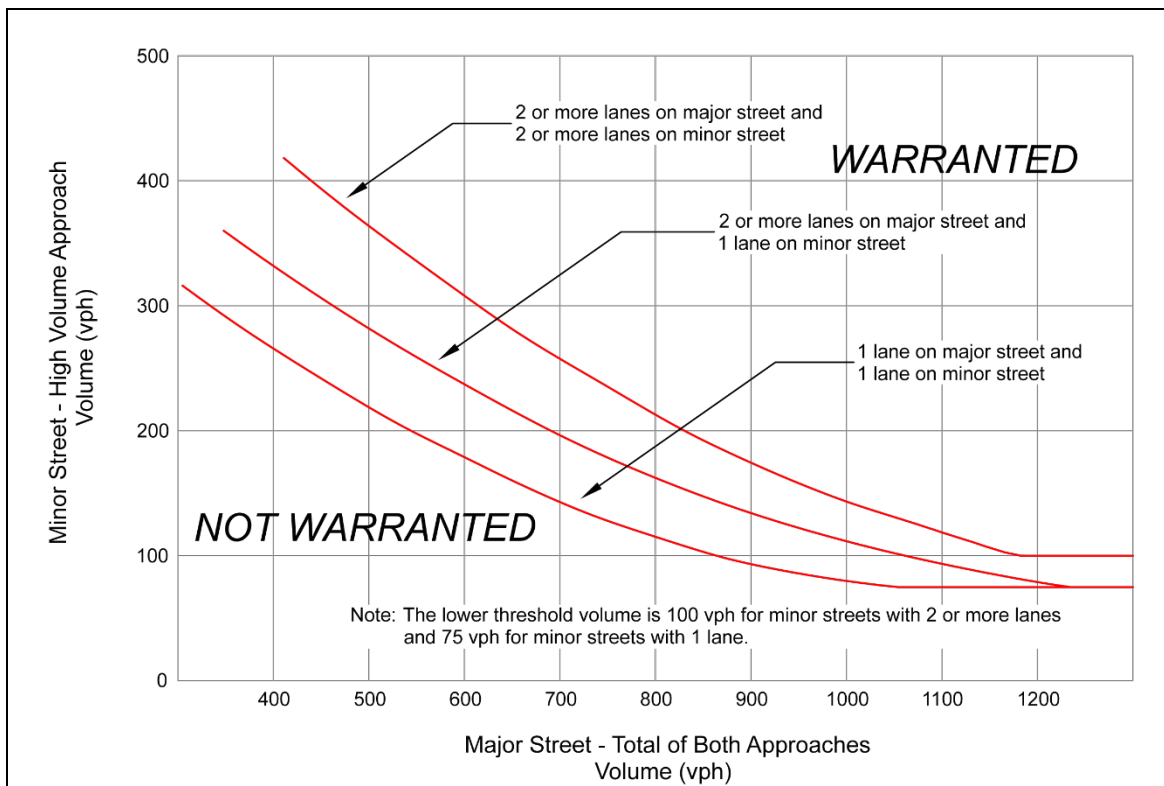


Figure 4. Warrant 9: Peak hour volumes 2.

402.4 PHASING

402.4.1 General

- .1 The definition of a signal phase is: "A signal phase is part of a cycle of all movements during which one or more non-conflicting movements are permitted to proceed".
- .2 This clause discusses the division of movements into phases and their operation with respect to each other. Because right turns are generally allowed during through movements, they are not explicitly considered. Rather, the movements to be incorporated into phases are through movements for each approach and optional separate left turn movements.
- .3 Phasing for specialized applications such as signalized right turns and diamond interchanges are not covered in this manual. Consult the Senior Traffic Operations Engineer where these or other specialized applications are encountered.

402.4.2 Direction Assignments

- .1 For naming purposes, movements are grouped. Each group is given a letter designation (A, B, C, etc.). The groups are determined according to the following rules:
 - .1 Through movements and separate left turn movements for the same approach are grouped together.
 - .2 Movements on opposing approaches are grouped together provided that the opposing through movements may operate simultaneously during at least part of the cycle.
 - .3 Highway movement groups are named first.
- .2 When describing all the movements in a group, its letter alone is used.
- .3 When describing particular movements within a group, suffixes are appended to the group letter as follows:
 - .1 A1 and A2 are opposing through movements.
 - .2 Ax and Ay are opposing protected left turn movements.
 - .3 A1→ and A2→ are opposing protected/permissive left turn movements.
- .4 In naming opposing movements, cardinal directions such as 'Northbound' or 'Southbound' are appended. For highways, northbound or eastbound movements are named first. For cross streets, southbound or westbound movements are named first. Figure 5 and Figure 6 illustrate examples of movement names. For intersections skewed or turned 45 degrees to the cardinal directions, the assignment of directions is arbitrary, but should conform to the direction assignments of nearby signals. A split phase example is shown in Figure 7 (example shows north-south movement with split phase on the cross street. Other split phase scenarios are shown in figures in 402.4.4) An intersection which is part of a route or corridor which is designated north-south may not in fact be oriented north-south because of local geography. In these cases, both 'True' north and a designated 'Signal' north must be marked on the signal sequence diagram on the traffic signal design drawings. The phasing must be oriented relative to the designated 'Signal' north.

TRAFFIC SIGNALS

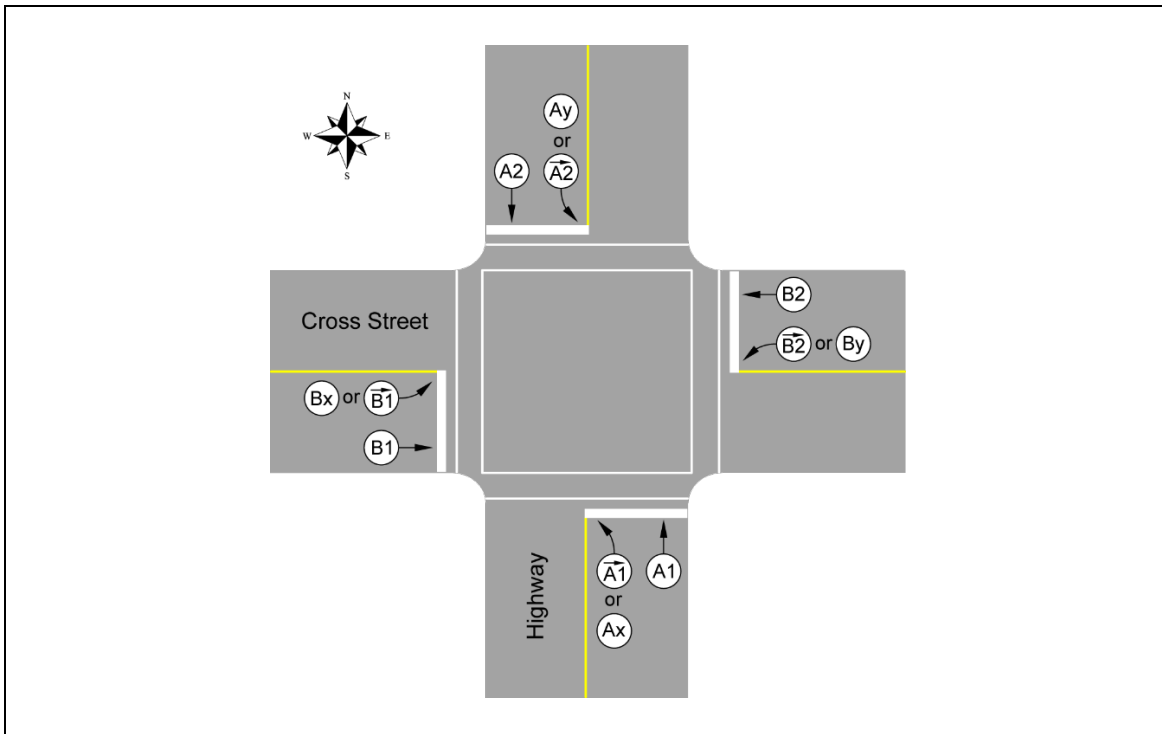


Figure 5. Direction assignments for a north-south highway

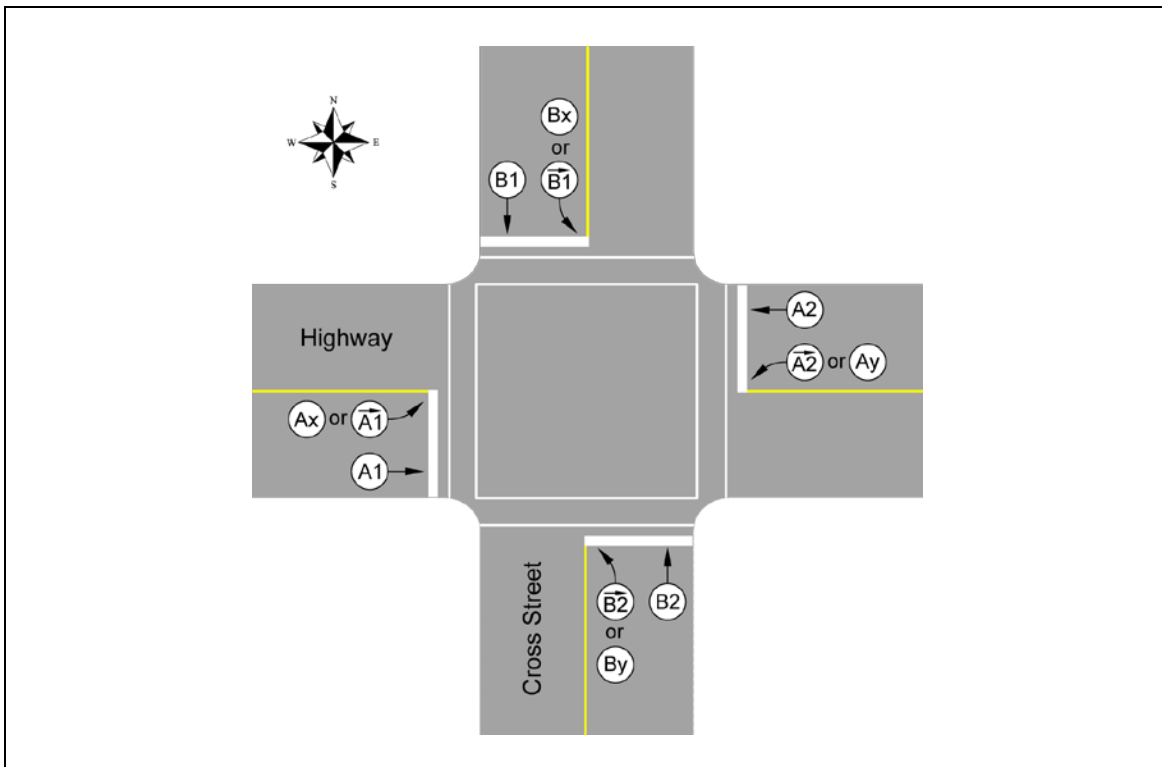


Figure 6. Direction assignments for an east-west highway

TRAFFIC SIGNALS

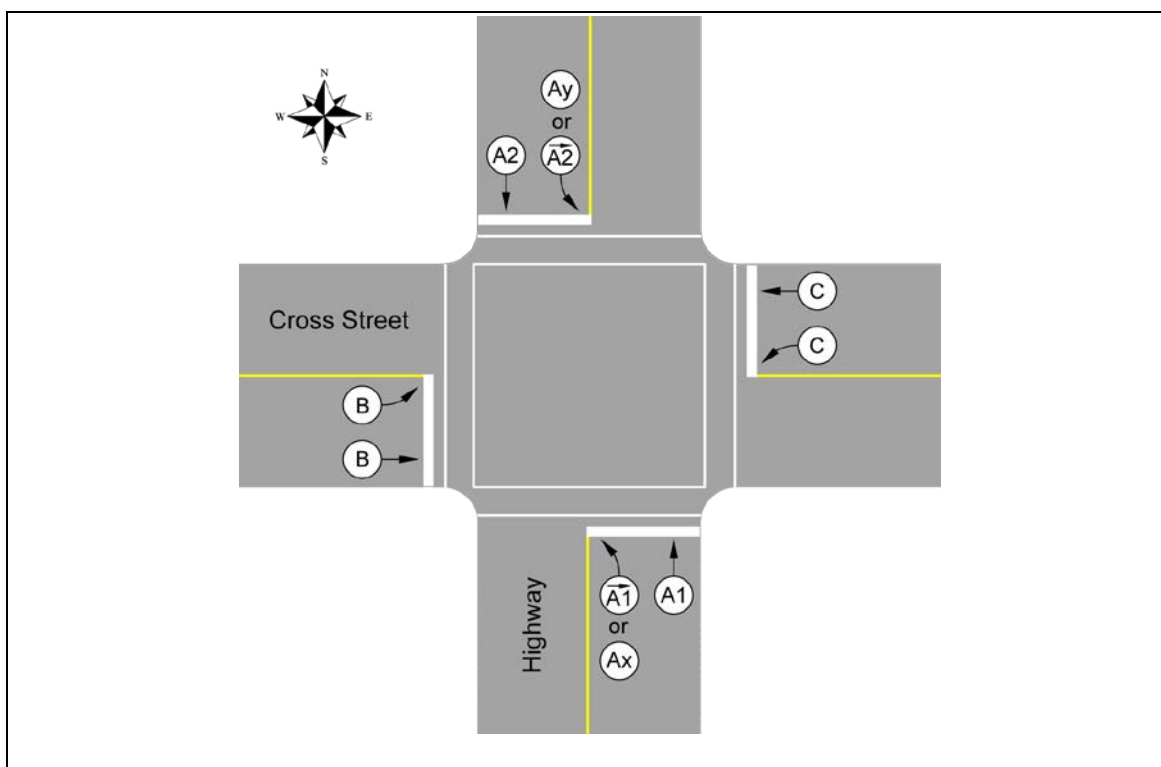


Figure 7. Direction assignments for a north-south highway with split phase operation

- .5 When assigning movements to phases, the movement names are used. Thereafter, phases may be referred to using their associated movement names. For example, if phase 2 is assigned the A1 movement, it may be referred to as the A1 phase.

402.4.3 Use of Separate Left Turn Movements

- .1 Separate left turn movements allow traffic to turn left while opposing vehicles are stopped and are used to reduce left turn traffic delay and collisions. Left turning traffic faces a green arrow signal head. Because opposing through traffic is stopped during the left turn phase and opposing volumes are generally higher than left turn volumes, left turn phases tend to cause increased overall delay at an intersection. Therefore, such phases should not be installed indiscriminately.
- .2 If a traffic signal can benefit from simultaneous left turns on the highway, but geometric constraints do not allow simultaneous left turns, then lead/lag phasing should be used as the ministry does not allow split phase operation on numbered Highway movements. Split phasing is permitted on Cross Streets.
- .3 Before installing a left-turn phase consider:

TRAFFIC SIGNALS

- .1 A left turn lane should be installed if one does not exist. If a left turn lane does not solve operational problems, a left turn phase should be considered.
 - .2 The effect of a left turn phase on progression on coordinated signals.
 - .3 The traffic volumes, speed, left turn delay and collision experience. Satisfaction of Guideline A, B, or C below suggests that left turn phasing may be worthwhile. Satisfaction of these guidelines does not mean that a left turn phase must be added. However, it should act as a trigger that the left turn movement needs further engineering assessment and/or action.
 - .4 Capacity analysis of the intersection should be undertaken with and without left turn phasing. When the left turn phase can be added without appreciably affecting the overall level of service, then it should be considered.
- .4 Guideline A: Minimum Peak Hour Volumes
- .1 Guideline A addresses locations where the peak hour left turn volume is the principal reason for consideration of a left turn phase. This guideline involves the product of left turning volume and opposing through volume and provides a combined scale for left turn demand and the opposing supply of gaps, which is partially a function of volume.
 - .2 This guideline is satisfied when one or both of the following conditions are met:
 - .1 The product of multiplying the left turning volume and opposing through volume exceeds $50,000 (\text{vph})^2$ for one opposing through lane and $90,000 (\text{vph})^2$ for two opposing through lanes.
 - .2 The left turning volume exceeds 90 vph where the major street 85th percentile or posted speed is 70 km/h or less, or 65 vph where the major street 85th percentile or posted speed exceeds 70 km/h.
- .5 Guideline B: Left Turn Vehicle Delay
- .1 This guideline is applied where delay for left turning vehicles is a major concern.
 - .2 This guideline is met when left turn vehicle delay equals or exceeds 2 vehicle-hours for any one hour of an average day. Average delay per vehicle, or the total delay encountered by vehicles on an approach during that peak hour, is measured (typically with a stopwatch) and recorded as Vehicle-Hours. An example for this calculation of Vehicle-Hour delay is as follows:

TRAFFIC SIGNALS

- .1 If there is a volume of 300 vehicles on the minor street approach during the peak one hour, and the average delay per vehicle on that approach during that peak hour is 60 seconds per vehicle, then there would be 300×60 or 18,000 vehicle-seconds of delay. 18,000 vehicle-seconds divided by 3600 seconds (one hour), equates to 5.0 vehicle-hours of delay.
- .6 Guideline C: Collision Experience
 - .1 This guideline is met when five or more reported left turn collisions, of types susceptible to correction by left turn signal control, have occurred within a 12-month period, with each collision involving personal injury or property damage of \$5000 or more.

402.4.4 Protected/Permissive Versus Protected Left Turn

- .1 Traffic engineers shall document the reasons for the choice in phasing.
- .2 Protected/permissive phasing is generally used for left turns because of its greater efficiency. However, protected phasing shall be used if the following conditions exist.
 - .1 Permissive left turning is deemed hazardous by a Traffic Engineer due to gap judgment difficulty caused by high speed, geometric or any other factors.
 - .2 There is more than one left turn lane for a given approach.
 - .3 Intersection geometrics make permitted turning confusing.
 - .4 Pedestrian volumes are high (protected left turns avoid the conflict between pedestrians and permitted left turning vehicles).
 - .5 The left turn phase is in a lead-lag operation. Refer to 402.4.5.
 - .6 The left turn signal is justified according to *Guideline C - Collision Experience*. Refer to 402.4.2.6.
 - .7 The sight distance to oncoming vehicles is less than that shown in Figure 8 for a left turning passenger car. This allows a car to complete its turn without requiring an oncoming vehicle to adjust its speed. A perception-reaction time of 2.0 s is assumed. Note that opposing left turning vehicles should be considered as visual obstructions, where applicable, in determining sight distance. Refer to Figure 9.
 - .8 The sight distance to oncoming vehicles is less than that shown in Figure 10 for a left turning WB-15 truck. This allows a truck to complete its turn without requiring an oncoming vehicle to adjust its speed. A perception-reaction time of 2.0 s is assumed. Because of the eye height of drivers in trucks, opposing left turning vehicles are not

TRAFFIC SIGNALS

considered as visual obstructions unless more than 10 percent of opposing turning vehicles are trucks.

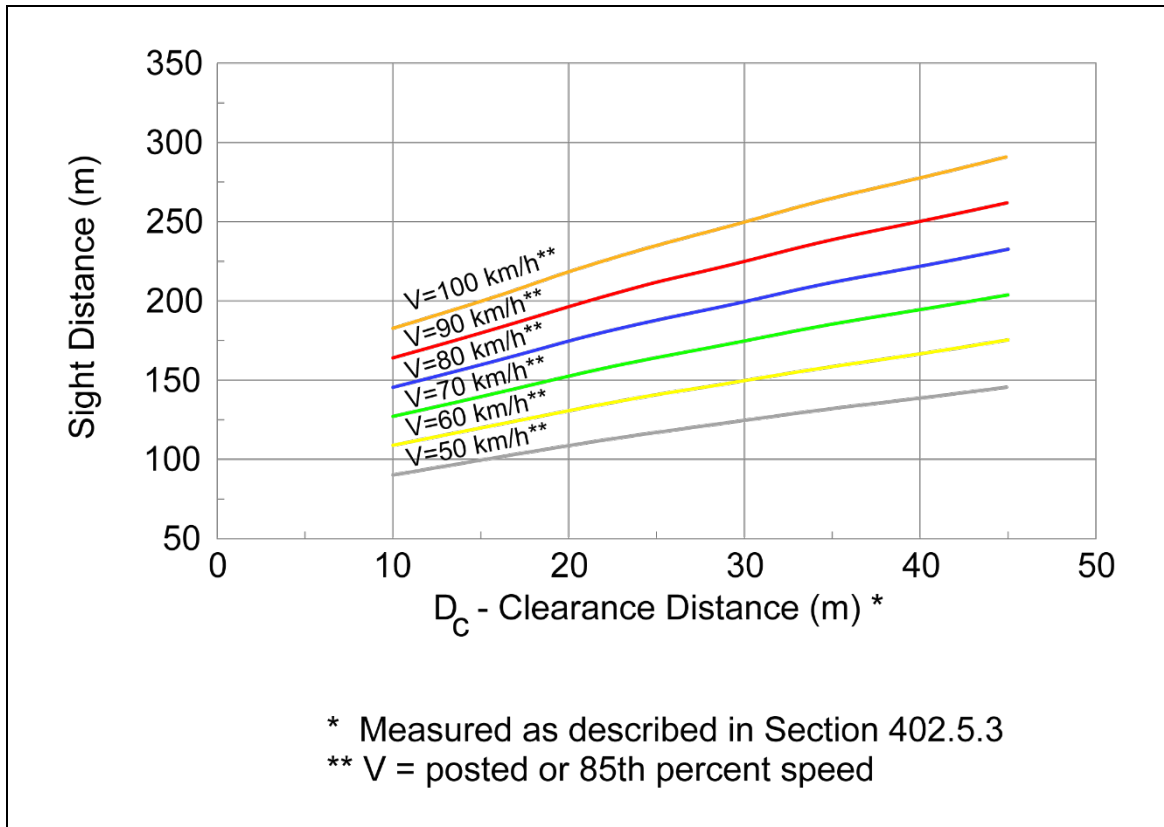


Figure 8. Protected/permissive sight distance requirement for passenger cars

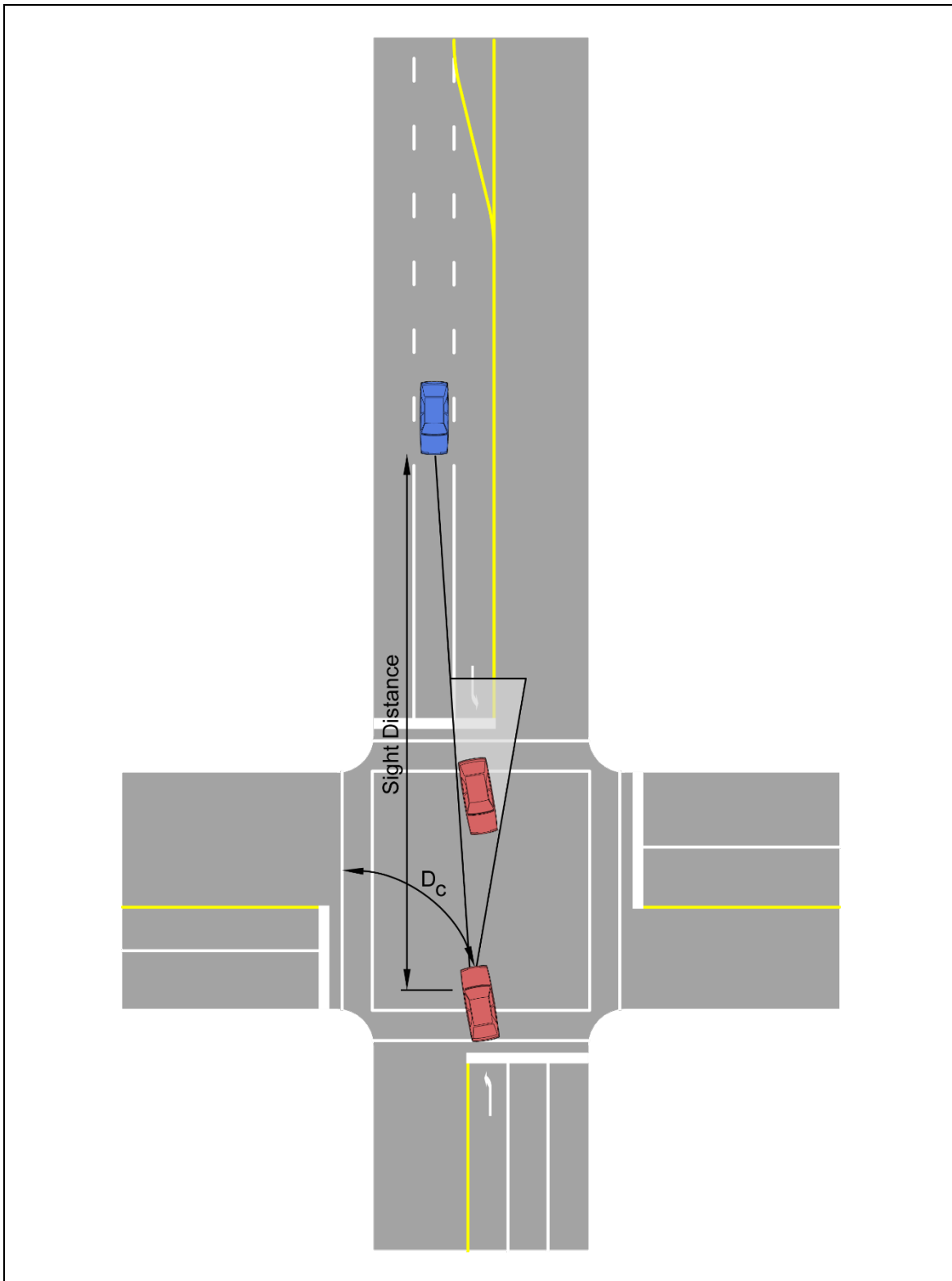


Figure 9. Opposing vehicle visual obstruction

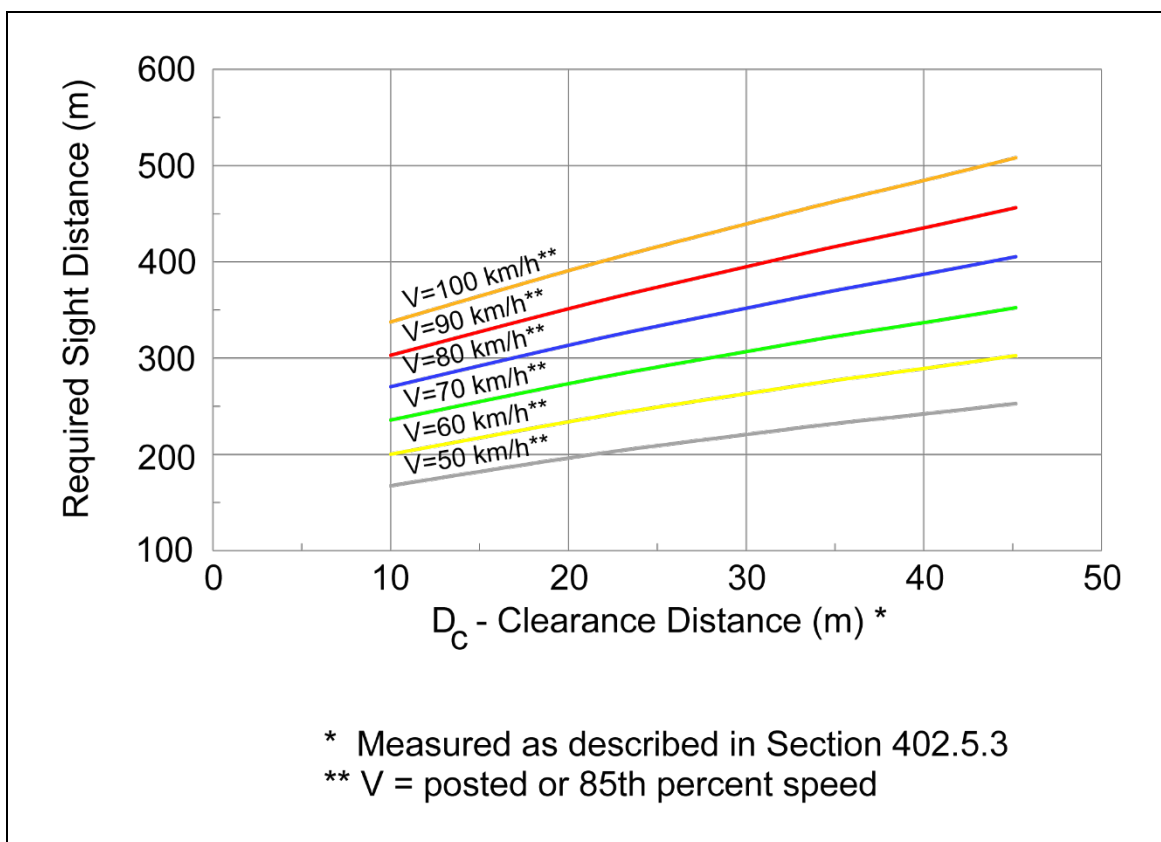


Figure 10. Protected/permissive sight distance requirement for WB-15 trucks

402.4.5 Phase Sequencing

- .1 NEMA TS2-TYPE1 controllers can accommodate sixteen phases and four rings. NEMA TS2-TYPE2 and NEMA TS1 controllers can accommodate up to eight phases in four operation scenarios. Figure 11 through Figure 21 illustrate these operations. Typically, signal phasing will be NEMA Dual Ring except for the special circumstances listed below.
- .2 The following rules govern phase sequencing.
 - .1 Phases are called from left to right.
 - .2 Only one phase in each ring can operate at one time.
 - .3 Only phases on the same side of a barrier can operate at the same time.
 - .4 Separate left turn phases are shown as leading. The use of lagging left turn phases is discussed in 402.4.5.

Note: For the purposes of saving space in this document, all possible phases are shown in one box. However, when preparing intersection phasing diagrams, each allowable phase sequence must be shown in a separate box.
- .3 NEMA Dual Ring shall be used in all scenarios except where 2 Over 2 Plus 4, 4 Plus 2 Over 2 and Sequential phasing are required. Figure 11 shows all

phase assignments and controller operation, except for split phasing. Split phasing allows a single approach to an intersection, including left turns, to proceed while all other approaches are stopped. This phasing is typically utilized where the intersection geometry prevents simultaneous left turns or where there are shared lanes. Figure 11 also shows how the phasing operation is represented on the *Signal Timing Sheet*.

- .4 NEMA Dual Ring operation should be used for split phasing on the main street, cross street, or both, where separate left turn signals are not used or anticipated on the street(s) with split phasing. Figure 12 and Figure 13 show the phase assignments and controller operation for split phasing on the highway (main street) and cross street, respectively, and also show how the phasing operations are represented on the *Signal Timing Sheet*. Pedestrian and lead/lag phasing are also covered in this document.

Note: The ministry generally will not split highway phases as this prevents resting both highway movements on green. In situations where lead-lag operation or split phasing is required, lead-lag operation is the preferred method.

- .5 Note: The LMD8000 controller does not support left turn trap (yellow trap) programming. This must be accomplished with dedicated hardware.
- .6 Other less common phasing scenarios are as follows:
 - .1 2 Over 2 Plus 4
 - .1 This operation has been used in the past with the LMD8000 controller to mitigate geometric conflicts. This sequence may also be used where there is split phasing on the cross-street and future left turn phases are anticipated for this movement. The split phasing operation would be considered temporary to accommodate present needs with clear direction to upgrade to left turn phases in the future. This phasing is required to minimize controller and wiring modification when the signal is modified to left turn phase operation.
 - .2 Figure 14 shows the phase assignments and controller operation. Note that A movements are on the highway and B and C are opposing movements on the cross street. The figure also shows how phase assignments appear on the *Signal Timing Sheet*.
 - .3 Where this scenario is applied the designer shall ensure that pavement markings and geometric will accommodate the future opposing left turn movements with no conflicts.
 - .4 This scenario shall also apply where geometric conflicts occur on the cross street. Refer to Figure 20.
 - .2 4 Plus 2 Over 2

TRAFFIC SIGNALS

- .1 This operation is required where there is split phasing on the highway and future left turn phases are anticipated for this movement. The split phasing operation would be considered temporary to accommodate present needs with clear direction to upgrade the left turn phases in the future. This phasing is required to minimize controller and wiring modification when the signal is modified to left turn phase operation.
 - .2 Figure 15 shows the phase assignments and controller operation. Note that A and B are opposing movements on the highway and C movements are on the cross street. The figure also shows how phase assignments appear on the *Signal Timing Sheet*.
 - .3 Where this scenario is applied, the designer shall ensure that pavement markings and geometrics will accommodate the future opposing left turn movements with no conflicts.
 - .4 This scenario shall also apply where geometric conflicts occur on the main street. Refer to Figure 21.
- .3 Sequential
- .1 This operation shall apply:
 - .1 Where a Type M (4 phase cabinet) is used.
 - .2 Other uncommon scenarios not listed may also require sequential phasing. Where these scenarios come up, the use of sequential phasing should be discussed with the Senior Traffic Operations Engineer.
- .4 Unwarranted left turn phases may be included in the original phase design if planning studies show the left turn phases may be warranted in the future. Such phases shall be turned off and marked as future.

TRAFFIC SIGNALS

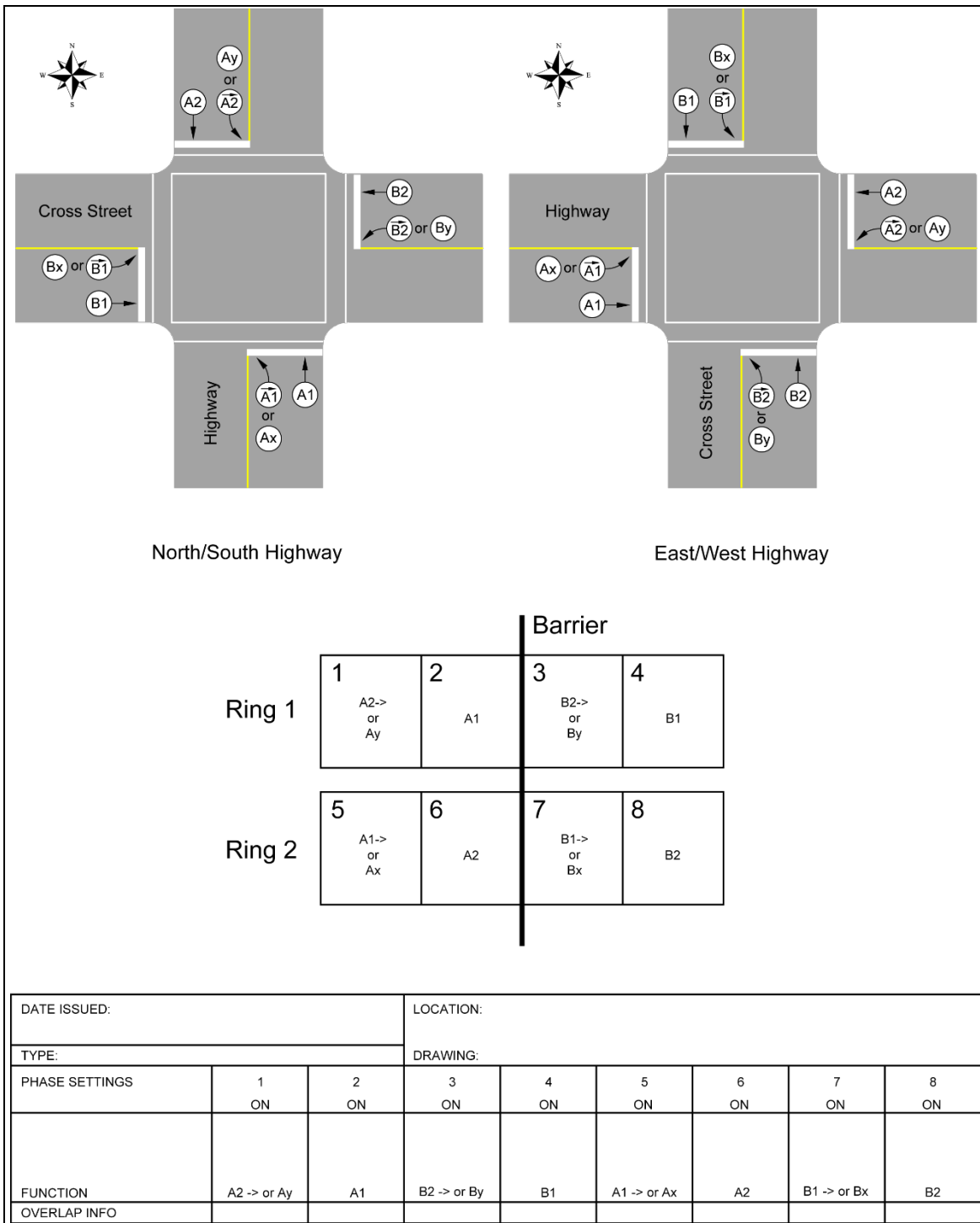


Figure 11. NEMA Dual Ring operation

TRAFFIC SIGNALS

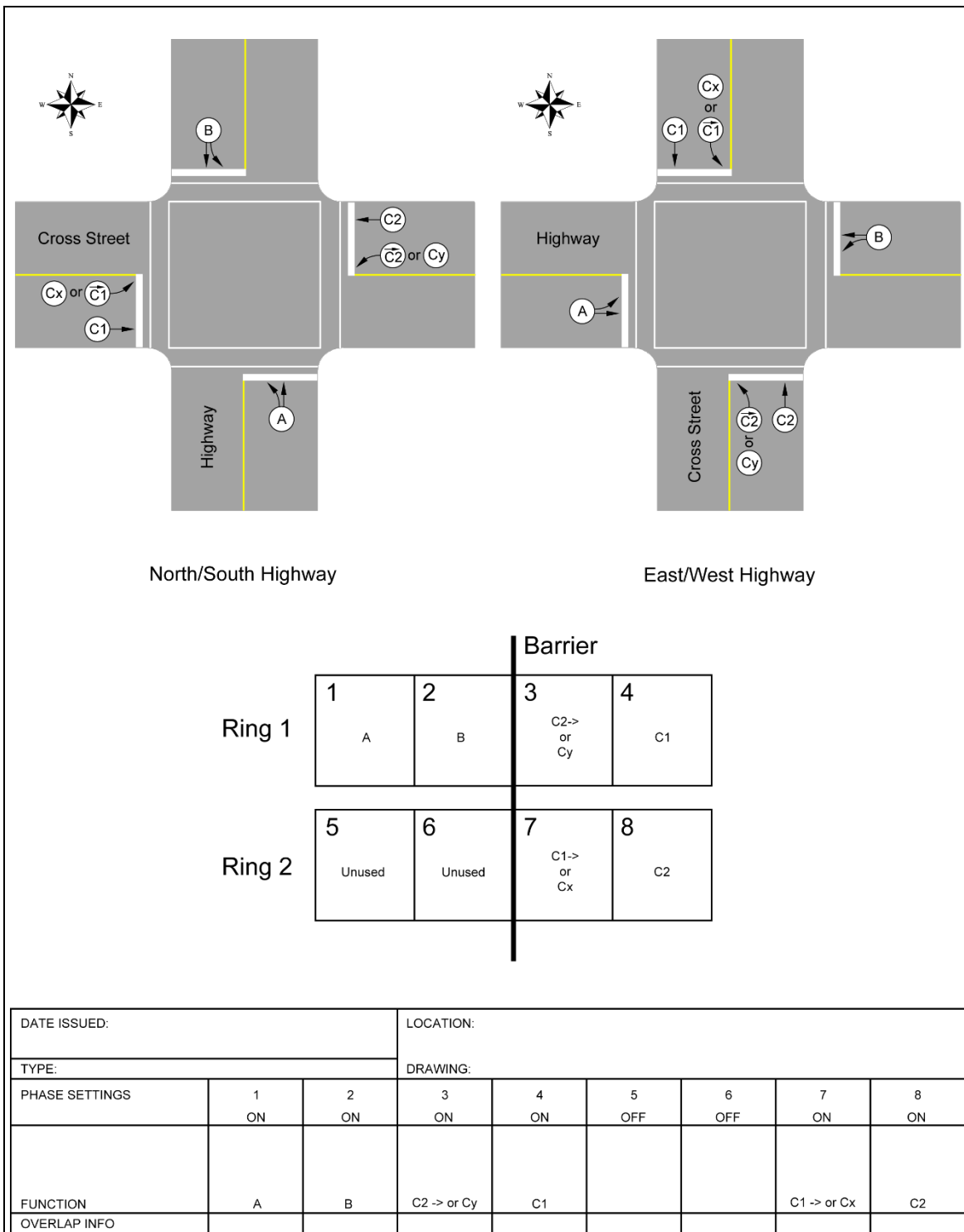


Figure 12. NEMA Dual Ring operation with split phasing on the highway

TRAFFIC SIGNALS

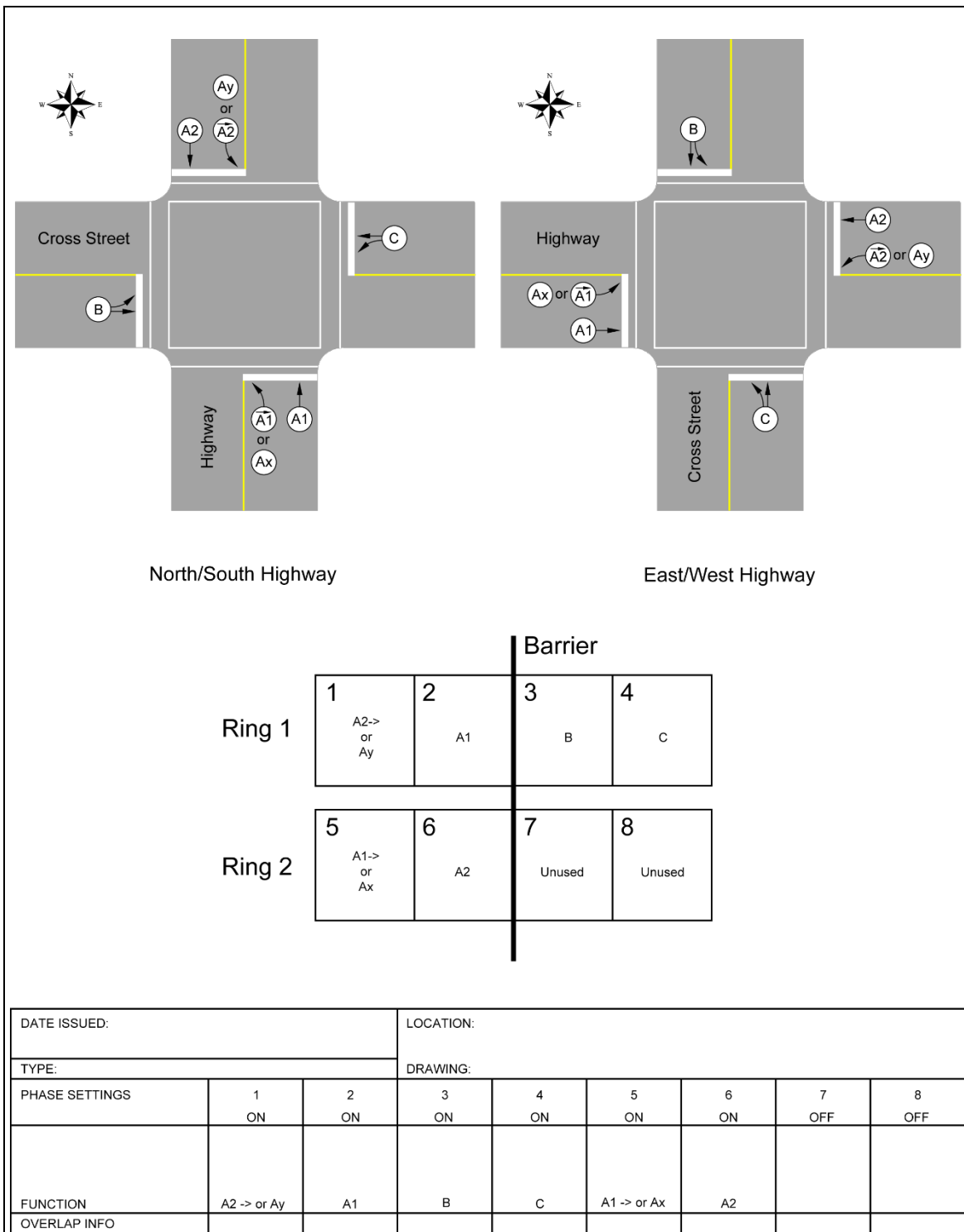


Figure 13. NEMA Dual Ring operation with split phasing on the cross street

TRAFFIC SIGNALS

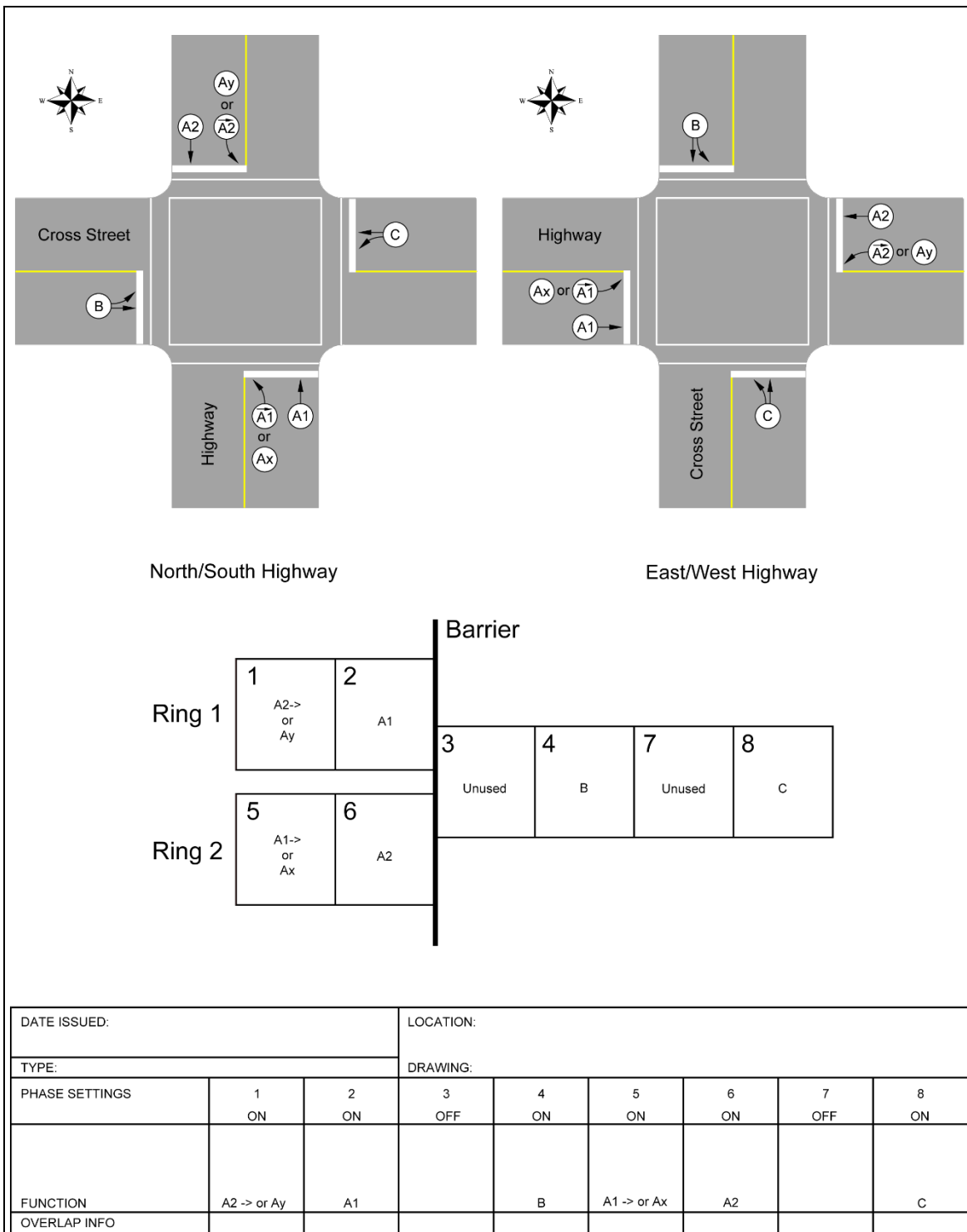


Figure 14. 2 Over 2 Plus 4 operation

TRAFFIC SIGNALS

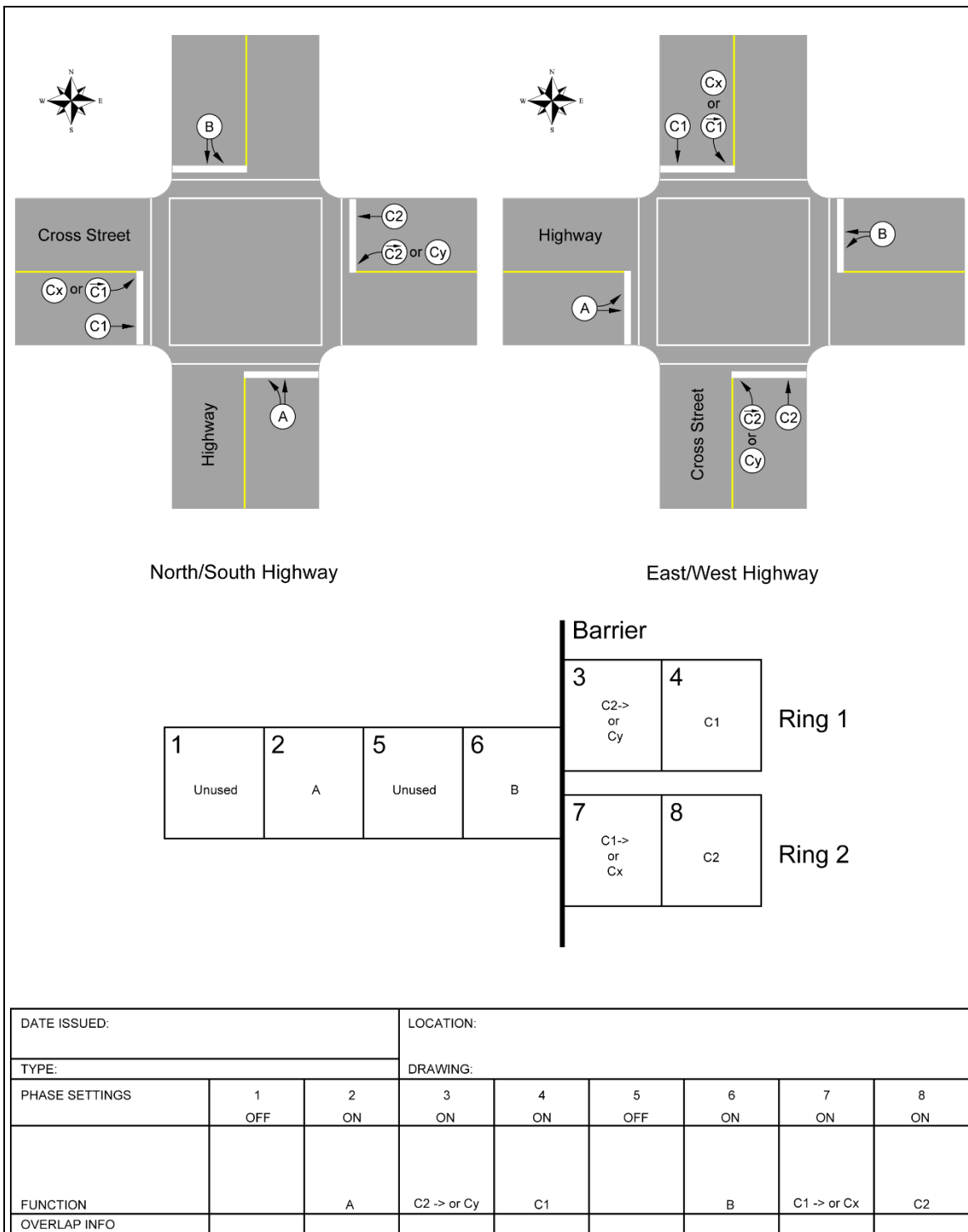


Figure 15. 4 Plus 2 Over 2 operation

TRAFFIC SIGNALS

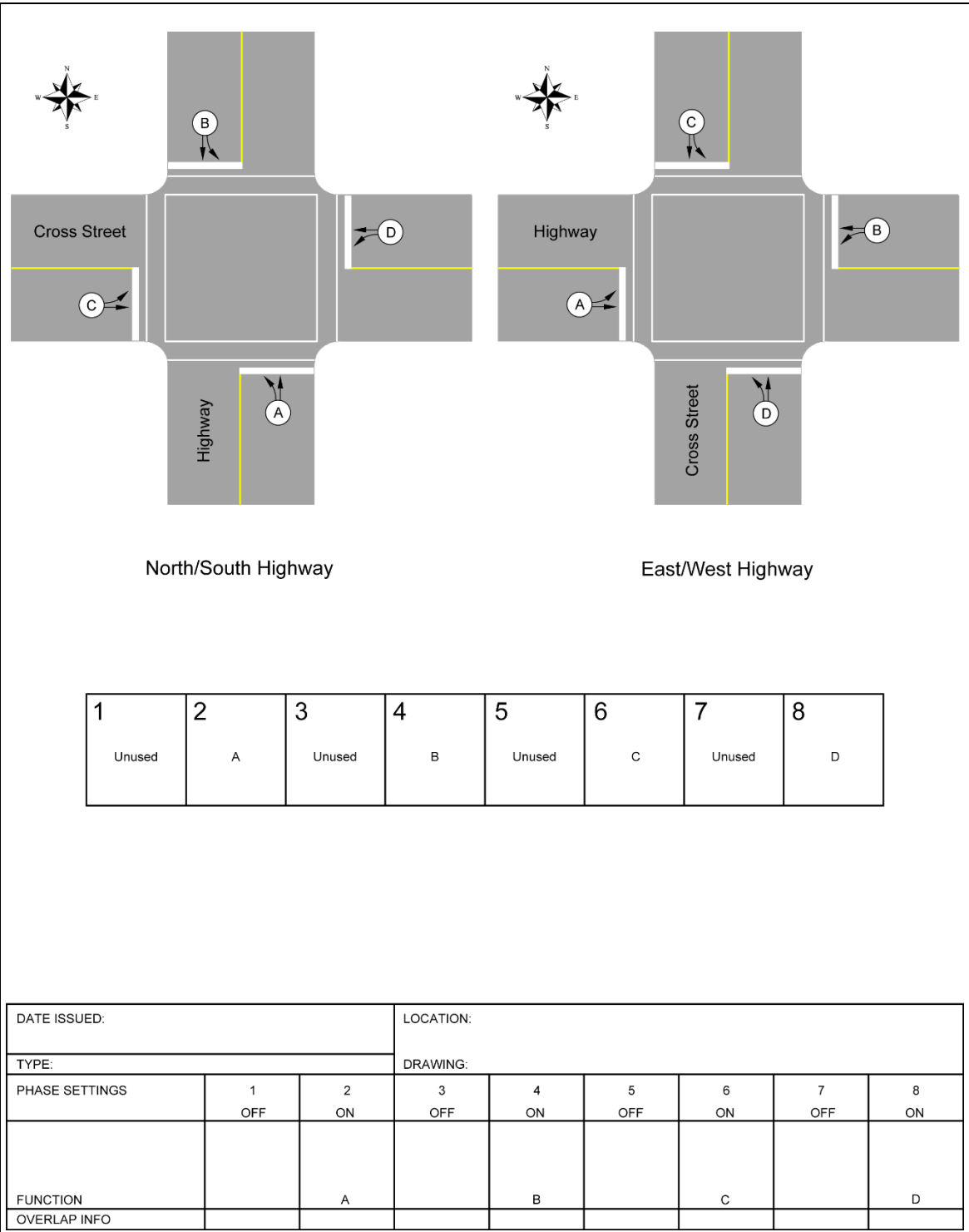


Figure 16. Sequential operation with split phasing and anticipated left turn signals

TRAFFIC SIGNALS

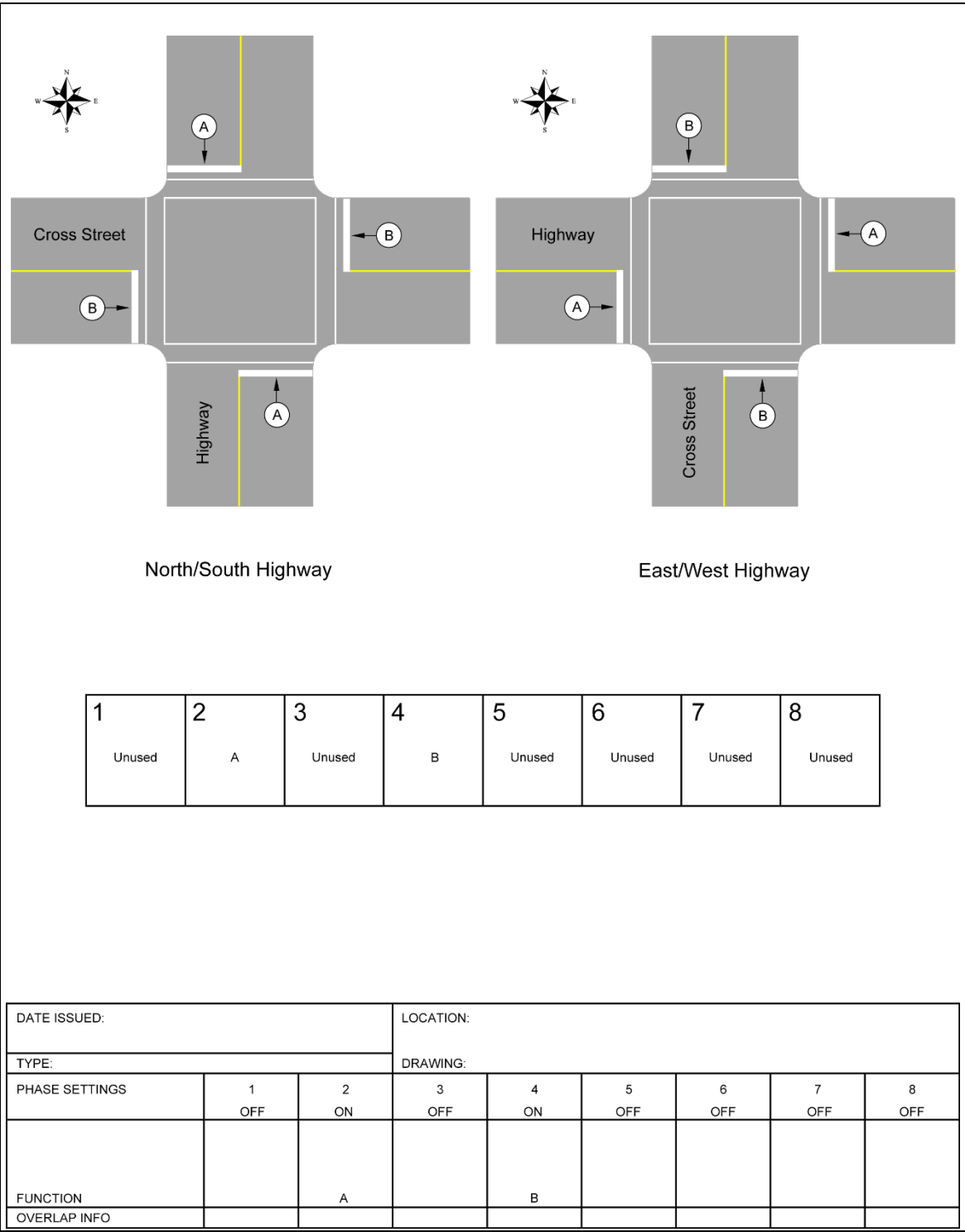


Figure 17. Sequential operation with no anticipated left turn signals

TRAFFIC SIGNALS

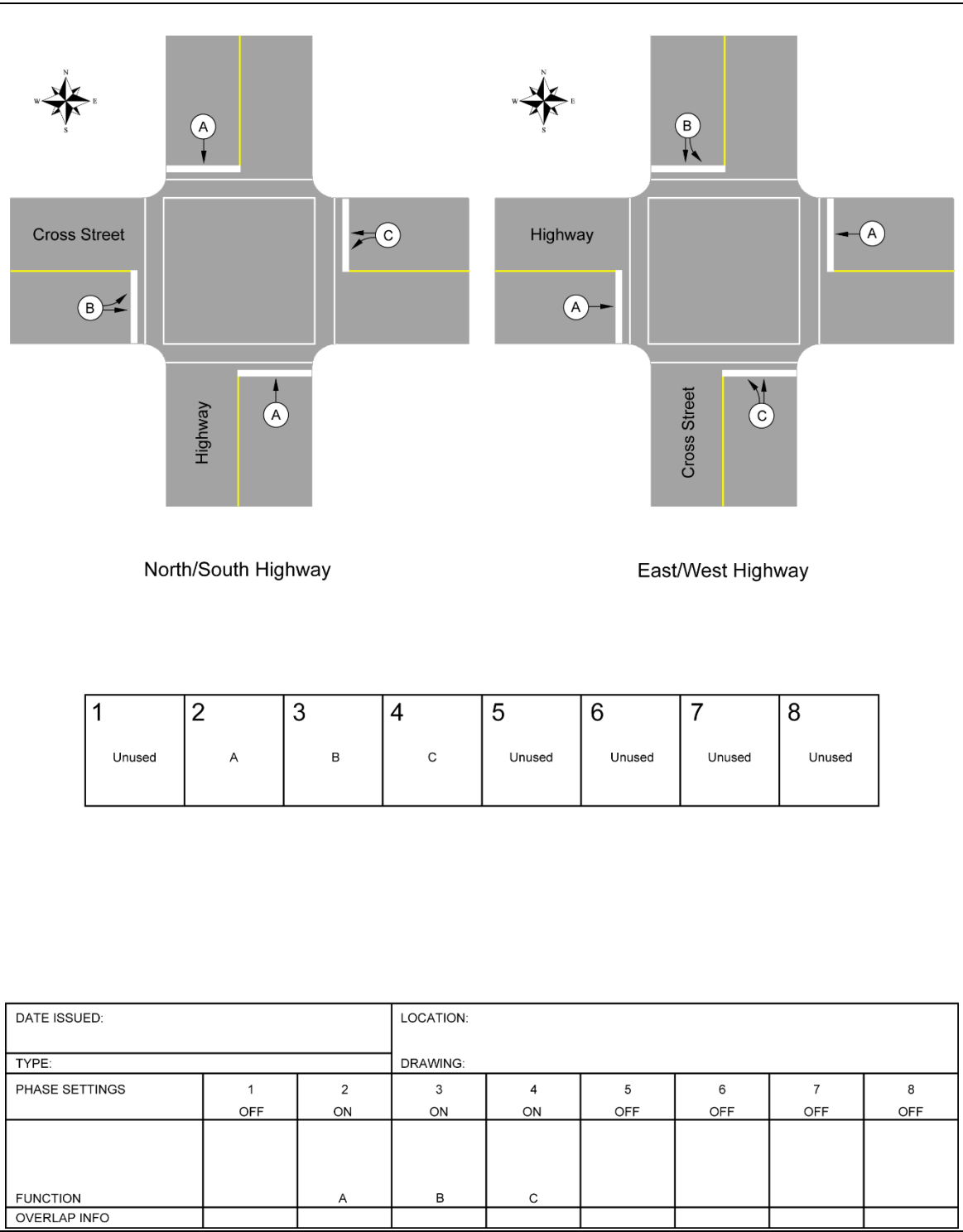


Figure 18. Sequential operation with split phasing and no anticipated left turn phases.

TRAFFIC SIGNALS

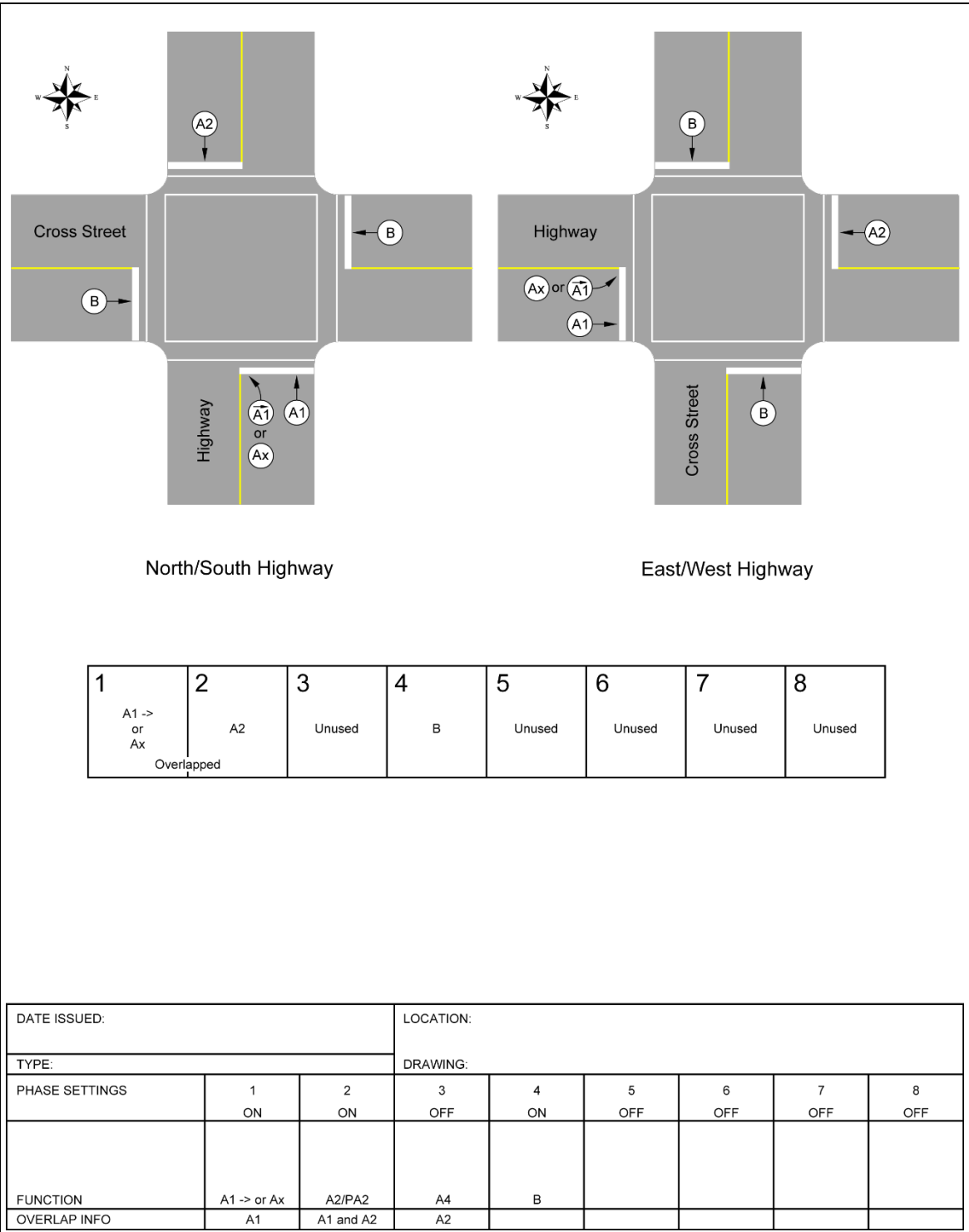


Figure 19. Sequential operation with one left turn signal.

TRAFFIC SIGNALS

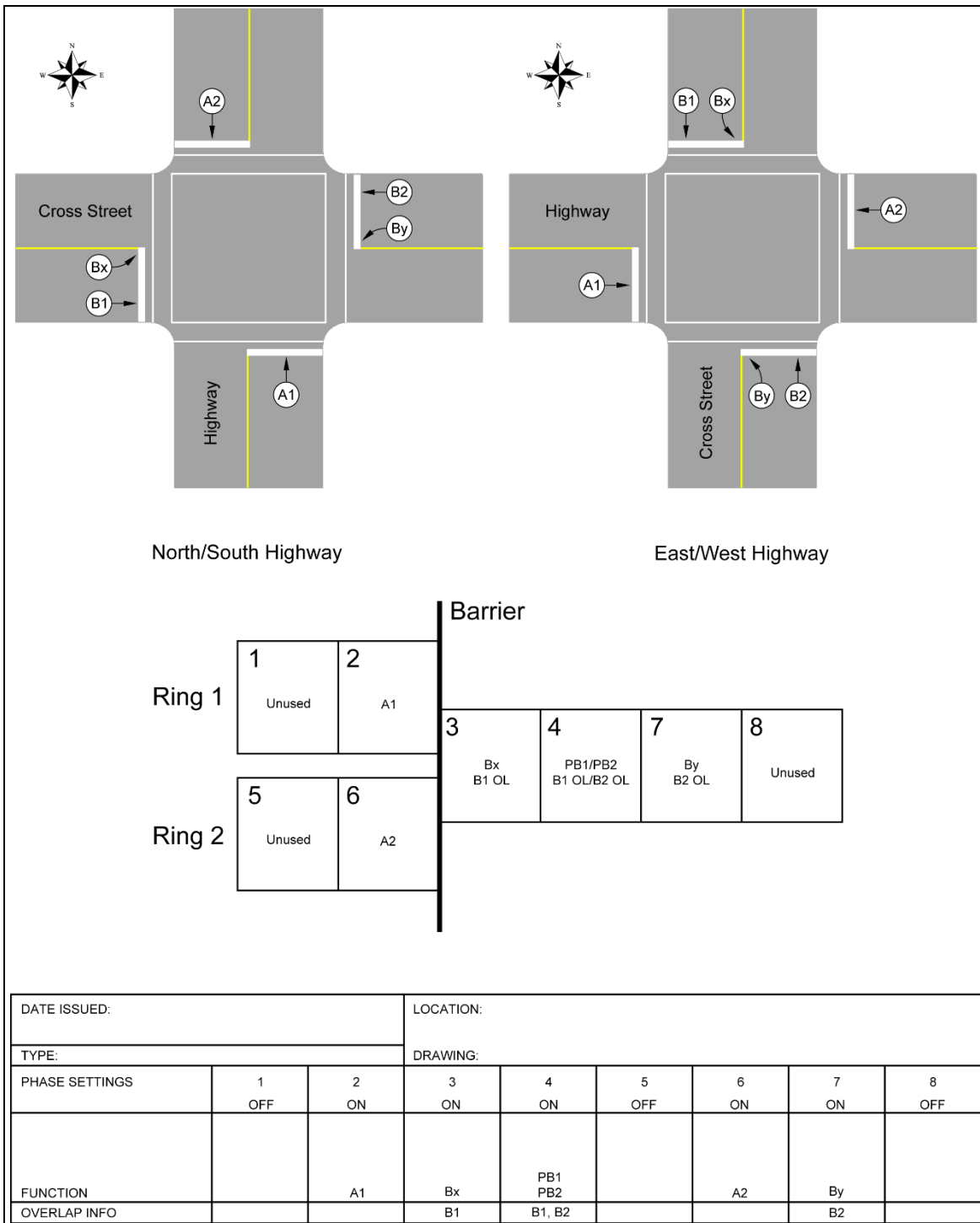


Figure 20. 2 Over 2 Plus 4 with geometric conflicts on the cross street.

TRAFFIC SIGNALS

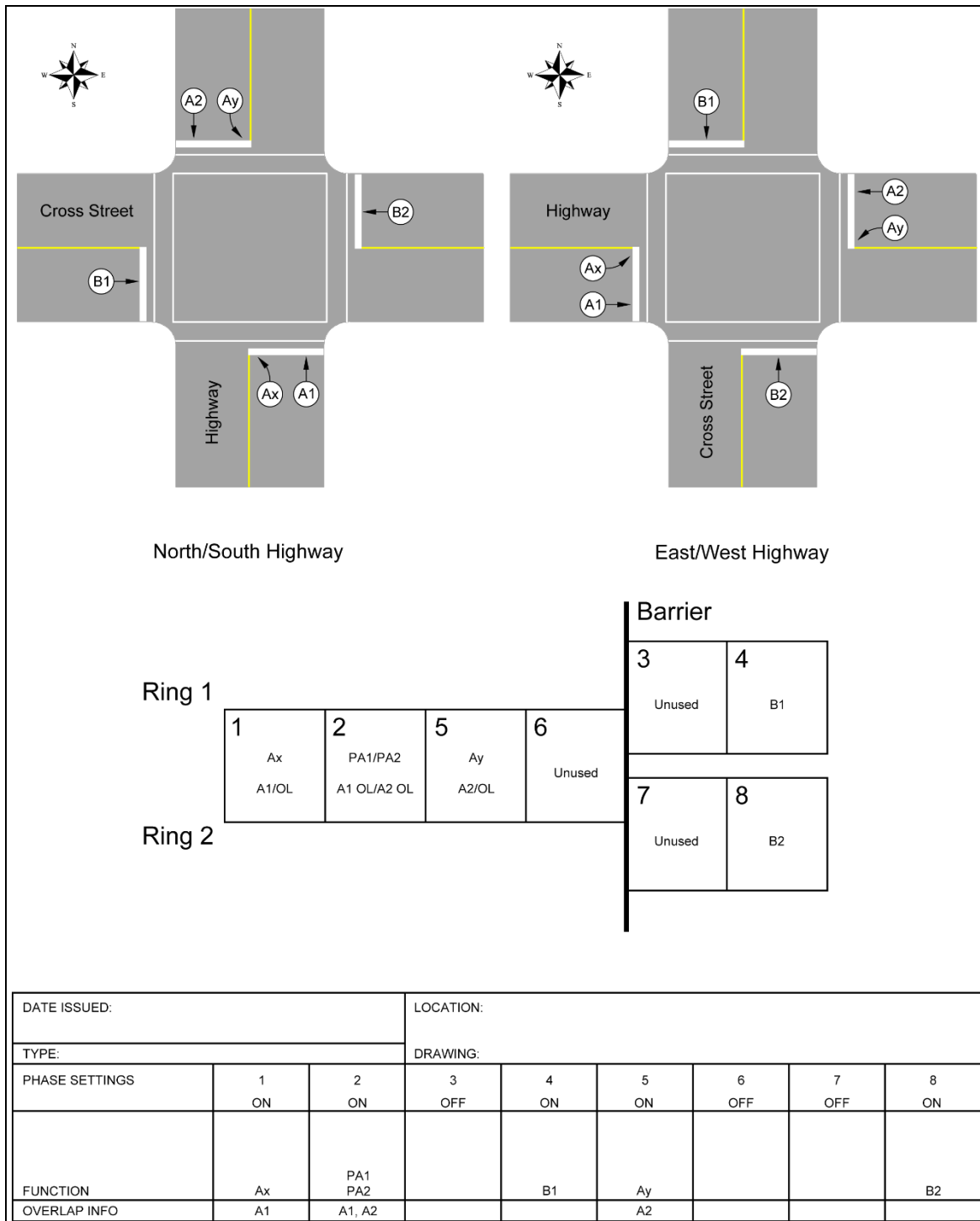


Figure 21. 4 Plus 2 Over 2 with geometric conflicts on the main street (highway).

402.4.6 Leading, Lagging and Lead-Lag Left Turn Phasing

- .1 In most cases, left turn phases should be leading, i.e., preceding their associated through movements. This is the most common operation and meets driver expectations. Simultaneous left turn phasing should not be used where the wheel path of left turning vehicles conflicts with that of opposing left turning vehicles.
- .2 Lagging left turn phases follow their associated through movements. Lagging left turn phasing shall be considered under the following scenarios:
 - .1 Where geometric constraints impact the operation of simultaneous opposing left-turn movements.
 - .2 The signal is part of a coordinated system and progression on the through movements is improved with the use of lagging left turn phases.

When implementing lagging left turn phasing, ensure:

- .1 Left turn bays exist and are long enough to contain the queue of vehicles expected to build while other phases are operating. This prevents left turning vehicles from blocking the adjacent through lane.
 - .2 The left turn phase is protected only. This avoids the “left turn trap.” The “left turn trap” occurs where, just before the start of a lagging left turn phase in direction 1, all vehicles in the opposite direction 2 face a yellow and then red light. Drivers turning left in direction 2 may assume that vehicles in direction 1 are also stopping and turn in front of them. If there is no opposing left turn then a lagging permitted may be considered.
- .3 In lead-lag phasing, one left turn movement operates with its associated through movement, then both through movements operate together, and finally the opposite left turn movement operates with its associated through movement. Lead-lag phasing shall be considered only where all the following conditions exist:
 - .1 Both left turn phases are protected only. This avoids the left turn trap (yellow trap) described in 402.4.5.2.4 above.
 - .2 The signal is part of a coordinated system and progression on the through movements is improved with the use of lead-lag left turn phases.
 - .4 Lagging left turn phases are incorporated into the controller operations discussed in 402.4.4 and illustrated in Figure 22. This applies to any adjacent pair of separate left turn phases and opposing through phases. On timing sheets, lagging left turn phases are named and listed in the same way as leading left turn phases except that “(Lagging)” is noted as part of the function.

TRAFFIC SIGNALS

- .5 The lagging phase may be on either ring or either side of the barrier.
- .6 An R-109-1 L or R-109-1 T sign stating “Signal Delayed” should always be utilized on the pole of the phase that is being delayed.

TRAFFIC SIGNALS

Leading Ring 1 <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="width: 20px;">1</td> <td style="width: 100px;">A2-> or Ay</td> <td style="width: 20px;">2</td> <td style="width: 100px;">A1</td> </tr> <tr> <td style="width: 20px;">3</td> <td style="width: 100px;">B2-> or By</td> <td style="width: 20px;">4</td> <td style="width: 100px;">B1</td> </tr> </table> Ring 2 <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="width: 20px;">5</td> <td style="width: 100px;">A1-> or Ax</td> <td style="width: 20px;">6</td> <td style="width: 100px;">A2</td> </tr> <tr> <td style="width: 20px;">7</td> <td style="width: 100px;">B1-> or Bx</td> <td style="width: 20px;">8</td> <td style="width: 100px;">B2</td> </tr> </table>		1	A2-> or Ay	2	A1	3	B2-> or By	4	B1	5	A1-> or Ax	6	A2	7	B1-> or Bx	8	B2	Barrier
		1	A2-> or Ay	2	A1													
		3	B2-> or By	4	B1													
		5	A1-> or Ax	6	A2													
7	B1-> or Bx	8	B2															
Lagging Ring 1 <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="width: 20px;">1</td> <td style="width: 100px;">A1</td> <td style="width: 20px;">2</td> <td style="width: 100px;">A2-> or Ay</td> </tr> <tr> <td style="width: 20px;">3</td> <td style="width: 100px;">B2-> or By</td> <td style="width: 20px;">4</td> <td style="width: 100px;">B1</td> </tr> </table> Ring 2 <table border="1" style="border-collapse: collapse; text-align: center;"> <tr> <td style="width: 20px;">5</td> <td style="width: 100px;">A1-> or Ax</td> <td style="width: 20px;">6</td> <td style="width: 100px;">A2</td> </tr> <tr> <td style="width: 20px;">7</td> <td style="width: 100px;">B1-> or Bx</td> <td style="width: 20px;">8</td> <td style="width: 100px;">B2</td> </tr> </table>		1	A1	2	A2-> or Ay	3	B2-> or By	4	B1	5	A1-> or Ax	6	A2	7	B1-> or Bx	8	B2	Barrier
		1	A1	2	A2-> or Ay													
		3	B2-> or By	4	B1													
		5	A1-> or Ax	6	A2													
7	B1-> or Bx	8	B2															

DATE ISSUED:			LOCATION:					
TYPE:			DRAWING:					
PHASE SETTINGS	1 ON	2 ON	3 ON	4 ON	5 ON	6 ON	7 ON	8 ON
FUNCTION	A2-> or Ay (Lagging)	A1	B2-> or By	B1	A1-> or Ax	A2	B1-> or Bx	B2
OVERLAP INFO								

Figure 22. Leading and lagging left turns in a *Signal Timing Sheet*

402.5 TIMING

- .1 All signal timings shall meet the approval of the Senior Traffic Operations Engineer. Traffic engineers and / or designers shall provide all supporting background data and calculations. Any variation from these standards must be approved by the Senior Traffic Operations Engineer.
- .2 All signal timings shall be submitted on a ministry *Signal Timing Sheet*. Refer to the ministry *Signal Timing Sheet - How to Complete the Form* along

with the current *Signal Timing Sheet*. A copy of both documents is located in Appendix 400.

- .3 The goal of ministry traffic engineering is the safe and efficient movement of personal and commercial vehicles along the provincial highway system. At intersections, the highway movements should operate at a better Level of Service (LOS) than non-highway movements. When highway movements and non-highway movements have the same LOS, then the signal timing should be set such that highway movements experience lower delay and volume to capacity (v/c) ratios than non-highway movements. At a ministry intersection of two non-highway roads or the intersection of two highways, then the Senior Traffic Operations Engineer will decide which movement should be given priority.

402.5.1 Minimum Green Time

- .1 Each time a phase is called, it receives at least its minimum green time. The ministry uses the minimum green times listed in Table 7. For highway movements, minimum green times exceeding 10 seconds maybe used by the Senior Traffic Operations Engineer to improve highway LOS, as it prevents signals from gapping out too quickly during non-peak hours.

MOVEMENT	MINIMUM GREEN TIME (S)
Highway Through Movements	10
Cross Street Through Movements	7
All Left Turns	6

Table 7. Minimum Green Times

402.5.2 Passage Time

- .1 Passage time is the maximum time between vehicle calls for a phase before the phase gaps out. Refer to Table 10 for passage times. Generally, short passage times result in snappier intersection operation. However short passage times can penalize trucks because of their longer headways.

TRAFFIC SIGNALS

ITEM	PASSAGE TIME (S)
Ministry Standard	3.0
Intersection approaches at a +2% grade or greater	4.0 to 5.0
Intersections with 10% trucks or greater	4.0 to 5.0

Table 8. Passage Times

- .2 Where passage times greater than 3.0 seconds are being considered, the primary time should be set at 4.0 seconds unless site inspection warrants increasing the passage time to 5.0 seconds.
- .3 At intersection where truck traffic is consistent, the passage time may be lengthened for a specific movement for a specific time of day and day of week.

402.5.3 Vehicular Clearance Periods

- .1 The vehicular clearance (or inter-green) period is the sum of the yellow and all-red time at the end of a green interval. The period allows motorists approaching an intersection at the end of the green interval time to either stop safely or, if a safe stop cannot be made, to enter and clear the intersection before a conflicting traffic stream receives a green indication and a vehicle in that stream enters the intersection far enough from the stop bar for a conflict.
- .2 The vehicular clearance period is calculated for each phase based on the appropriate clearance distance measurements described in section 402.5.3.6. The vehicle clearance period calculation for the various intersection phasing configurations shall be as follows:
 - .1 Through phases (A1, A2, B1, B2):
When the intersection includes permitted left turns (i.e. no left turn phases), the vehicular clearance period shall be calculated for the through and left turn movements, and the longest period used. This way A1/A2 and B1/B2 will have identical clearance periods respectively.
 - .2 Protected left turn phases (Ax, Ay, Bx, By):
Calculated individually for each left turn phase.
 - .3 Protected/Permissive Left Turn phases on the Highway (A1→, A2→ or both):
Calculated separately for the left turn phase(s).

TRAFFIC SIGNALS

The A1/A2 through phase clearance periods shall be identical and equal to the longer of the two.

- .4 Protected/Permissive Left Turn phases on the Cross Street (B1→, B2→ or both):
Use the maximum of the vehicular clearance periods calculated for all left turn and through movements.
- .5 Split Phase:
Use the maximum of the vehicular clearance period calculated for the left turn movement and the adjacent through movement.

TRAFFIC SIGNALS

- .3 All vehicular clearance periods are calculated using Equation 1. The elements of this equation as they apply to different movements are defined below.

$$I = t_{pr} + \frac{V_a}{2(f + AG)g} + \frac{D_c}{V_c} - \frac{D_b}{V_b} \quad \text{Equation 1}$$

where

- T_{pr} = perception/reaction time (s)
- V_a = approach speed (m/s)
- f = friction factor on wet pavement (varies depending on speed). See *Table 18*
- AG = approach grade (m/100 m), positive if approach traffic is Climbing; negative if approach traffic is descending
- g = 9.81 m/s²
- D_c = clearance distance (m)
- V_c = clearance speed (m/s)
- D_b = conflict distance (m)
- V_b = conflict speed (m/s).

Note: When modifying an existing *Signal Timing Sheet* the traffic engineer and / or designer shall ensure the inter-green times have been calculated using the correct friction factor (f). Refer to Table 18 - for Friction Factors.

- .4 The perception/reaction time shall be 1.0 second.
- .5 Approach Speed:
- .1 Through Movements: Equal to the posted speed.
 - .2 Left Turn Movements: Refer to Table 11.

POSTED SPEED	APPROACH AND CLEARANCE SPEEDS (V_A & V_C)	
(km/h)	(km/h)	(m/s)
50	40	11.1
60	45	12.5
70	55	15.3
80	55	15.3
90	55	15.3

Table 9. Approach speeds for protected left turn phases

TRAFFIC SIGNALS

.6 Clearance Distances:

Clearance distances shall be measured along the path a vehicle would track through the intersection for each individual movement.

The start point of the measurements shall be determined as follows:

- .1 A Single Protected/Permissive Left Turn phase on the Highway (A1→ or A2→ but not both):
From a point in the intersection where vehicles typically stop when opposing traffic prevents a left turn movement. See Figure 23.
- .2 All other through and turn phasing not covered in 402.5.3.6.1:
From the approach side of the departure lane's stop bar.

The end point of the measurement shall be the far edge of the receiving lane crosswalk. For locations with no crosswalk, the nose of an island, an adjacent lane stop bar, or the far side of the conflict area can be used as reference.

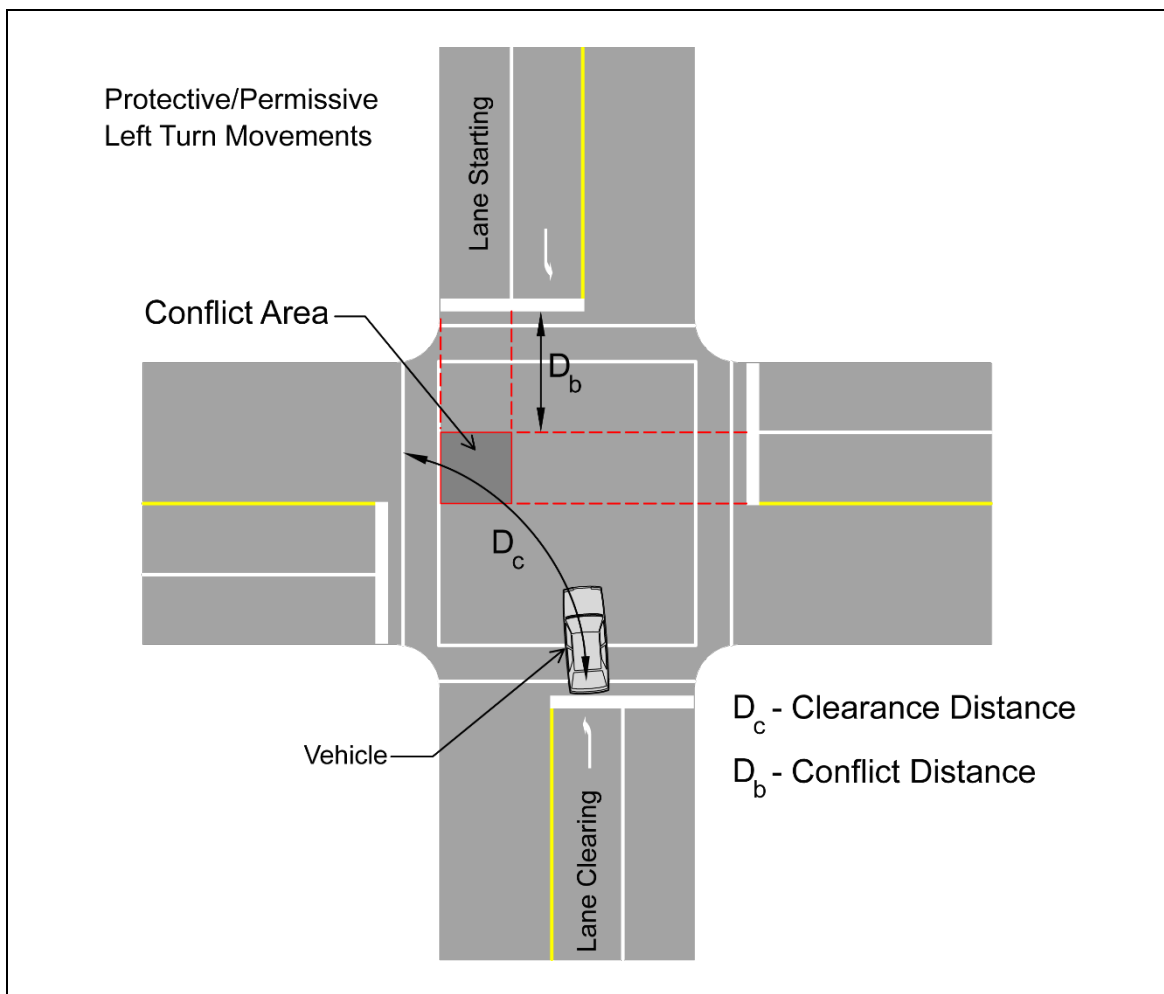


Figure 23. Clearance and conflict distances for protected/permissive left turns

TRAFFIC SIGNALS

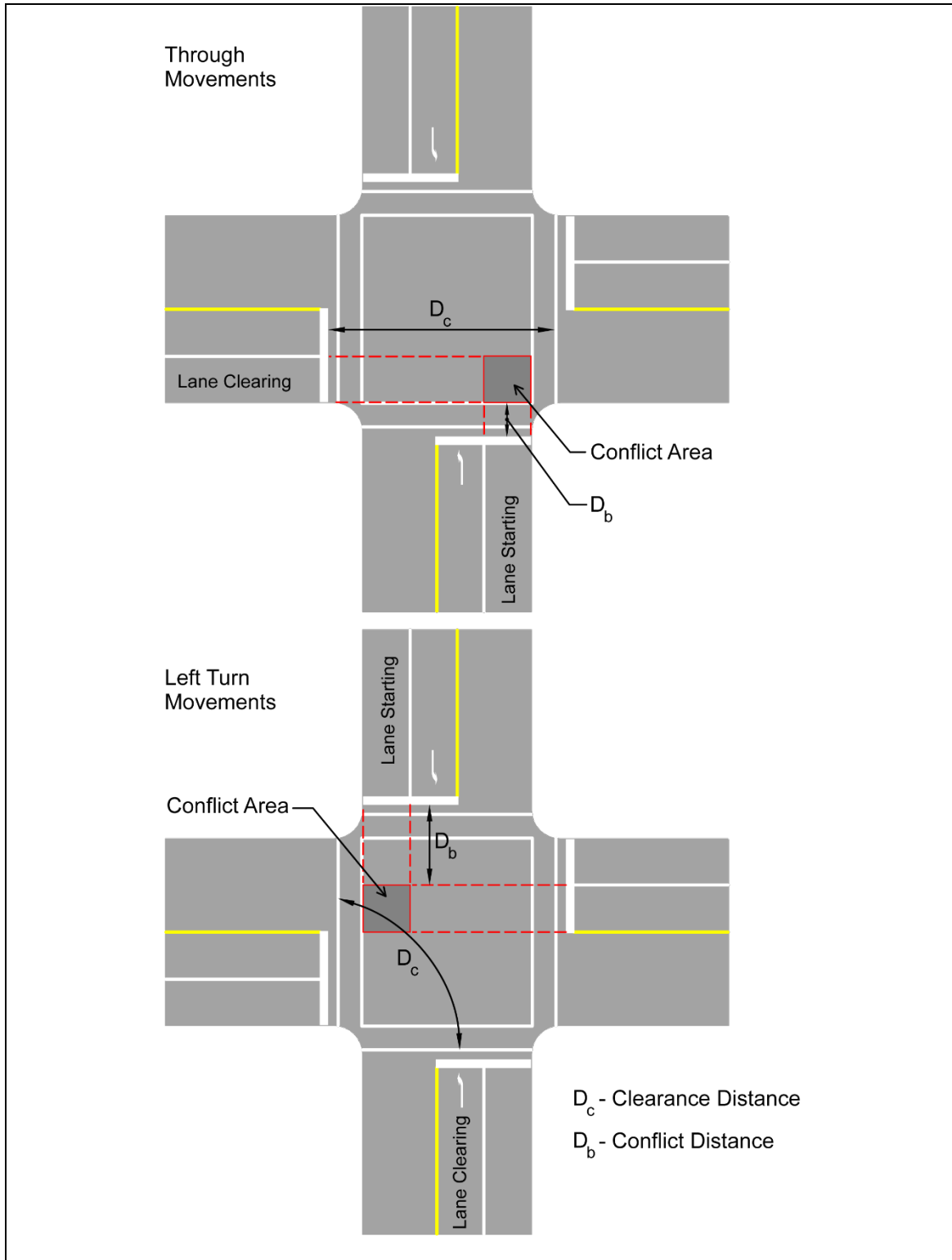


Figure 24. Clearance and conflict distances

- .7 Clearance Speed:
 - .1 Through Movements: Equal to the posted speed.
 - .2 Left Turn Movements: Refer to Table 11.
- .8 Conflict Distance:
 - .1 Through Movements: The governing conflict after a phase change is assumed to be with near side pedestrians. The conflict distance is virtually nil and assumed to be zero.
 - .2 Left Turn Movements: To determine the conflict distance, conflict areas are set out as shown in Figure 24. These areas surround the intersection of two conflicting vehicle paths. All possible conflicting phases are checked in relation to the path of the left turning vehicle. The shortest conflict distance governs. Any phase may follow and therefore conflict with a left turn phase with one exception. If a highway left turn phase is leading, and the highway through phases are set to recall, the opposing highway through phase is the only possible conflict.
 - .3 Conflict distances less than 6.0 m are not used in clearance time calculations.
- .9 The conflict speed is taken to be 10 km/h less than the posted speed on the conflicting phase, allowing for a "rolling" start.

402.5.4 Yellow - All-Red Split

- .1 The maximum allowable yellow time is 5.0 seconds.
- .2 The vehicular clearance period is split between yellow and all-red for each phase according to the following:
 - .1 Through Phases (A1, A2, B1, B2) or Advance Protected/Permissive Left Turn Phasing on the Cross Street (B1→ , B2→ or both) or Split Phasing - Refer to Table 12. Yellow time shall be no less than 3.5 seconds. If a clearance interval is greater than 6.6 seconds, then the red interval shall be the clearance interval minus the yellow of 5.0 seconds.
 - .2 All Other Phase Combinations not covered in 402.5.4.2.1 - Refer to Table 13. Yellow time shall not be less than 3.0 seconds. The reduced value for left turns is intended to minimize yellow run on with advance left turn phasing.

TRAFFIC SIGNALS

VEHICLE CLEARANCE (s)	YELLOW (s)	ALL-RED (s)
6.6	5.0	1.6
6.5	5.0	1.5
6.4	4.9	1.5
6.3	4.8	1.5
6.2	4.7	1.5
6.1	4.6	1.5
6.0	4.5	1.5
5.9	4.5	1.4
5.8	4.5	1.3
5.7	4.5	1.2
5.6	4.5	1.1
5.5	4.5	1.0
5.4	4.4	1.0
5.3	4.3	1.0
5.2	4.2	1.0
5.1	4.1	1.0
5.0	4.0	1.0
4.9	4.0	0.9
4.8	4.0	0.8
4.7	4.0	0.7
4.6	4.0	0.6
4.5	4.0	0.5
4.4	3.9	0.5
4.3	3.8	0.5
4.2	3.7	0.5
4.1	3.6	0.5
4.0	3.5	0.5

Table 10. Yellow/all-red splits for through movements

TRAFFIC SIGNALS

VEHICLE CLEARANCE (s)	YELLOW (s)	ALL-RED (s)
5.5	4.5	1.0
5.4	4.4	1.0
5.3	4.3	1.0
5.2	4.2	1.0
5.1	4.1	1.0
5.0	4.0	1.0
4.9	3.9	1.0
4.8	3.8	1.0
4.7	3.7	1.0
4.6	3.6	1.0
4.5	3.5	1.0
4.4	3.5	0.9
4.3	3.5	0.8
4.2	3.5	0.7
4.1	3.5	0.6
4.0	3.5	0.5
3.9	3.4	0.5
3.8	3.3	0.5
3.7	3.2	0.5
3.6	3.1	0.5
3.5	3.0	0.5

Table 11. Yellow/all-red splits for left turn movements.

402.5.5 Maximum Green Times

- .1 The maximum green time is the longest time that a phase can remain green. Maximum green times for each phase should be determined according to the *Highway Capacity Manual, Chapter 9 - Signalized Intersections* or by using signal timing software which meets the approval of the ministry's Senior Traffic Operations Engineer.
- .2 The LMD 8000 controller offer Max I, Max II and eight Maxplans. When more than two sets of green times are used, then the green times are designated as Maxplans. Maxplans may be invoked by time of day or may be tied to cycle, split, offset combinations.
- .3 Refer to Sub-clause 402.5.15.12 for more information.

- .4 The Naztec 980 controller provides up to five programs, allowing phase intervals and max times to be adjusted by time of day.
- .5 The Cobalt controller accommodates up to four timing plans, and each timing plan can have three maximum green times (Max 1, 2 and 3). These max times can be assigned to coordination and/or time of day plans. In free operation, the controller automatically uses Max 1 from Timing Plan 1.

402.5.6 Pedestrian Walk Intervals

- .1 A pedestrian walk interval is the time during which a "WALK" indicator is displayed on a pedestrian signal head. During this time, pedestrians may start to walk across traffic lanes in a crosswalk. The "WALK" indicator should be displayed for a minimum amount of time, allowing pedestrians time to notice and react to the signal.
- .2 A walk interval of 7 seconds should be used. However, if the sum of this interval and the pedestrian clearance time exceeds the maximum green time of the corresponding vehicle phase, a minimum walk interval of 5 seconds may be used.
- .3 Pedestrian countdown timers are used at all new signals and other locations as specified by the Senior Traffic Operations Engineer.

402.5.7 Pedestrian Clearance Times

- .1 Pedestrian clearance time is defined as the time required for a pedestrian entering a crosswalk at the end of the walk interval to comfortably reach the safety of a pedestrian refuge or the other side of the road.

Pedestrian Clearance time is equal to Flashing don't walk and Steady don't walk intervals.

Flashing Don't Walk: A flashing red hand symbol indicates it is no longer safe to begin crossing. If the pedestrian has started walking before the signal began to flash, they have enough time to cross the street.

Countdown timers (where installed) run for this duration and countdown at the start of flashing hand phase.

Steady Don't Walk: A solid red hand symbol indicates that the pedestrian should not be in the crosswalk at this time. This duration is an interval equivalent to sum of yellow and red time of associated vehicular through phase that allows for any unfinished crossing before a conflicting phase comes on.

- .2 Pedestrian clearance times are dependent on whether a crosswalk passes through a pedestrian refuge, a central median or a raised island.

TRAFFIC SIGNALS

- .1 Pedestrian clearance for crosswalks without pedestrian refuges is calculated in Equation 2.

$$PC = \frac{D_w}{V_{ped}} \quad \text{Equation 2}$$

$$SDW = Y + R$$

$$FDW = PC - SDW$$

where

PC = pedestrian clearance time (s)

D_w = the length of the crosswalk, measured at the midpoint between the edge lines (m)

V_{ped} = comfortable pedestrian walking speed (m/s)

= 1.2 m/s under usual circumstances

= 1.0 m/s for special situations (e.g., high percentage of elderly pedestrians or school children)

FDW = Flashing Don't Walk time (s)

SDW = Steady Don't Walk time (s) Y = yellow time (s) of the associated vehicle phase

R = all red time (s) of the associated vehicle phase.

- .2 At crosswalks with pedestrian refuges, the pedestrian clearance is calculated in Equation 3. Note that to be considered a refuge, a central island shall have a pedestrian pushbutton on it and be constructed in accordance with the ministry *BC Supplement to TAC Geometric Design Guidelines*. Otherwise, Equation 2 is used for the whole distance.

$$PC = \frac{\max(D_1, D_2)}{V_{ped}} \quad \text{Equation 3}$$

$$SDW = Y + R$$

$$FDW = PC - SDW$$

where

PC = pedestrian clearance time (s)

$\max(D_1, D_2)$ = the largest crosswalk section length, measured at the midpoint between the edge lines (m)

V_{ped} = comfortable pedestrian walking speed (m/s)

= 1.2 m/s under usual circumstances

= 1.0 m/s for special situations (e.g., high percentage of elderly pedestrians). The use of slower walking speeds should be marked on the *Signal Timing Sheets*

FDW = Flashing Don't Walk time (s)

SDW = Steady Don't Walk time (s) Y = yellow time (s) of the associated vehicle phase

TRAFFIC SIGNALS

R = all red time (s) of the associated vehicle phase.

Where $FDW < 5$ seconds, a minimum time of 5 seconds shall be used.

402.5.8 Recall

- .1 Recall is a means of determining when and how a phase will be serviced. The following are possible recall settings:
 - .1 **OFF:** The phase will **only** be serviced when it is actuated by a field input. The phase will be called for its minimum (min) green time and then extend by the passage time to the max green time. The extension of the phase to the max green time is dependent upon vehicle actuations. An actuated phase may be skipped in absence of vehicular or pedestrian calls. Phases other than the highway through movements shall have recall set to OFF.
 - .2 **EXT (Extendible) or MIN:** The phase will **always** be serviced each cycle for the min green time. The phase will be extended by the passage time to the max green time dependent upon vehicle actuations. If there are no calls to other phases after the EXT phase has gapped out, then the controller will rest in green in this phase. Phases other than the highway through movements should have recall set to OFF. EXT recall may be used on cross street movement in order to enable coordination across the highway. EXT recall should be used on non-highway through movements in the following situations:
 - .1 Where the highway changes direction at an intersection, (i.e., the highway was north-south and turns to east-west) EXT recall may be placed on the turning movement which facilitates highway movement.
 - .2 In cases where cross street volumes exceed highway volumes or where there is no clearly designated highway phase, consideration may be given to using EXT recall on phases that will move the most traffic with the least delay.
 - .3 **MAX:** The phase will **always** be served each cycle for its max green time. Field inputs have no effect. After the phase has maxed out then it will rest in green unless there are other phases with calls. Max recall will be used when a movement does not have any detection.
 - .4 **PED:** The pedestrian times (i.e., WALK and PED CLEAR) are **always** serviced. This is rarely used.
 - .5 **SOFT:** Soft Recall provides a call similar to recall extendible-but only if no other "real" calls (by detector actuation) exist. Typically used on main street in fully actuated (almost) application so that

controller will rest in main street in the absence of any other real calls, but will not serve main if other calls exist and no "real" (detector actuated) call on main. To use soft recall, all phases must be actuated, including the soft recall phase (i.e. main street must have detection).

- .6 **CNA (Call to Non-Actuated Mode):** The phase will **always** serve the Walk plus Ped Clear time and field input has no effect. The phase will rest at the end of the WALK. When the phase terminates it must time the PED CLEAR before proceeding to the YELLOW and RED. CNA is used for pedestrian signals in conjunction with setting the WALK to FLASH to bring up the flashing green ball for the through movement. Refer to Section 402.5.7.

402.5.9 Detector Memory

- .1 Detector memory is used to lock in a vehicle call into the controller for a phase during the phase yellow and red intervals regardless of whether the vehicle leaves the loop.
- .2 When MEMORY is OFF then the detector input must be active at the time the controller makes its "this phase next" decision.
- .3 MEMORY should be set to **OFF** unless the intersection has advance loops in which case MEMORY may be ON. MEMORY shall be **OFF** for shared through and right turn lanes.

402.5.10 Intersection Flash

- .1 Intersection flash is used by the ministry only when the signal is malfunctioning or undergoing required maintenance which precludes it from being in three colour operation.
- .2 When a signal is in flash, it is only flashing one colour in each direction.
- .3 Highway through phases may flash yellow unless any of the following apply, in which case the through phases must flash red:
 - .1 There are protected left turns off the highway.
 - .2 There exists intersection geometric or sight distance restrictions.
 - .3 The intersection has a high collision rate.
- .4 Cross street phases always flash red.
- .5 All-red flash should be considered when the volumes on the highway and cross street are comparable. All-red flash should be used at off-ramp signals.
- .6 Protected left turns (Ax, Ay, etc.) flash red on their own separate signal head.

- .7 If a phase has an associated overlap phase then the overlap phase must also have its flash shown (e.g., RED/RED).
- .8 Phases for protected/permissive left turns do not themselves flash since the red display follows the adjacent through movement.

402.5.11 Detector Delay/Extension

- .1 Detector delays are programmed for detectors to prevent phases from being called prematurely. They are required for the following lane configurations (Refer to Figure 25):
 - .1 Highway protected/permissive left turn lanes: 10 Seconds
 - .2 Cross street lanes which allow right turning vehicles: 5 - 15 seconds
The value for this setting shall be determined as a function of right turning volume and gap distribution for merging vehicles.
 - .3 Cross street lanes which are clipped by either right or left turning vehicles: 3 seconds
 - .4 Dedicated right turn lanes that are set up to call the associated through phase: minimum 15 seconds
- .2 If there are no detector delays, enter “NONE” on the first row of the “LOOPS” column in this section of the *Signal Timing Sheet*. This will indicate that delay detection has been reviewed.
- .3 Delays may be inhibited during coordination and/or during peak periods.
- .4 Extension times shall be calculated based on the posted speed and road grade.
- .5 Set back loop(s) may be used to call a left turn phase. The traffic engineer and / or designer shall review with the Senior Traffic Operations Engineer prior to use.

TRAFFIC SIGNALS

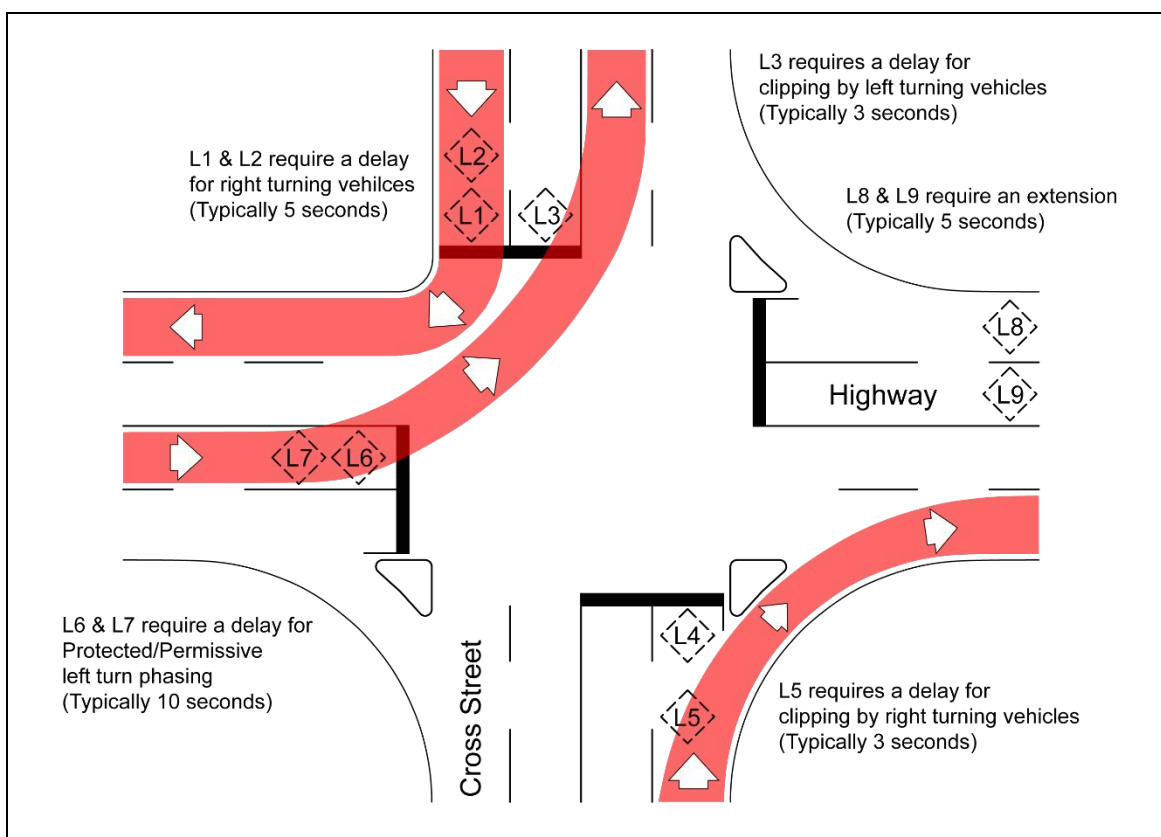


Figure 25. Examples of delay/extension detection

402.5.12 Coordination

- .1 Coordination is the synchronized operation of two or more traffic signals. The green intervals are timed, allowing vehicles to travel through the signals with minimum delay.
- .2 Coordination is used for arterial or network systems where the main movement should move relatively unimpeded.
- .3 The spacing between signals and the posted speed affect the dispersion of the vehicle platoon as it travels downstream from a signal. The platoon should be relatively intact when it reaches the next signal for successful coordination.
- .4 Where traffic signals are located within one Km of each other, Traffic engineers and / or designers shall confirm with the Senior Traffic Operations Engineer if traffic signal coordination is required. The Senior Traffic Operations Engineer should also advise as to the type of coordination system.
- .5 The coordinated phase must be identified on the *Signal Timing Sheet*.
- .6 The intersections within the coordinated system must be listed on the *Signal Timing Sheets* "Comments" section.

402.5.13 Coordination Cycle Length and Splits

- .1 The ministry standards for cycle length are:
 - .1 Minimum: 60 seconds
 - .2 Maximum: 120 seconds
- .2 Signal timings shall be calculated with ministry approved signal capacity software. Contact the Senior Traffic Operations Engineer for ministry approved software packages.
- .3 Cycle lengths greater than 120 seconds shall be approved by the Senior Traffic Operations Engineer.
- .4 All traffic signal controllers within a coordinated system shall run the same cycle length at the same time. Signal controllers may run a double cycle, which is half as long as a standard cycle. The double cycle is useful when an intersection requires a significantly shorter cycle length.
- .5 For the Econolite Cobalt and Naztec 980 controllers, the total time allocated to each individual phase is set by the splits, which are entered in units of seconds. The LMD8000 defines the phase time during coordination thus establishing the force-off points.
- .6 The split for each phase shall be at least high enough to provide the minimum phase time given by Equation 4. For the purposes of coordination timing, the pedestrian times may be omitted for minimum phase times only if the pedestrian counts are low for a particular time of day and approval for this is given by the Senior Traffic Operations Engineer. Note that the controller will always time the pedestrian phases when there is a pedestrian call. However, if the pedestrian phase was omitted in the coordination calculation, it may cause the phase to time longer than would be best for coordination. Hence, an analysis of how traffic will be affected by pedestrian service shall be included. Minimum phase times for non-pedestrian phases are given by Equation 5.

$$P_{\min} = \max(G_{\min} + Y + R + AW, W + PC + Y + R + AW) \quad \text{Equation 4}$$

where

$P_{\min}$	= minimum phase time (s)
$G_{\min}$	= minimum green time (s)
Y	= yellow time (s)
R	= all red time (s)
AW	= advanced warning (s)
W	= pedestrian walk time (s)
PC	= pedestrian clearance time (s)

$$P_{\min} = G_{\min} + Y + R + AW \quad \text{Equation 5}$$

where

$P_{\min}$	= minimum phase time (s)
$G_{\min}$	= minimum green time (s)
Y	= yellow time (s)
R	= all red time (s)
AW	= advanced warning (s)

- .7 The objective of coordination timing is to provide maximum vehicular throughput for the highway system while minimizing total delay.
- .8 Where traffic patterns vary, separate timings plans should be developed for different times of the day and days of the week.
- .9 In calculating cycle lengths and splits, the following assumptions should be made:
 - .1 The number of "sneakers" turning left during the yellow of a phase should not be greater than 1.
 - .2 If no field measurement is available, a maximum of 10 percent of right turn volumes may be allocated to proceed on a red light where there is no free right turn lane. When field measurement is available, then that value should be used.
 - .3 Up to 100 percent of right turn volumes can proceed on a red light where there is a free right turn lane.
 - .4 Saturation flow rates may be determined according to the Highway Capacity Manual. Field measurements are preferred.
 - .5 The posted speed shall be used as the travel speed unless field measurements show it to be less, in which case the field measurement shall be used. Speeds higher than the posted speed shall not be used.
- .10 Coordination is optional when analysis of the signal system shows a total system delay of less than 30 vehicle-hours.
- .11 All parameter settings shall be approved by the Senior Traffic Operations Engineer.

402.5.14 Coordination Offsets

- .1 Offset is the time difference between the clocks of individual intersection controllers within a set of coordinated signals. One of the signals, called the Reference Controller is arbitrarily assigned an offset of 0. The offset of the other signal controllers is the time difference between the end of the

TRAFFIC SIGNALS

Reference Controller's cycle and the end of their cycles. Offsets are set to allow progression on the main street in the peak direction.

- .2 Offsets shall be referenced to the end of the cycle.
 - .1 Most commercial signal timing packages for progression reference the offset from the start of the coordinated phase. However, the ministry references all offsets to the end of the coordinated phase. The ministry uses this convention because all non-coordinated phases are actuated. When they are actuated, they may gap out early or not come up at all if there is no call on the phase. In these cases, the start of the coordinated phase is variable and cannot be used as an offset reference. The end of the coordinated phase (barrier) is always at the end of the cycle so its position is always known. Note that when using lead/lag operation, the offset is referenced to the end of the coordinated phase on the ring which has the lagging left turn.
 - .2 When a coordinated phase has advance warning on it, the ministry's advance warning hardware holds the phase green for the time of the advance warning. Since the ministry references all offsets to the end of the coordinated phase, and the advance warning holds the phase green past its force off point for a time equal to the advance warning time, then the offset to that intersection is later than if there had been no advance warning. To correct for this, the advance warning time shall be subtracted.
 - .3 Offsets are adjusted according to Equation 6.

$$O_b = O_f + G_I - G_R - AW_I \quad \text{Equation 6}$$

where

- O_b = back offset (s)
- O_f = front offset (s)
- G_I = maximum green time on coordinated phase at intersection
- G_R = maximum green time on coordinated phase at reference intersection
- AW_I = advance warning time (s) at intersection

402.5.15 Coordination Force-Offs and Permissives

- .1 The ministry uses NEMA TS1 and TS2 standard traffic signal controllers however all new controller are TS2. The force-off and permissive calculations apply to TS1 controllers only.

- .2 In free operation, ministry signals service phases in the order that arriving vehicles make calls for them. For such operation, any phase can be serviced at any point in the cycle. When in coordination, the coordinated phase shall be serviced at the same part of the cycle each time. For ministry signals, the coordinated phase is set to Ext-Recall and comes at the end of the cycle. To ensure that this is the case, other phases are given permissive periods early in the cycle when calls for them may be serviced. They are also given force off points, ensuring that they and any following non-coordinated phases do not extend into the latter part of the cycle.
- .3 During the permissive period for each phase, the controller checks whether or not there is a call on that phase. If there is a call within that permissive period, then the phase will be serviced. When in coordination, the permissives are used by the controller to make the "this phase next decision." Once a non-coordinated phase green is started, all phase omits are dropped and all phases with calls are served in order.
- .4 The force-offs are assigned to correspond to the phase that they are forcing off (i.e., FO1 is the force-off for phase 1, FO4 is the force-off for phase 4 etc.). The permissive periods are assigned sequentially starting at the first phase(s) following the coordinated phase. Permissive periods are also assigned 1 to 1.
- .5 For Dual Ring operation, force-offs and permissive periods are calculated separately for each ring, as shown in Figure 26. Round up force-offs and round down permissives.

TRAFFIC SIGNALS

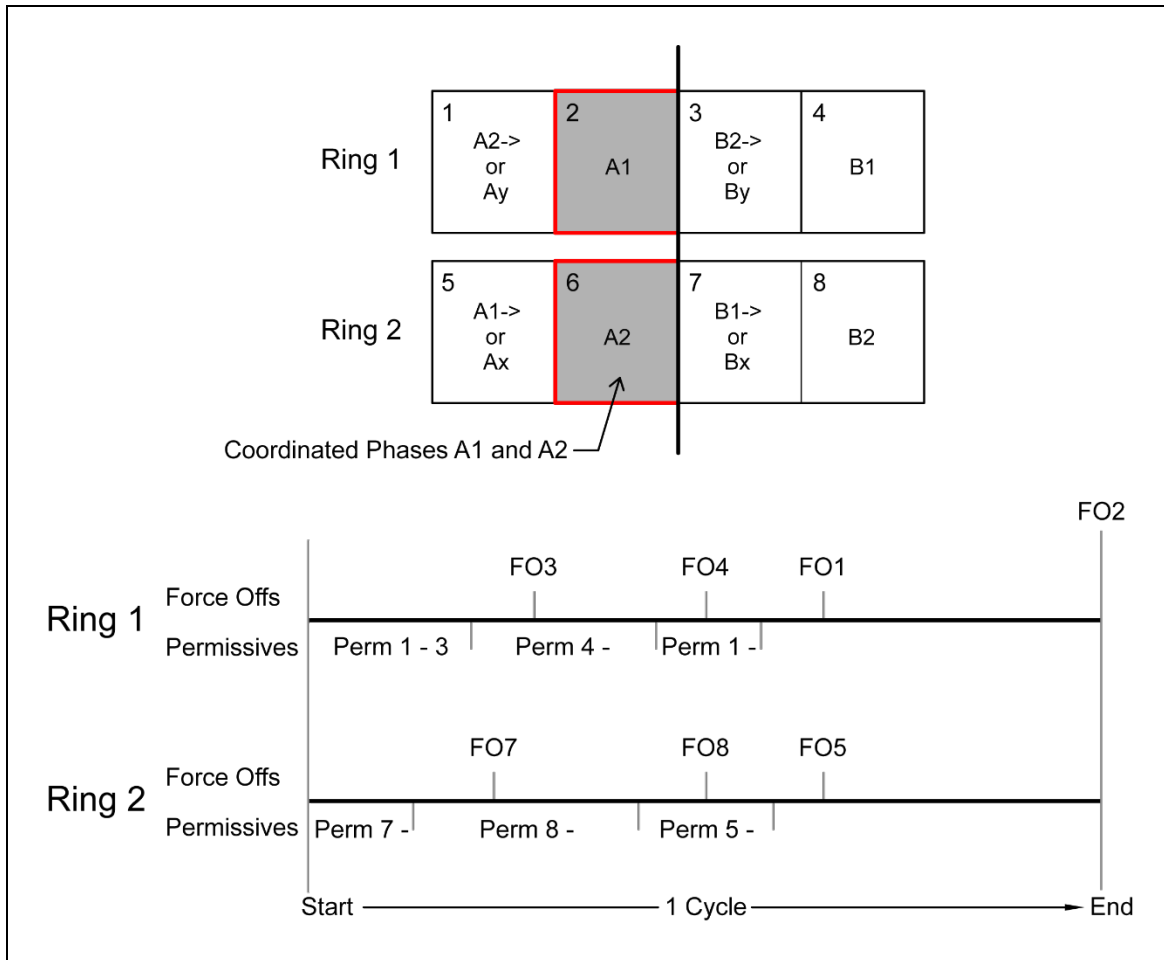


Figure 26. Force-offs and permissives for NEMA Dual Ring operation

.6 Force-offs are calculated for each non-coordinated phase using Equation 7.

$$FO_i = FO_{i-1} + I_{i-1} + AW_{i-1} + S_i - I_i \quad \text{Equation 7}$$

where

- FO_i = force off of phase i
- FO_{i-1} = force off of previous phase
= 0 if i is the first phase on the ring or sequence
- I_{i-1} = vehicular clearance time of previous phase (s)
- AW_{i-1} = advance warning of previous phase (s)
- S_i = total split of phase i (in seconds) (including intergreen from Synchro)
- I_i = inter-green of phase i (s)

- .7 The end of the permissive period for each non-coordinated phase is calculated using Equation 8.

$$EP = FO - G_{\min} - Y_c - R_c - AW_c \quad \text{Equation 8}$$

where

EP	= end permissive (s)
FO	= force off (s)
$G_{\min}$	= minimum green time (s)
Y_c	= yellow time (s) on coordinated phase
R_c	= all red time (s) on coordinated phase
AW_c	= advance warning (s) on coordinated phase

- .1 Where an existing controller with a sequential sequence and a dummy phase (dummy phase is present during the left turn trap (yellow trap) situation) is in coordination, then the dummy yellow time must be included in the permissive time calculation for the advance left turn. The dummy phase must be associated with the same permissive as the advance left turn.
- .8 The start of the first permissive period is 0 and the start of each successive permissive period is equal to the end of the previous permissive period.
- .9 For lead/lag operation on the highway, force-offs and permissives are determined as shown in Figure 27. The lagging left turn phase is the first force-off to be determined. The lagging left turn phase is the first phase in its ring, with the other force-offs in that ring following in order. In the other ring, the coordinated through phase is given the first force-off at the same time as for the lagging left turn phase. Then the other force-offs are calculated. The first permissive in the second ring begins at the force-off point for the coordinated through phase.

TRAFFIC SIGNALS

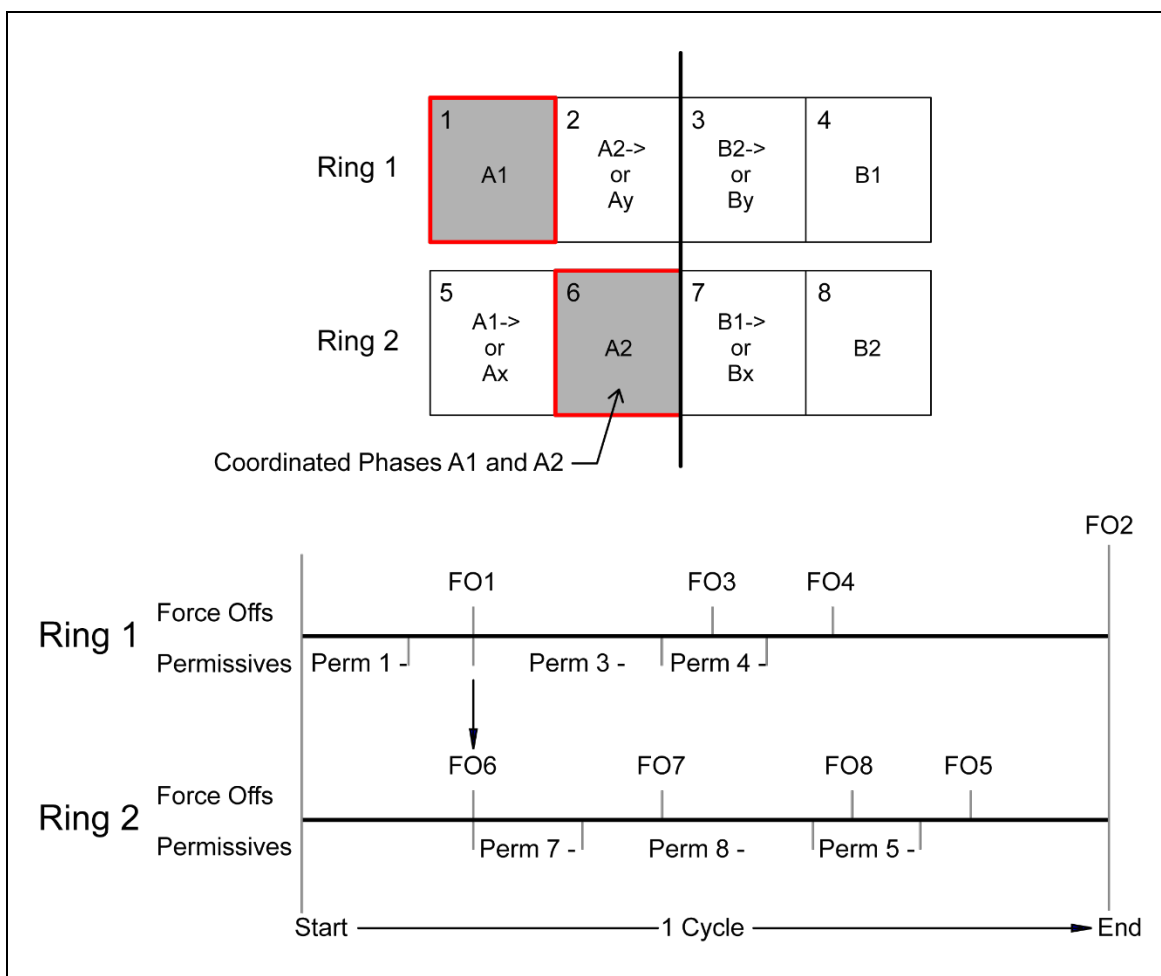


Figure 27. Force-offs and permissives with lead/lag operation

- .10 Pedestrian permissive calculation (for LMD 8000 only. Cobalt and Naztec 980 controllers do this automatically):
 - .1 Pedestrian and vehicle permissive periods begin at the same time on each phase.
 - .2 If the phase does not have advance warning, the LMD 8000 can auto-calculate pedestrian permissives if you set ped permissive = 0. If the phase has advance warning, the pedestrian permissive shall be calculated manually for each timing plan. The lowest value is then entered into the controller, since the LMD 8000 will only accept one value which is applied for all timing plans.
 - .3 If the phase:
 - .1 Does not have advance warning, the LMD 8000 can auto-calculate pedestrian permissive if ped permissive = 0.

TRAFFIC SIGNALS

- .2 Has advance warning, the pedestrian permissives shall be calculated manually for each timing plan using Equation 9. Enter the lowest value into the controller. The LMD 8000 accepts only one value, which is applied for all timing plans.

$$EP_{ped} = FO - PC - W - Y_c - R_c - AW_c \quad \text{Equation 9}$$

where

EP_{ped}	= end of pedestrian permissive period (s)
FO	= force off of vehicle phase (s)
PC	= pedestrian clearance time (s)
W	= pedestrian walk time (s)
Y_c	= yellow time (s) of coordinated phase
R_c	= all red time (s) of coordinated phase
AW_c	= advance warning time of coordinated phase (s)

- .11 Rounding of calculated values
- .1 Force-offs are always rounded UP.
 - .2 Permissives are always rounded DOWN, however, a phase shall have at least a one second permissive.
- .12 Maxplan times during coordination
- .1 The Maxplan times as shown on the *Signal Timing Sheet* only affect the green time for the phase when the Maxplan time is in effect and its' time is LESS than the effective green time, as governed by the split. When the Maxplan time is reached before the force-off of the phase, then the phase will terminate early (i.e., "max out"). It is ministry practice to set this Maxplan time so that it is always higher than the effective Maxplan time from the split. When the maxplan time is higher, the phase will force-off before it reaches the max value. The Maxplans are used to prevent over timing the green time for a phase which misses its force-off.
- .13 In addition to force-offs and permissives, a timeline diagram shall be drawn to show the relationship between the phases. Examples of timeline diagrams are shown in Figure 26 and Figure 27.
- .14 Each timing plan shall include the time(s) of day, and day(s) of the week it is to be in effect.

402.5.16 Pre-emption

- .1 The purpose of pre-emption is to provide exclusive right-of-way for specific vehicle movements in lieu of the regular sequence of phases. Types of pre-emption covered in this section are rail pre-emption (for train crossings) and emergency pre-emption (for fire, police and ambulance).
- .2 Pre-emption standards are based on ministry standard controllers and may not be applicable to other controllers.
- .3 Pre-emption priorities:
 - .1 Each high priority pre-emption shall be assigned a priority (rail or emergency). Higher priority pre-emptions override lower priority.
 - .2 Rail pre-emption is always assigned the highest priority and overrides all other pre-emptions.
 - .3 All multi-directional pre-emptions of the same priority are handled on a first come, first served basis. Further pre-emption calls will not be answered until the first one has been serviced.
 - .4 Transit/HOV pre-emptions should be assigned a lower priority.
 - .5 The Senior Traffic Operations Engineer shall approve pre-emption priorities other than rail pre-emption.

402.5.17 Emergency Pre-emption

- .1 Fire, police and ambulance pre-emption are referred to as emergency pre-emption in this chapter.
- .2 All municipal requests to have emergency pre-emption installed at a ministry owned traffic signal are to be forwarded to the District Transportation Manager, who forwards the requests to the Senior Traffic Operations Engineer for approval.
- .3 Municipal and ministry cost sharing breakdowns are as per the current municipal programs cost sharing circular.
- .4 Operation
 - .1 Upon receiving a pre-emption signal, the controller immediately terminates the active phases and enters its pre-emption sequence. However, if there is a higher or equal priority pre-emption, then the controller waits until that pre-emption has finished.
 - .2 Pre-emption entry timings are applied globally to all phases and override all other timing entries. These timings apply only when the controller is terminating the active phases and entering its pre-emption sequence.

TRAFFIC SIGNALS

- .3 For signals with permitted left turns, controllers are programmed to go to an “all red” condition for two seconds as the first step of pre-emption.
- .4 During pre-emption, the signal displays may be either all-red or display green on the pre-empt phases. If the controller is already in the first phase of pre-emption, then it will stay there.
- .5 Once the pre-emption sequence is completed, the controller reverts to normal operation and services the next phase with a call.
- .5 The Senior Traffic Operations Engineer shall approve all pre-emption timings.
- .6 Pre-empt entry timing standards are shown in Table 14.

INTERVAL	TIME (s)
Minimum Green	4
Yellow	No Change
Red	No Change
Advance Warning	No Change
Walk	0
Pedestrian Clearance	No Change

Table 12. Emergency pre-emption entry timing standards

- .7 The pre-empt dwell time for hardwire connected emergency pre-emption is 40 seconds. The default pre-emption delay time is the time the controller waits before servicing pre-emption and is a function of the distance from the emergency station to the signal. The pre-empt delay time shall be determined in consultation with the Senior Traffic Operations Engineer.
- .8 The pre-empt time for sensor activated pre-emption is variable depending upon the length of time the sensor receives the signal. No pre-emption delay time is required.

402.5.18 Railway Pre-emption

- .1 Railway pre-emption is designed to allow the traffic signal to clear any waiting vehicles which may be obstructing the railroad crossing and to prevent movements from occurring which feed into the railroad crossing at the intersection while the train is approaching or crossing.
- .2 Requirements for Railway Pre-emption:

TRAFFIC SIGNALS

- .1 All traffic signals located within 30 m of a signalized railway crossing shall have a railway pre-emption system installed.
 - .2 All traffic signals beyond 30 meters of a railroad crossing, or any railroad crossing which could have vehicles queued because of a traffic signal should be evaluated for possible interconnection.
 - .3 Contact the Senior Traffic Operations Engineer and the ministry Rail and Navigable Water Coordinator to determine the requirements for railway pre-emption and the details for interconnecting the traffic signal with the railway controller.
 - .4 Cost sharing for railway pre-emption shall be as determined by the ministry Rail and Navigable Water Coordinator.
- .3 Interconnection:
- .1 Railway companies are responsible for installing or modifying sensors to detect when a train is approaching a road crossing.
 - .2 Railway sensor systems are designed to provide an electronic signal to the ministry Traffic Controller Assembly, with sufficient time before the train actually crosses the road to ensure that the ministry controller can safely clear the intersection of any conflicting traffic. The amount of warning time required is a function of the size of the intersection, the phasing and the equipment installed in the controller cabinet.
 - .3 Ministry Traffic Engineering calculates the timing between the train activating the railway sensor and the railway warning lights flashing and gates lowering. A record of these calculations is then forwarded to the ministry Rail and Navigable Water Coordinator.
- .4 Pre-emption Operation:
- .1 Upon receiving a pre-emption signal, the controller immediately terminates the active phases and enters its pre-emption sequence.
 - .2 Pre-emption entry timings are applied globally to all phases and override all other timing entries. These timings apply only when the controller is terminating the active phases and entering its pre-emption sequence.
 - .3 LMD and NAZTEC controllers are programmed to go to an “all red” condition for 2.0 seconds as the first step of pre-emption if there are any permitted left turn movements.
Econolite COBALT Controllers utilize "TERMINATE ALL PHASES" programming to cause the signal to go to an “all red” condition before servicing the Pre-empt phases. - 'STEP 1 OF PRE-EMPTION IS "PREEMPTOR TERMINATE ALL PHASES = YES".'

TRAFFIC SIGNALS

The length of time would depend on whether the signal is Red Reverting back to the same phase or going to a different phase. If Red Reverting, then the “all red” time would include the programmed Red Revert time which is typically set at 2.0 seconds.

- .4 Blank out “no left turn signs” are turned on or the protected left turn signal shall display a red ball for the duration of the pre-emption (refer to 402.7.7.5 for further details). Where blank out “no right turn signs” are required, they shall be turned on for the duration of the pre-emption (refer to 402.7.7.6 for further details).
 - .5 A railway clearance stage is executed.
 - .6 The controller remains in the pre-emption sequence servicing movements which do not conflict with the railway until a signal indicating that the train has passed is received. The gates (if any) are raised and the railway warning lights cease flashing.
 - .7 Once the pre-emption sequence is completed, the controller reverts to normal operation and services the next phase with a call.
- .5 Pre-emption entry timings are listed in Table 15.

INTERVAL	TIME (sec)
Minimum Green	4
Yellow	No Change
Red	No Change
Advance Warning	No Change
Walk	0
Pedestrian Clearance	0

Table 13. Railway pre-emption entry timing standards

- .6 The railway clearance stage is used to clear any vehicles queued on the railway tracks.
- .1 The controller displays a green through and left turn arrow for the traffic on the railway crossing leg of the intersection. Note that if the left turn arrow is not warranted for normal operation then it will only be activated only during the rail clearance stage. Refer to Figure 28.
 - .2 The traffic signal indication is terminated to prevent other vehicles from blocking the tracks.
 - .3 The clearance stage is only used once, at the beginning of the pre-emption sequence.

- .4 The green time for the track clearance phases shall be calculated such that any queued vehicles resting on the tracks can move off the tracks and clear the intersection.
- .5 The time for the controller to reach the track clearance phase depends upon which phase interval it was in operation when the pre-emption signal was received.
- .6 The maximum time required for the controller to reach the track clearance phase occurs when the controller has just started a phase which has advance warning. In this case, the time before clearance begins is given by Equation 10. This case causes the least amount of time to be available for track clearance. Traffic engineers and / or designers shall check the time necessary for queue clearance to ensure that it is met before the gates descend or ten seconds (Railway Design Standard) before the train arrives in a non-gated scenario. If there is not sufficient clearance time, then either the minimum green time shall be reduced, or the railway signal shall be received earlier.

$$T_{\max} = G_{\min} + AW + Y + R + AR \quad \text{Equation 10}$$

where

$T_{\max}$	= maximum time before clearance phase (s)
$G_{\min}$	= pre-emption entry minimum green (s)
AW	= advance warning (s)
Y	= yellow time (s)
R	= all red time (s)
AR	= added all red interval (s)
	= 2s

- .7 The minimum time for a controller to get to the track clearance phase occurs when the controller finishes timing the yellow of a phase. In this case the time is given by Equation 11.

$$T_{\min} = R + AR \quad \text{Equation 11}$$

where

$T_{\min}$	= minimum time before clearance phase (s)
R	= entry phase red (s)
AR	= added all red interval (s)
	= 2 s

- .8 For gated crossings, the track clearance phase green time shall be sufficient to clear the queue between the time the railway signals start flashing to when the gates descend for the minimum time case. Refer to Equation 12.

$$G_p = t_{gates} - T_{min} \text{ where } T_{min} = R + AR \quad \text{Equation 12}$$

$$G_p = t_{gates} - R - AR$$

where

G_p = pre-empt clearance green (s)

t_{gates} = time to gate closure (s)

R = entry phase red (s)

AR = added all-red phase (s)

= 2s

- .9 For non-gated crossings, the track clearance phase green time shall be sufficient to clear the queue between the time the railway signals start flashing to ten seconds (Railway Design Standard) before the train arrives for the minimum time case. Refer to Equation 13.

$$G_p = t_{lights} + t_{buffer} - R - AR \quad \text{Equation 13}$$

where

G_p = pre-empt clearance green (s)

t_{lights} = time to onset of railway warning lights (s)

t_{buffer} = typical time difference between onset of railway warning lights and gate closure for gated crossings

= 10 s (max)

R = entry phase red (s)

AR = added all red interval (s)

= 2s

- .7 Railway pre-emption stage - the controller shall only allow phases or movements which do not conflict with the train crossing.

- .1 The controller remains in this stage until it receives a signal from the railway that the train has cleared the crossing. Typically, the left turn movement onto the train crossing leg and any through movements passing through the affected leg are not permitted. Refer to *Figure*

TRAFFIC SIGNALS

28. This stage remains in effect until the pre-emption call is terminated. Hence, the controller only cycles through the allowed phases. Normal timings for each phase are maintained.
- .2 In this stage, phases may be activated which are not permitted during normal traffic signal operation. For example, a phase B2→ consisting of a flashing green arrow and a solid yellow arrow may be considered. The phase could be activated when vehicles wish to turn left from the cross street onto the highway while a train is crossing. This should be considered for situations where the rail pre-emptions are very long. The Senior Traffic Operations Engineer shall approve additional phases.
- .8 Confirm with the Senior Traffic Operations Engineer if the coordination timing will be maintained during the rail pre-emption.
- .9 Confirm with the Senior Traffic Operations Engineer which pedestrian phases shall be serviced during rail pre-emption.

TRAFFIC SIGNALS

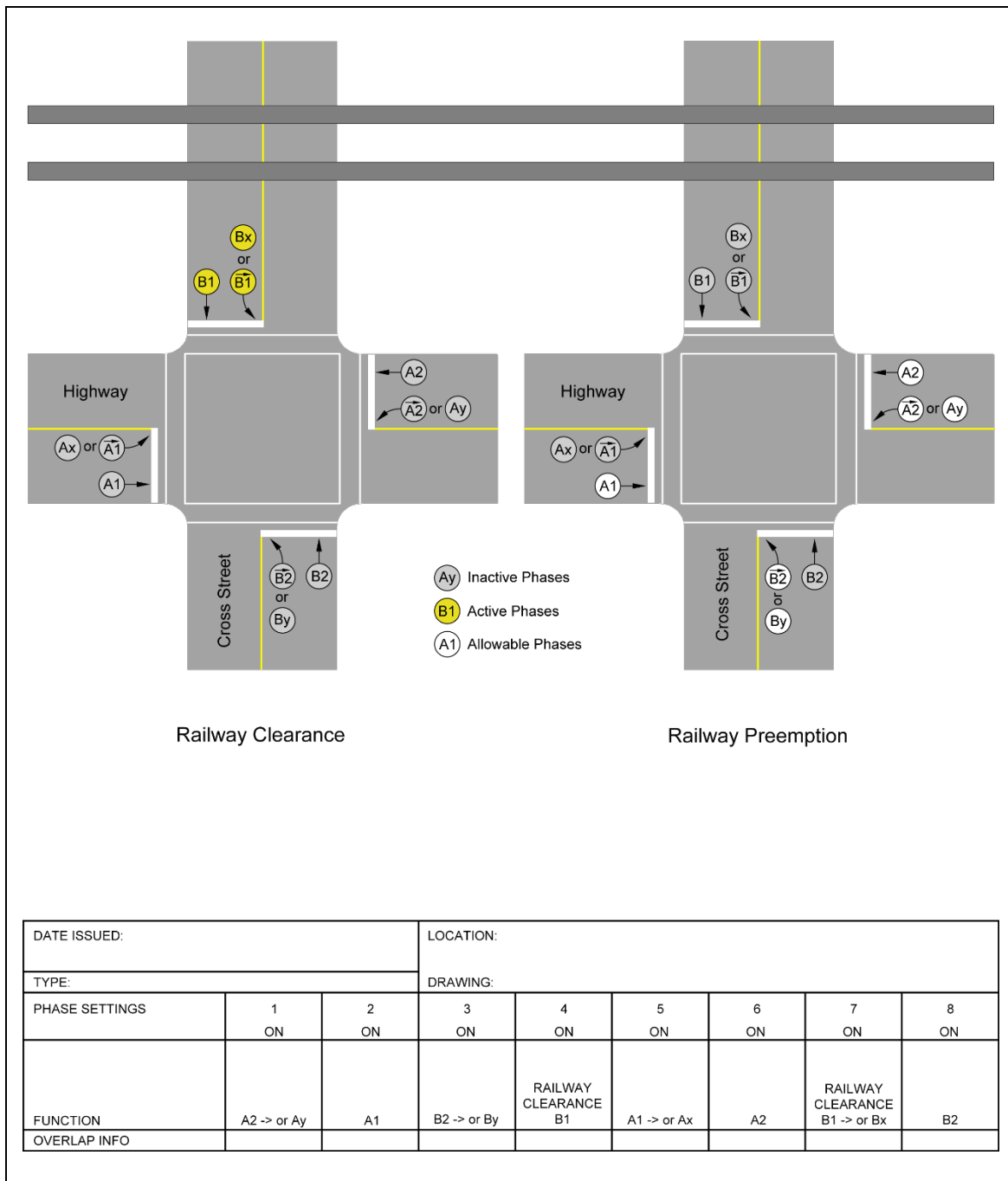


Figure 28. Railway pre-emption

402.5.19 First Green Display

- .1 This is the phase(s) to display green upon entering three colour operations from a flashing state.
- .2 A first green display must be designated for each active ring
- .3 The standard first green displays are typically on the cross street (for NEMA Dual Ring operation typically phases 4 and 8).
- .4 The term Full Operation Point (FOP) may appear on some earlier timing sheets. Sheets now show the first green display. FOP is the flash exit point to three colour operation. Typically this point is Highway yellow or red, depending on the flash colour on the Highway.

402.5.20 Time Clock Settings

- .1 Due to the variability of traffic patterns during the day and between different days of the week, there may be a requirement to have different controller settings to match these different traffic patterns. The Traffic Controller Assembly can select these different timing plans by internal time clock setting.
- .2 Clearance intervals (yellow, red, ped clearance) are constant and shall not be altered via time clock settings.
- .3 Coordination (i.e., cycle/split/offset combinations), maxplans, min greens, passage times, recall and detector settings may be changed by the internal time clock.
- .4 For max green times, MAX I is in effect unless another maxplan or Max II is in effect via the internal time clock or through coordination.

402.6 SIGNAL DESIGN

402.6.1 General

- .1 This section describes the use of items specific to signal designs, such as, signal heads, pedestrian pushbuttons, audible signals, telephone services, Traffic Controller Assembly, advance warning flashers, detector loops and other methods of detection and pre-emption equipment. Refer to the latest edition of the *Manual of Uniform Traffic Control Devices* for Canada (MUTCD) for thorough information on signal concepts and terminology.
- .2 Signal designs shall be undertaken by an electrical engineering firm that is experienced in traffic signal design.
- .3 The designer shall be the individual or individuals working under the direction of the Engineer of Record (EOR).

TRAFFIC SIGNALS

- .4 The ministry *Standard Specifications for Highway Construction, Section 635 - Electrical and Signing*, further details the various traffic signal equipment. Traffic or Electrical engineers and / or designers shall use these specifications as a reference when preparing a design.
- .5 The use of other signal equipment such as concrete bases, poles, luminaires, frangible bases, service equipment, junction boxes, concrete vaults, conduits, small overhead and street name signs etc., are described in Section 500 of this manual and are important components in all signal designs.
- .6 The designer shall note the following issues before starting a signal design:
 - .1 Obtain *Traffic Engineering Checklist* signed off by the Engineer of Record and the ministry Senior Traffic Operations Engineer prior to proceeding with the signal design.
 - .2 Consider any temporary signals required to suit construction staging.
 - .3 If a signal is to be installed as part of a road construction project, Traffic engineers and / or designers shall confirm all intersection geometrics, pavement markings and wheelchair ramp locations with the road designer. If the intersection geometrics are not being revised, the designer shall confirm possible revisions to pavement markings and wheelchair ramp locations with the Senior Traffic Operations Engineer.
 - .4 Contact the applicable ministry Manager, Electrical Services to determine any construction requirements for the signal design such as the possible use of signal cable, preformed loops or a specific type of pole.
 - .5 If an existing signal is replaced or upgraded:
 - .1 Confirm what equipment can be re-used or requires replacement with the ministry Electrical and ITS Engineering.
 - .2 Ensure the existing signal can remain in operation until the new signal is operational.
 - .6 Refer to *Appendix 400* for a list of general requirements for traffic signal design.

402.6.2 Traffic Signal Indications and Signal Heads

- .1 The definition of signal indications may be found in the Province of BC Motor Vehicle Act Regulation. As defined in the BC Motor Vehicle Act Regulation, an “indication” means a signal lens display that is activated by internal illumination.
- .2 The positioning of signal indications within a traffic signal head are defined in the BC Motor Vehicle Act Regulation. Where transit priority signals are

TRAFFIC SIGNALS

required, they shall be positioned above the red signal indication. Figure 29 shows typical signal indication positioning.

- .3 A signal head consists of up to five signal indications. Signal heads fall into the following categories and are described in more detail in 402.6.4:
 - .1 Primary.
 - .2 Secondary.
 - .3 Auxiliary.
 - .4 Pedestrian.
- .4 All primary signal heads shall be equipped with yellow backboards.
- .5 Secondary and auxiliary signal heads may be equipped with yellow backboards if requested by the Senior Traffic Operations Engineer.
- .6 All traffic signal backboards shall include 75 mm, micro prismatic, retro-reflective tape around the perimeter.
- .7 Protected/permissive left turn indications shall be bimodal LED type, displaying both yellow and green arrows.

TRAFFIC SIGNALS

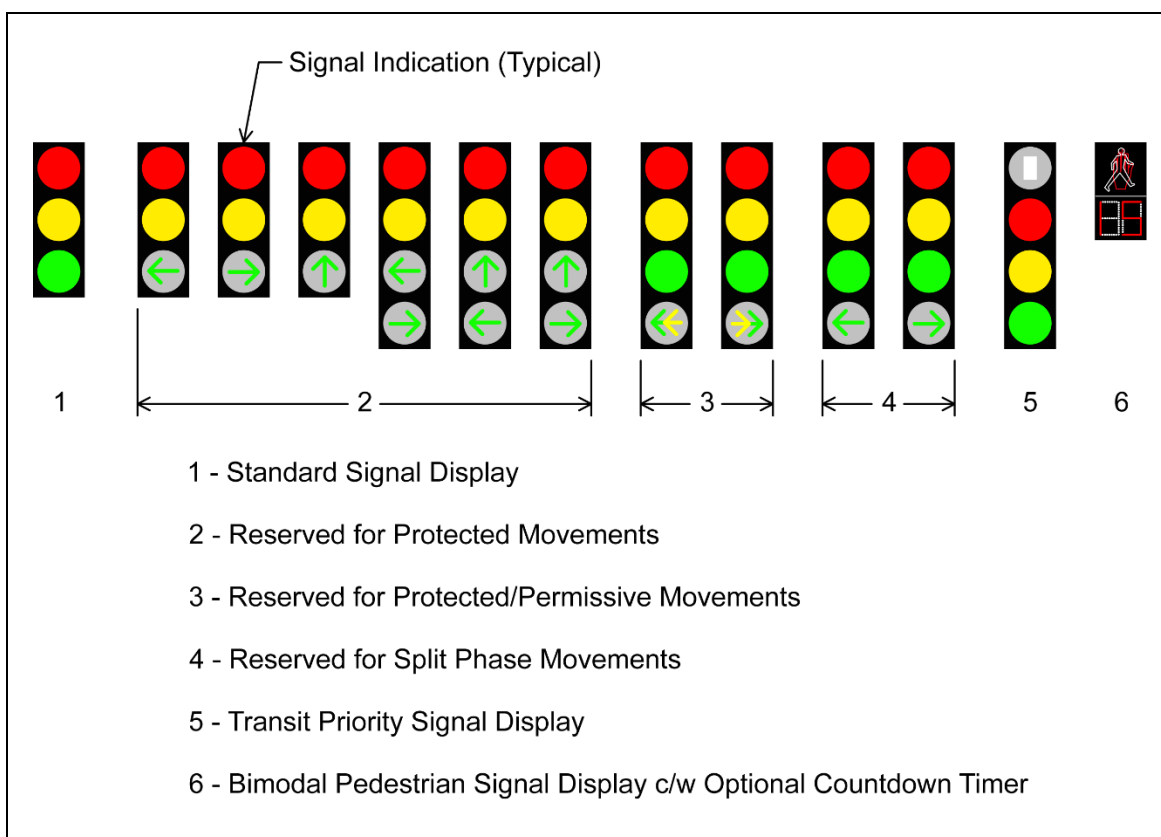


Figure 29. Typical signal indication positioning

- .8 A steady or flashing green arrow indication is used only when there is no conflict with other vehicles or with pedestrians crossing with a walk indication. A steady green arrow is reserved for a fully protected movement and a flashing green arrow is reserved for protected/permissive movements. A steady green up-arrow shall be used for through movements when there is no other movement permitted for that lane.
- .9 Sizes of signal lenses and the signal heads to which they apply are listed in Table 16.

TRAFFIC SIGNALS

SIGNAL HEAD TYPE	LENS
Primary	Shall have 300 mm diameter round LED lenses for all signal indications.
Secondary	Shall have 300 mm diameter round LED lenses for all signal indications except arrow indications which shall have 300 mm diameter round lenses.
Auxiliary	Shall have 300 mm diameter round LED lenses for all signal indications.
Pedestrian	Shall have single 300mm square LED lens displaying the “walk” and “don’t walk” symbols incorporated into a bi-modal display, which displays both symbols at different times. A 300mm LED countdown display may be located below the bi-modal display. Requirements for countdown displays are defined in Section 402.6.17.

Table 14. Signal head lenses.

- .10 All signal indications shall have cowl visors with the exception of the following:
 - .1 Fully protected left turn signal heads shall use tunnel visors.
 - .2 At skewed intersections where the signal heads may be viewed from other approaches, tunnel visors shall be used.
 - .3 Where two or more secondary heads are installed on a pole.
- .11 Optically programmable signal heads may be considered where a signal indication can be easily viewed from other signalized movements or intersections. An example of this is at diamond interchanges where two intersections may be located in close proximity to one another. The use of optically programmable signal heads must be approved by the ministry Electrical Representative and Senior Traffic Operations Engineer. The designer shall ensure that full installation instructions are provided as part of the design.
- .12 Flashing signal indications shall be as follows:
 - .1 Flashing green and yellow left and right turn arrow indications shall flash at a rate of 120 flashes per minute.
 - .2 Flashing green indication on pedestrian controlled signals shall flash at a rate of 60 flashes per minute.
 - .3 Flashing red or flashing yellow indications such as flashing beacons shall flash at a rate of 60 flashes per minute.

- .4 “Don’t walk” flashing hand indication during the pedestrian clearance interval shall flash at a rate of 60 flashes per minute.
- .13 Interchange signals designs shall use green arrows instead of green balls, where applicable to provide enhanced positive guidance.

402.6.3 Signal Head Light Sources

- .1 All new and replacement traffic signal head sections shall use LED’s as the light source.

402.6.4 Signal Head Locations

- .1 Signal heads are installed on signal poles and located in positions which are easily visible to motorists.
- .2 Primary signal heads shall be fully visible from distances listed in the Transportation Association of Canada (TAC), *Manual of Uniform Traffic Control Devices* for Canada (MUTCD). In situations where these minimum sight distances cannot be maintained due to road geometrics, additional signal heads or revisions to the road geometrics may be required.
- .3 For speeds under 70 km/h, the maximum visibility distance of the signal must equal or exceed the minimum stopping sight distance. If not, the installation of an advance warning sign should be considered.
- .4 Each signal movement shall have at least one primary head and one secondary head for each direction.

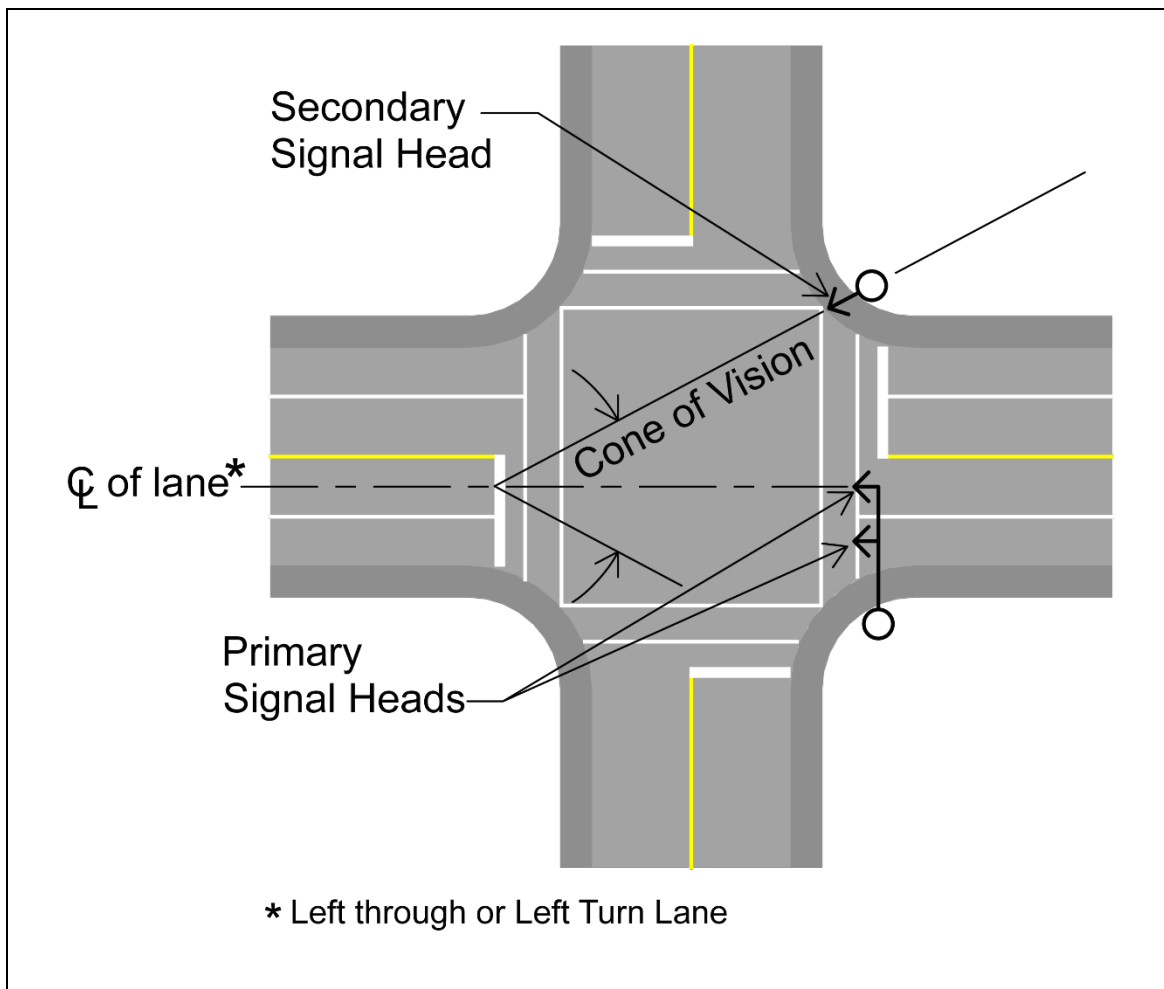


Figure 30. Secondary head cone of vision

- .5 Primary signal heads shall be located on the far side of the intersection as follows:
 - .1 Single through lane - one primary signal head located over centre of through lane.
 - .2 Two through lanes - two primary heads, one located over centre of each through lane.
 - .3 Three through lanes - two primary heads, one signal head over the lane line between each through lane.
- .6 Refer to Figure 32 through Figure 37 for signal head locations used for typical scenarios.
- .7 Secondary heads shall be located on the far-left side of the intersection adjacent and clear of the roadway. The horizontal positioning of secondary heads shall conform to the following guidelines:

TRAFFIC SIGNALS

- .1 Single primary head - the secondary head position shall be within a 40-degree horizontal cone of vision (Refer to Figure 30).
- .2 Multiple primary heads, the secondary head position should be placed as close as practical to within the horizontal 40-degree cone of vision but should not exceed a 60-degree cone of vision. Refer to Figure 30.
- .3 Where the 40-degree cone of vision cannot be met for far left side secondary heads and there is only one primary head or where there are protected left turn signals, an additional right side mounted auxiliary head will be required.
- .8 All primary heads shall be located within a 10 degree cone of vision with the exception of protected/permissive left turn indications which are to be mounted over the centre of the left most through bound lane.
- .9 Generally, secondary and pedestrian heads shall be oriented on specific quadrants of the poles as shown on Figure 31.

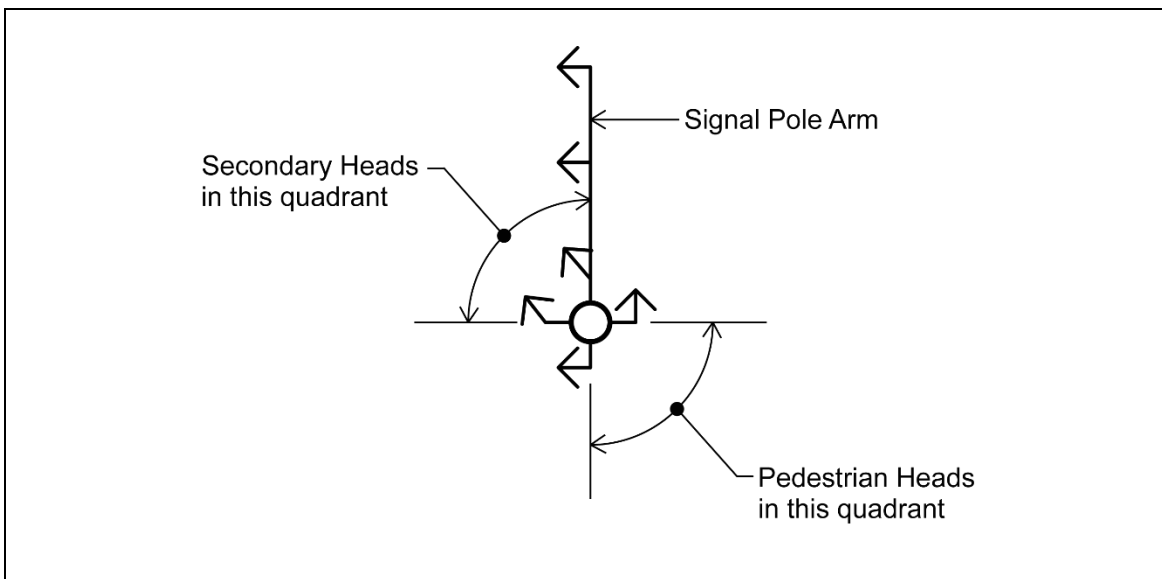


Figure 31. Signal and pedestrian head orientation

- .10 Primary and secondary protected/permissive left turn signal heads shall be located as follows:
 - .1 One primary signal head for the left turn and through movement signal head shall be located over the centre of the left most through lane. Refer to A1 arrowhead in Figure 35.
 - .2 The secondary signal head for the left turn and through movements shall be located on the far left side of the intersection. Refer to A1 arrowhead in Figure 35.

TRAFFIC SIGNALS

- .11 For a single left turn lane, with a fully protected movement, one primary, one secondary and one auxiliary signal head shall be provided:
 - .1 One primary head shall be located in the far side raised median mounted on a Type 4A or Type 5 shaft at a height of 4.0m or 5.0m respectively. Refer to Ax & Ay in Figure 36.
 - .2 One secondary head shall be located at the far left side of the intersection, adjacent to and clear of the roadway, mounted on pole at a height of 2.5 m. Refer to Ax and Ay in Figure 36.
 - .3 One auxiliary head shall be located in the near side median mounted at a height of 1.25 m. Refer to Ax and Ay in Figure 36.
 - .4 The secondary head for the through movement shall be mounted on the far right side of the intersection at 2.5 m. Refer to A1 and A2 in Figure 36.
 - .5 If there is no raised median, then the primary head shall be mounted overhead on the signal pole arm. If there are no raised medians, the auxiliary head cannot be installed.
- .12 Primary and secondary protected left turn signal heads for double left turn lanes shall have one primary head, one secondary head and one auxiliary head:
 - .1 For a double left turn lane, one primary signal head shall be located on a Type 2-6.5m shaft at a height of 5.0m or a Type 3 signal pole in the far side raised median. Refer to Figure 37 and Figure 38.
 - .2 One auxiliary secondary head shall be located in the near side median mounted at a height of 1.25 m. Refer to Ax and Ay in Figure 37.
 - .3 One secondary head shall be located at the far left side of the intersection, adjacent to and clear of the roadway, mounted on pole at a height of 2.5 m. Refer to Ax and Ay in Figure 37.
 - .4 The secondary head for the through movement shall be mounted on the far right side of the intersection at 2.5 m. Refer to A1 and A2 in Figure 37.
- .13 Split phase left turn signal heads shall be located as follows:
 - .1 One primary left turn signal indication and through movement signal head shall be located over the centre of the left most through lane. Refer to B and C in Figure 36.
 - .2 The secondary signal head for the left turn movement shall be located on the far left side of the intersection. Refer to the B and C in Figure 36.
 - .3 The secondary signal head for the through movement shall be located on the far right side of the intersection. Refer to B and C in Figure 36.

TRAFFIC SIGNALS

- .14 All marked crosswalks at fully actuated signalized intersections shall have pedestrian heads and pedestrian pushbuttons with the exception of those crossing free right turn lanes. Pedestrian signal heads shall be located as follows:
 - .1 At each end of a crosswalk.
 - .2 2.5 m above the roadway.
- .15 Signal pole arm orientations may affect signal head visibility. Refer to 504.2.5 for more information on signal arm orientation.

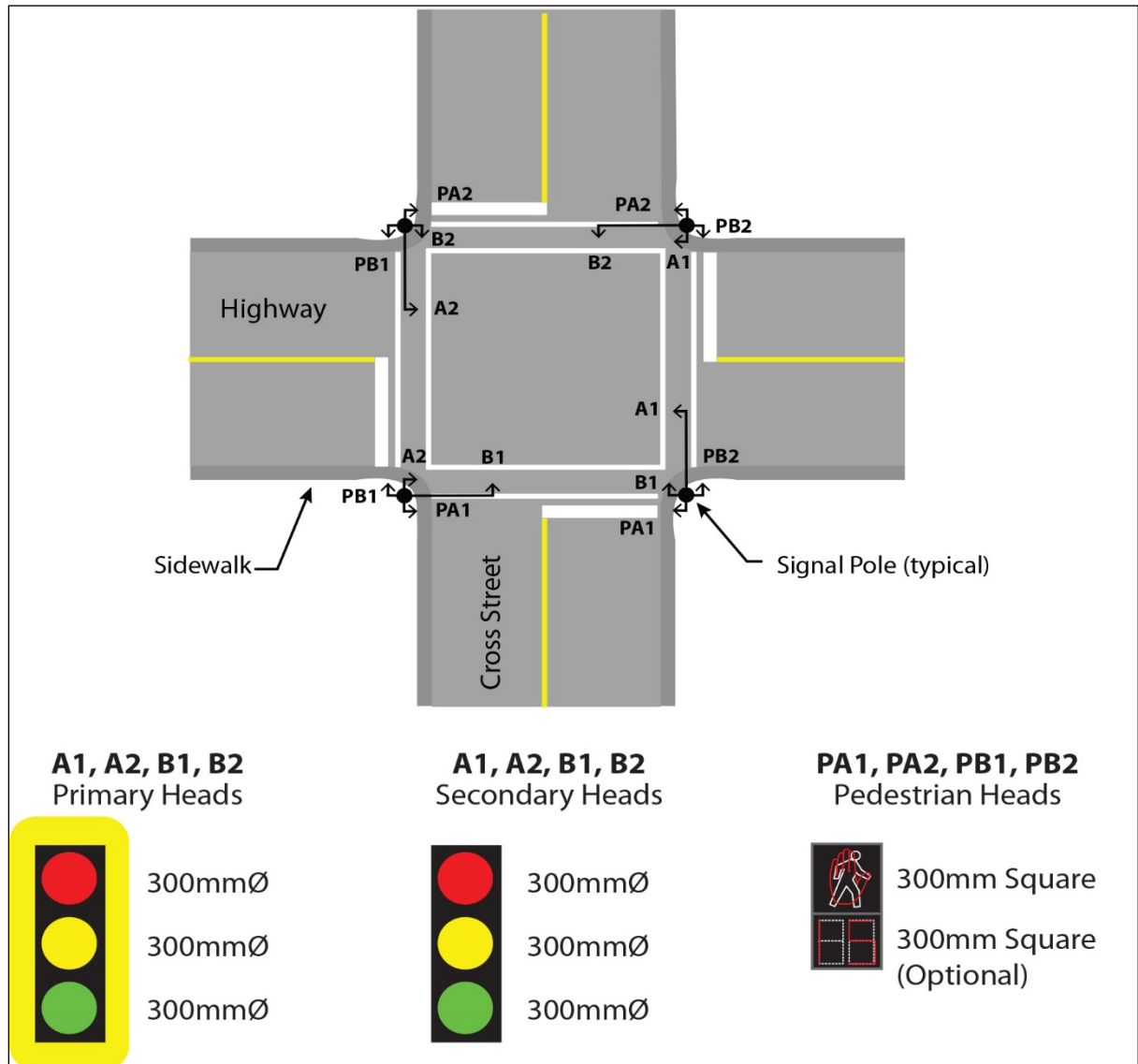


Figure 32. Full intersection with sequential operation and no left turn signals.

TRAFFIC SIGNALS

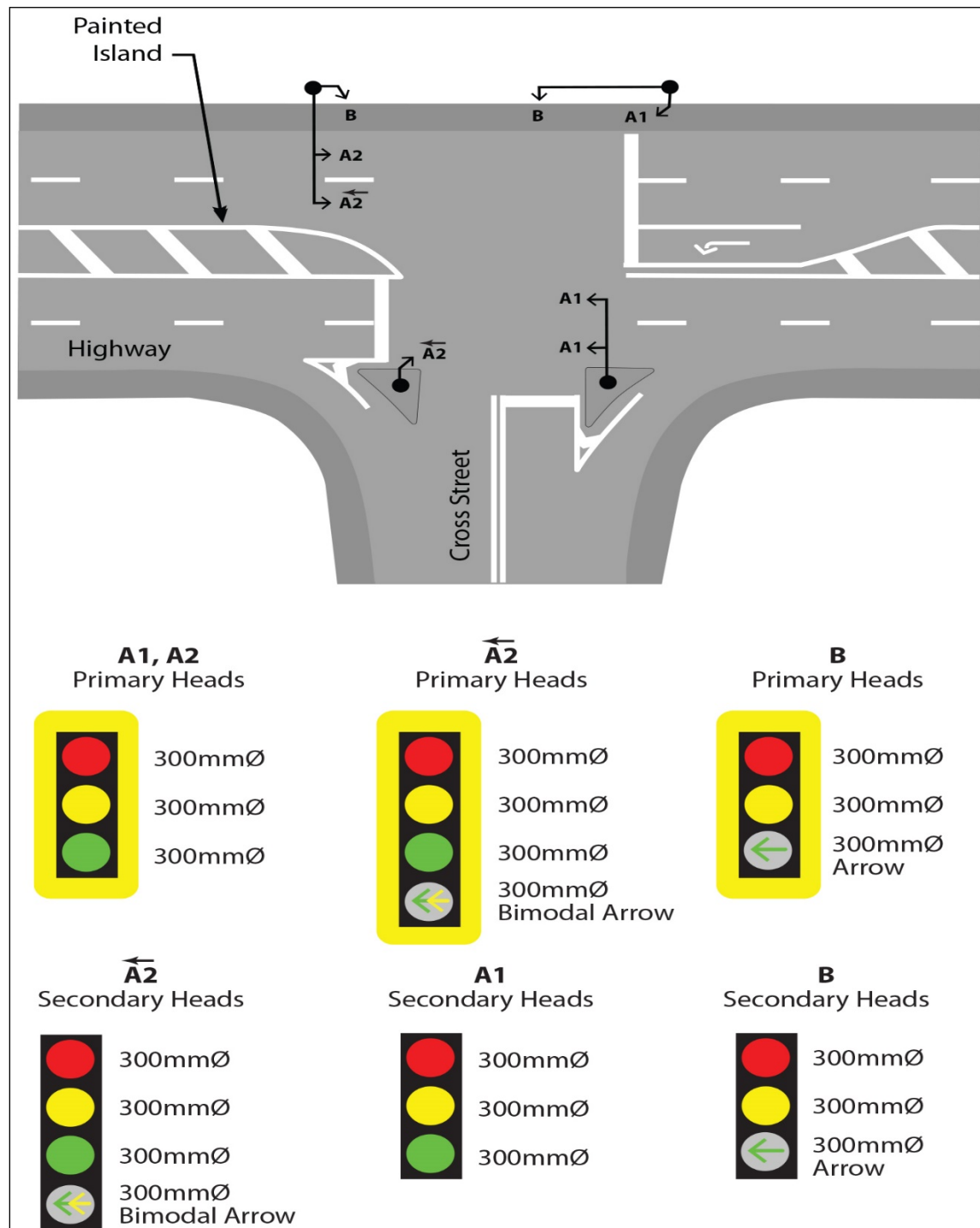


Figure 33. "T" intersection with sequential operation and left turn signals.

TRAFFIC SIGNALS

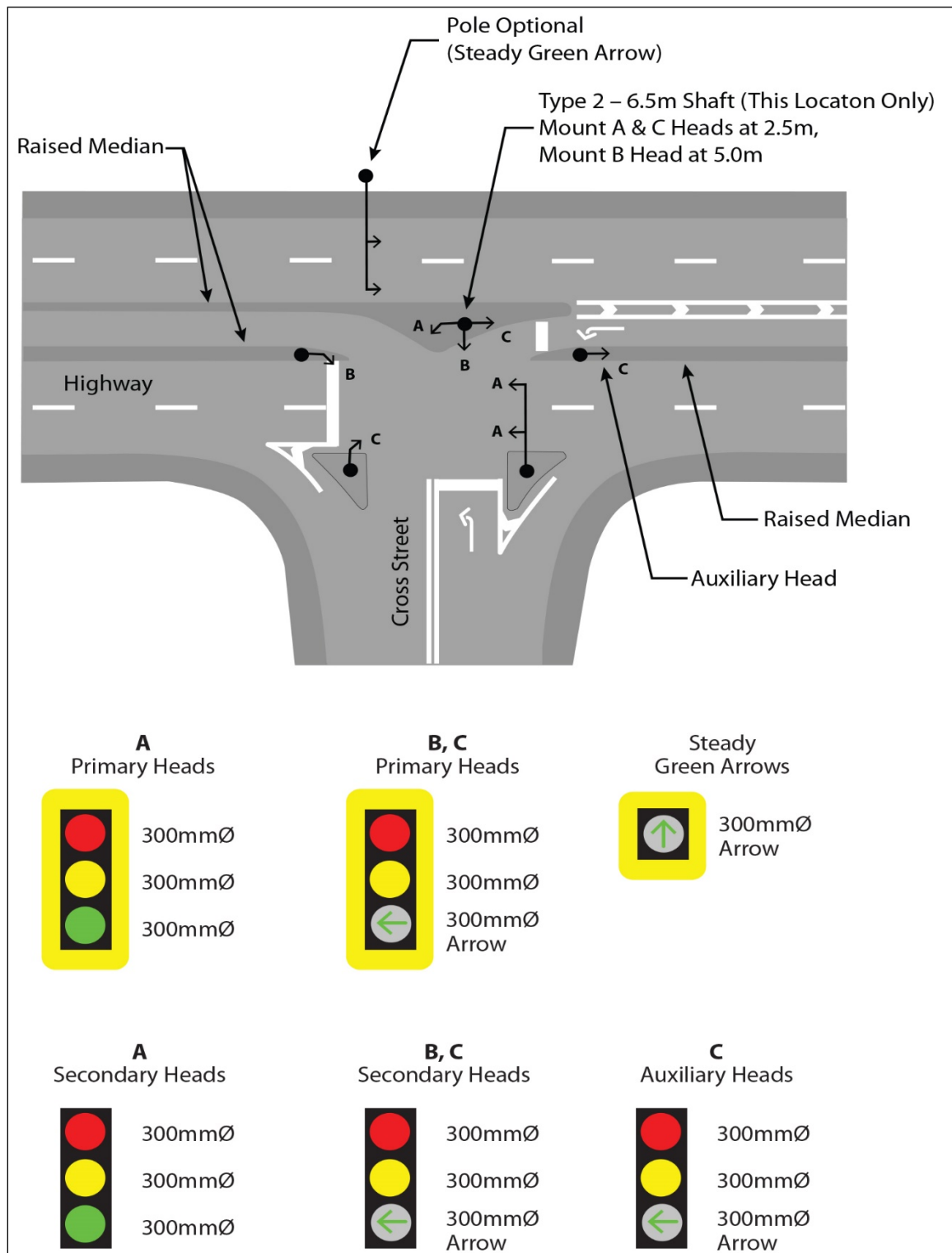


Figure 34. Channelized “T” intersection with sequential operation and left turn signals.

TRAFFIC SIGNALS

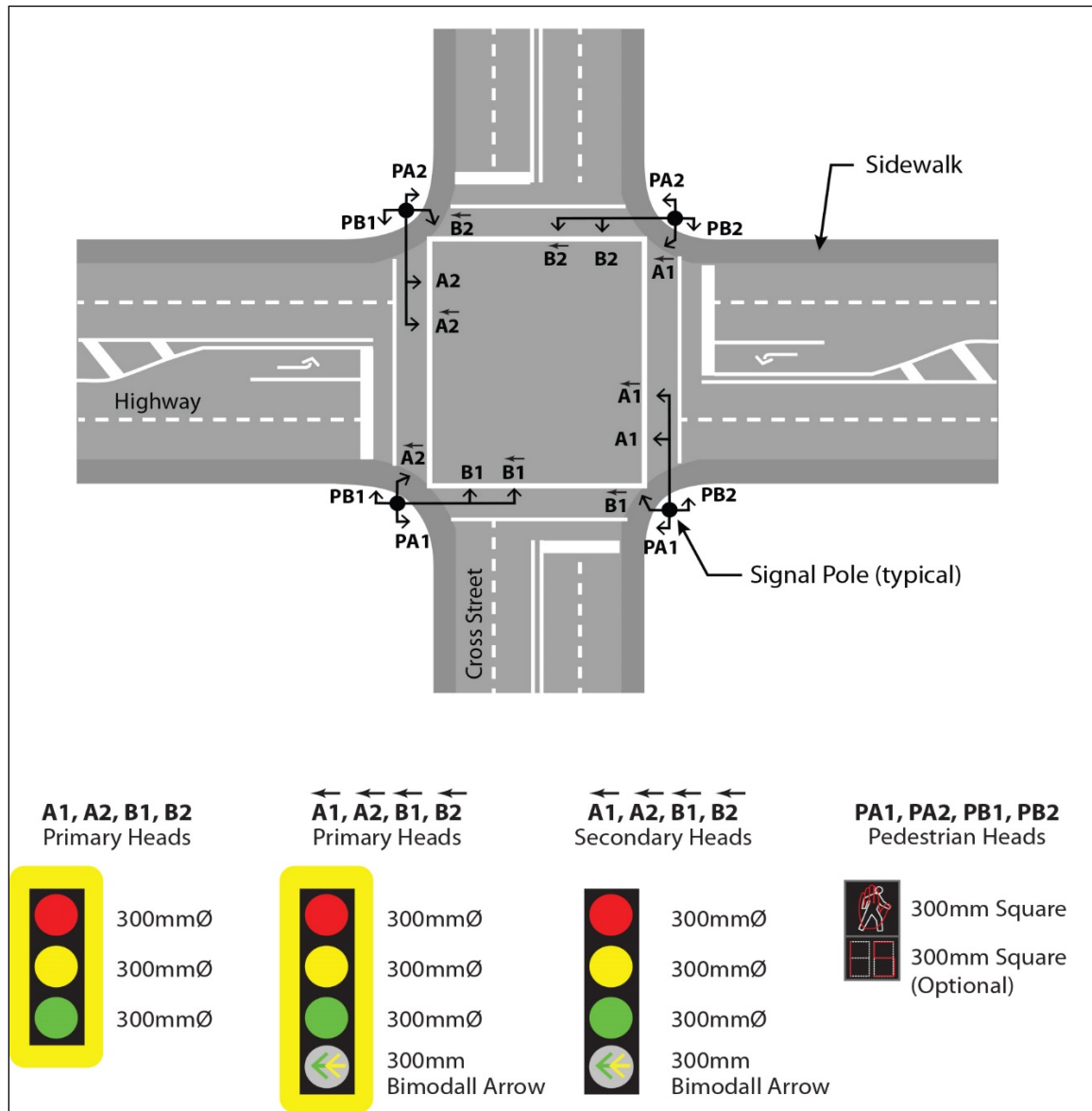


Figure 35. Full intersection with NEMA Dual Ring & protected/permissive left turn.

TRAFFIC SIGNALS

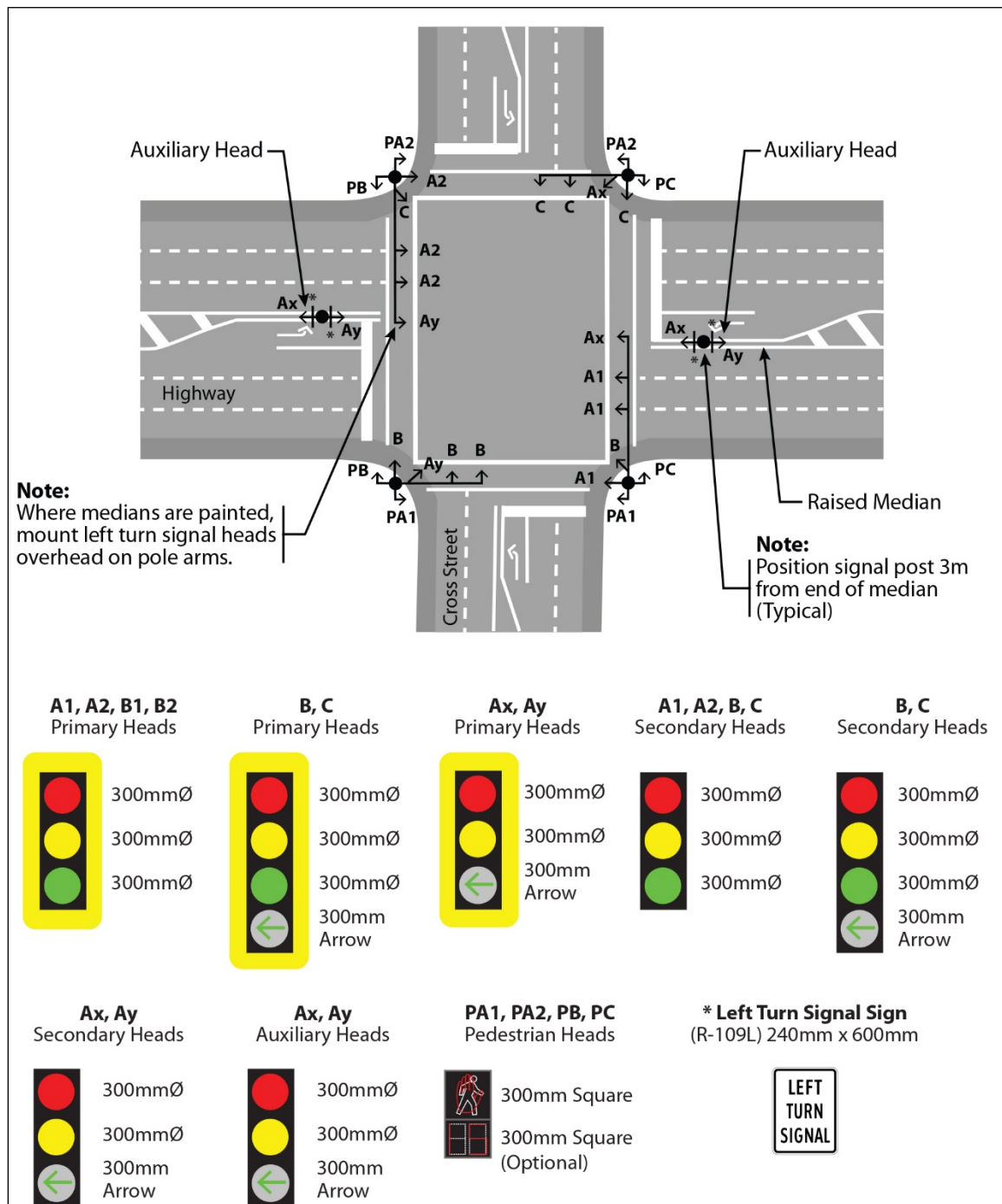


Figure 36. Full intersection with NEMA Dual Ring, protected left turn (single lane) & split phase on cross street.

TRAFFIC SIGNALS

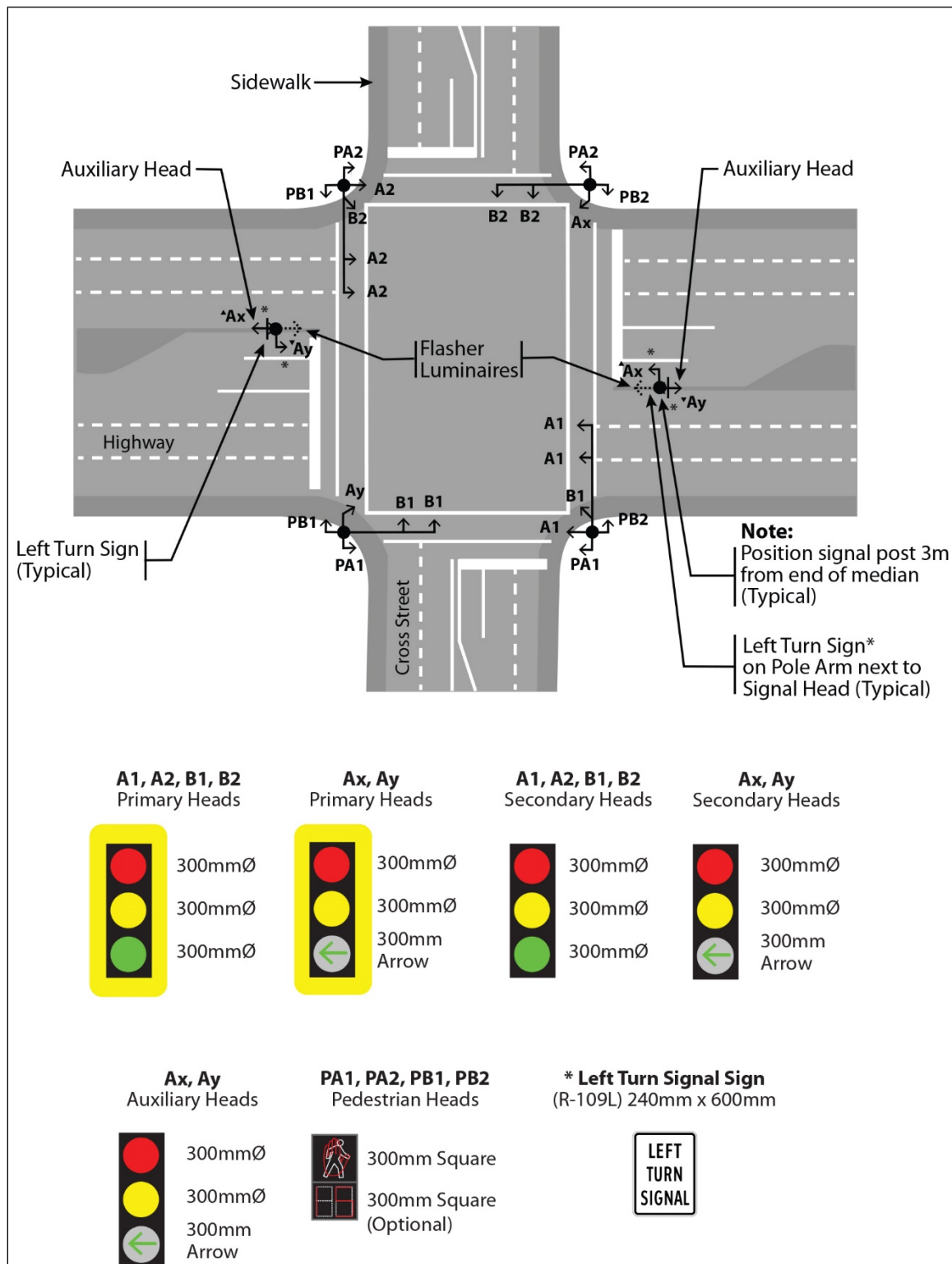


Figure 37. Full intersection with NEMA Dual Ring operation and protected left turn signals (double lane) on the highway.

TRAFFIC SIGNALS

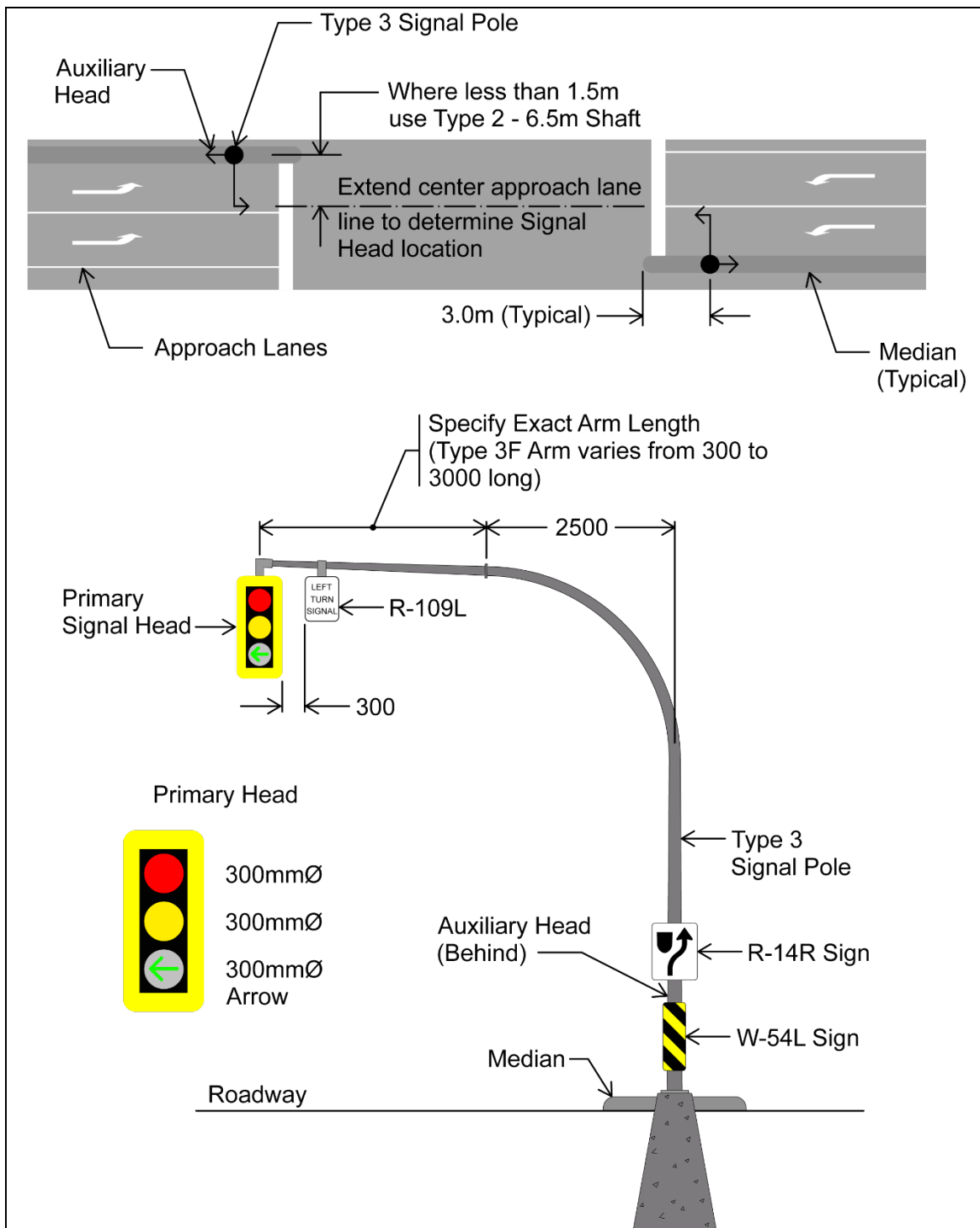


Figure 38. Double left-turn primary signal head locations.

402.6.5 Pedestrian Pushbuttons

- .1 Pushbuttons are required to activate the walk signal.
- .2 Traffic engineers and / or designers shall locate the pushbutton on the quadrant of the pole most accessible to pedestrians. Avoid locating pushbuttons on the roadside of the pole. Pushbuttons shall be placed in logical locations for easy pedestrian and wheelchair access and shall not be more than 2.3m from the crossing.
- .3 The pushbutton shall fit into a cast aluminum sign. The sign shall have integral raised black hand/button walking symbol and directional arrow in accordance with the PS-015 series MUTCDC sign layout. Pushbutton symbols and arrows shall be available in left, right and bi-directional arrows as well as the cyclist symbol, if specified.
- .4 Pedestrian pushbuttons shall have an integral momentary red LED indication.
- .5 Designers shall specify the correct pushbutton sign to indicate the direction of the pedestrian crossing as indicated on the drawing *SP635-2.3.7 Pedestrian Pushbutton with Integral Sign Installation Details* in Section 635 of the ministry *Standard Specifications for Highway Construction*.

402.6.6 Bicycle Signals & Detection

- .1 Currently the *Motor Vehicle Act* does not recognize signal displays specific to bicycle traffic control. Because the ministry is obligated to abide by the regulations of the *Motor Vehicle Act*, signal displays dedicated to bicycle traffic control are not used in ministry traffic signals.
- .2 Bicycle detection may be by detector loops and/or pushbutton.
- .3 Bicycle pushbutton posts shall be installed as indicated in drawing *SP635-2.3.14 Pushbutton Post Installation Details* of the ministry *Standard Specification for Highway Construction*.
- .4 Bicycle detector loops and markings shall be installed as indicated on drawing *SP635-2.3.15* of the ministry *Standard Specification for Highway Construction*.

402.6.7 Audible Pedestrian Signals

- .1 Audible signals are devices which emit sounds, aiding the visually impaired in crossing signalized intersections. The requirement for audible signals shall be confirmed by the traffic engineer on the *Traffic Engineering Checklist*.
- .2 Audible signals shall follow the guidelines noted in Section A.6.10 of the Transportation Association of Canada (TAC), *Manual of Uniform Traffic Control Devices* (MUTCD).

TRAFFIC SIGNALS

- .3 Synthesized bird sounds have been used to indicate the time and direction to cross, with a 'chirp' sound for east-west and a 'cuckoo' sound for north-south. The synthesized bird sounds have been replaced by the 'Canadian Melody' sound as they do not get mistaken for actual birds and it is easier to discern in high-noise environments.
- .4 Further to the *Manual of Uniform Traffic Control Devices* for Canada (MUTCD), cardinal directions shall be used for audible signal orientation. However, when the intersection is skewed or at 45° to a cardinal direction, the sound/direction choice is ambiguous, therefore, consistency with adjacent ministry and municipal signals is critical. Some municipalities follow the convention that streets are north/south and avenues are east/west or vice versa. This convention should be followed, where applicable. Refer to Figure 39. If Traffic engineers and / or designers have questions about the orientation of the audible signals, they should contact the Canadian National Institute of the Blind (CNIB) mobility specialist for that area.
- .5 Before changing existing installations to this standard, or installing new audible signals, the traffic engineer should contact the nearest CNIB mobility specialist with the location of the change or new installation and the proposed start-up date.
- .6 Two audible signal units are generally required for each pedestrian crossing. The audible signal unit is mounted on and wired directly into the pedestrian head, as indicated on the drawing *SP635-2.3.8 Audible Signal Installation Details* in Section 635 of the ministry *Standard Specifications for Highway Construction*.

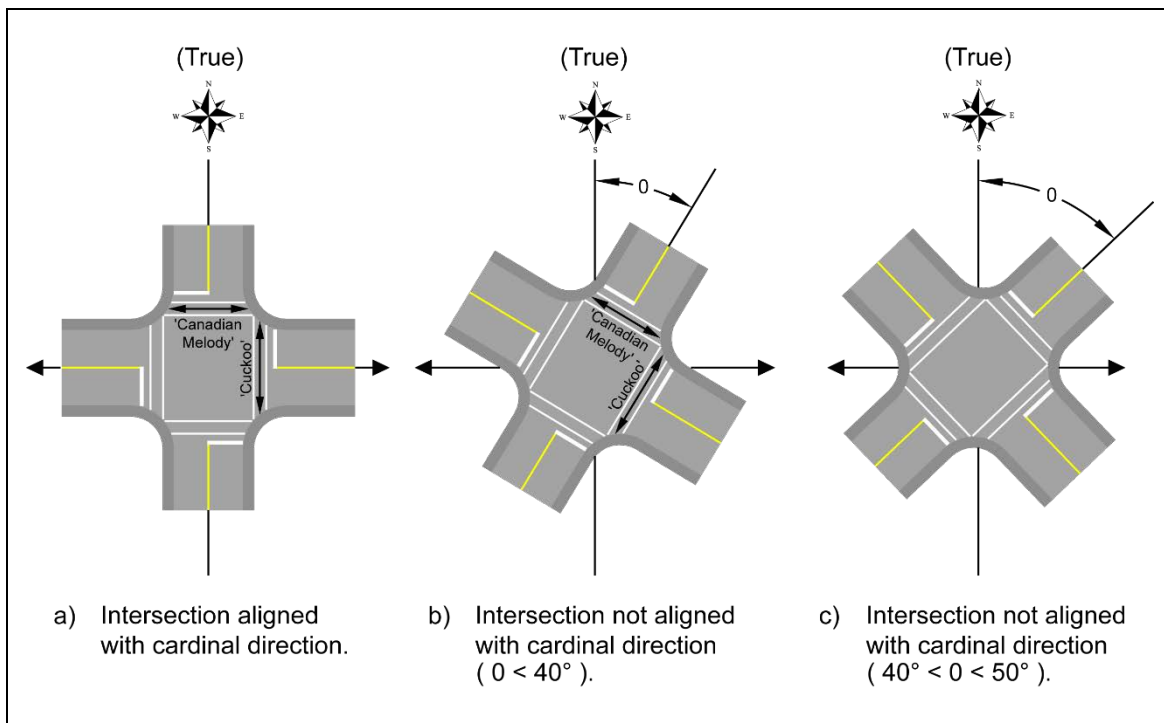


Figure 39. Audible Signal Orientation at Intersections

402.6.8 Communications Services

- .1 Communications services may be installed at signalized intersections to remotely obtain data from the controller. Typically this is done with a cellular data modem, however other means such as fibre-optic cable may be used. Communications services will only be required where specifically requested by the ministry Senior Traffic Operations Engineer or ITS Engineer.
- .2 Cellular telecommunications services must be arranged through the ministry Information Management Branch, Telecommunications Service Coordinator.
- .3 Fibre-optic cables are installed along several corridors in the South Coast Region. Fibre-optic is the preferred method for communications, as the ministry owns the cable and there are no monthly fees. Consult with the ministry Manager, ITS Engineering to determine if there is fibre-optic cable available.
- .4 For further information on telephone services refer to 504.4.15.

TRAFFIC SIGNALS

402.6.9 Traffic Controller Assemblies

- .1 For the purposes of standardization, traffic controller assemblies are defined as the controller, cabinet, detector cards, flashers, MMU's and all related electronic equipment that makes up the control system for a signalized intersection. Traffic controller assemblies are supplied by the ministry at the project expense. The ministry uses standard traffic controller assemblies for various applications, as indicated in Table 17.

CABINET TYPE	MOUNTING	NEMA TYPE	MODELS USED BY MINISTRY	APPLICATION
P6	Concrete base	NEMA TS2-TYPE1	Naztec 980, Econolite Cobalt	Used for all new traffic signal installations. Cabinet can handle up to 32 detector channels and the mainframe can handle up to 64 channels.
S	Concrete base	NEMA TS2-TYPE2 NEMA TS1	LMD 8000, LMD9200, Naztec 980, Econolite ASC2, Econolite Cobalt.	Traffic signals over 4 phases or signals with the potential to expand beyond 4 phases. Cabinet can handle up to 40 detector channels and the mainframe can handle up to 24 channels. No longer used in new installations.
M	Concrete base	NEMA TS2-TYPE2 NEMA TS1	LMD 8000, LMD9200, Naztec 980, Econolite ASC2, Econolite Cobalt.	Pedestrian signals and traffic signals which are not foreseen to expand to beyond 4 phases. Cabinet and mainframe can handle up to 24 detector channels. No longer used in new installations.
PED X	Pole	Pedestrian Signal Controller	P6, Novax PXO II	Special crosswalk signals.

Table 15. Traffic Controller Assemblies and Applications.

- .2 The ministry uses several different types of traffic controllers. Designers shall confirm the type of controller with the Senior Traffic Operations Engineer.
- .3 Place controllers at the quadrant of the intersection which:
- .1 Provides the best view of signal operation.
 - .2 Is least susceptible to damage.
 - .3 Provides a suitable refuge for maintenance staff and vehicles.
 - .4 Is located as close as possible to the service panel.
- .4 Traffic Controller Assemblies should not be located in traffic islands.

TRAFFIC SIGNALS

- .5 For Traffic Controller Assemblies and concrete base installation details refer to drawings *SP635-1.1.38 to SP635-1.1.42 Controller Base Installation Details* in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .6 For traffic controller cabinet installation details, both base-mount and pole-mount, refer to drawings *SP635-2.7.1 to SP635-2.7.3 Controller Cabinet Installation Details* in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .7 Traffic engineers and/or designers shall orient the traffic controller cabinet and conduits into the controller bases as noted on drawings *SP635-1.1.38 to SP635-1.1.42 Controller Base Installation Details* in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .8 Traffic Controller Assembly installation, testing and commissioning shall be made by the Electrical Maintenance Contractor.

402.6.10 Advance Warning Flashers

- .1 Warrants - Advance warning flashers shall be used on each intersection approaches where at least one of the following is satisfied:
 - .1 The posted speed on the highway or roadway is 70 km/h or greater.
 - .2 The view of the signals is obstructed due to vertical or horizontal alignment, regardless of the posted speed limit, such that a safe stopping distance is not available.
 - .3 There is a grade approaching an intersection sufficient to require more than the normal braking effort.
 - .4 In cases where drivers are exposed to many kilometers of high speed driving, regardless of posted speed limit, and then encounter the first signal in a built-up community.
- .2 Timings - Advance warning timings shall be as follows:
 - .1 Advance warning flashers are timed to come on at a pre-determined or calculated number of seconds before the signals at an intersection turn yellow. This time is calculated so that a driver who passes the advance flashers as they are activated is afforded time to clear the intersection safely. The length of time the signs flash before the signals change to yellow is determined using Equation 14.

$$AW = \frac{D + D_p}{V} \quad \text{Equation 14}$$

where

TRAFFIC SIGNALS

- AW = advance warning time(s). This time shall be round up to next integer if a Naztec controller is used.
- D = distance (m) of the advance warning sign from the stop bar. Refer to 402.6.9.4 for distance calculation.
- D_p = minimum distance at which the flashers can be perceived
= 21.3 m
- V = posted speed limit (m/s).

- .2 Opposing advance warning flashers usually start flashing simultaneously. If advance warning flasher times differ both the LMD8000 and Naztec 980 controller deal with this differently as defined below:

LMD8000

- a) If opposing advance warning times differ by less than 0.5 seconds, the larger time of the two is used for both directions. However, if calculated advance warning times for opposing directions differ by more than 0.5 seconds, cascading advance warning is used. Cascading advance warning is not necessary at locations with opposing protected left turn phasing. This is to avoid a "left turn trap (yellow trap)".
- b) For cascading advance warning, flashers in opposing directions are set to begin at different times so that both directions of the signal change to yellow at the same time.
- c) The ministry uses external advance warning packages which apply stop time to the ring of the phase with advance warning. Effectively, this holds the phase green for a period equal to the advance warning time. When calculating maximum green times for phases with advance warning, the advance warning time shall be subtracted from the calculated green time. Otherwise, the phase will receive more green time than intended.

Naztec 980

- a) Advance Warning Operation - the Naztec controller uses a Trailing Green Extension overlap to provide the additional timing parameters required for advance warning operation.
- b) Cascading Advance Warning Operation - if cascading advance warning is required, the advance warning flashers will begin at different times. There is no external timing hardware to provide this function. The differential time between the two advance warning flashers is accomplished using an additional trailing green extension overlap.
- c) When calculating maximum green times for phases with advance warning, the advance warning time shall be subtracted

TRAFFIC SIGNALS

from the calculated green time. Otherwise, the phase will receive more green time than intended.

- .3 When advance warning flashers are required for only one direction, then the advance warning time will be applied to both directions. There will not be a sign in the direction not requiring advance warning flashers. In this case, there shall be a note on the *Signal Timing Sheet* indicating there is no advance warning for that given phase (i.e., No advance warning flashers for Highway 1 southbound (A2)).
 - .4 Advance warning also affects the offset during coordination. The ministry standard is to reference offsets from the end of the coordinated phase green which is also the end of the cycle. Because advance warning effectively moves that end point, the advance warning time shall be subtracted from the offset time.
 - .5 When advance warning signs are no longer warranted, the *Signal Timing Sheet* shall be amended to indicate disabled advance warning. The sign should be bagged when the *Signal Timing Sheet* is implemented and later removed.
 - .6 If the speed zone is changed and advance warning signs are in place and still warranted, the position and timing of the advance warning sign shall be recalculated, the sign moved, and a revised *Signal Timing Sheet* issued immediately with the new advance warning time indicated. Typically an existing advance warning sign location can be maintained in its current location if the timing can be maintained within 0.5 seconds of the required timing.
 - .7 Advance warning sign timing and placement in construction zones shall reflect the highest speed posted during construction and must be located to account for part-time construction zone speed limits.
 - .8 If the Naztec 980 controller is installed in a Type M or S cabinet, the external advance warning package can be used in place of the overlaps to provide advance warning operation.
-
- .3 Advance warning flasher signs are W-012-XXX for traffic signals and W-010-1XXX for railway crossings, as detailed in the ministry *Manual of Standard Traffic Signs and Pavement Markings*. For new signal locations 300 mm signal heads shall be used. For existing signals, 300mm yellow signal head section (to be confirmed with the Senior Traffic Operations Engineer) is located in each of the upper corners of the sign and operate in an alternating flashing mode at 60 flashes per minute with a symmetrical duty cycle.
 - .4 Advance warning flashers are placed before the stop line, at a distance equal to that required for a driver to perceive and react to the flashers and bring the vehicle to a comfortable stop. In the case of railway advance warning signs, the stop bar shall be located on the near side of the railway crossing. This is calculated using Equation 15 resulting in the values given in Table 19.

$$D = VT_{pr} + \frac{V^2}{2g(f + G)} \quad \text{Equation 15}$$

where

- D = distance from stop bar to advance warning (m).
 V = posted speed limit (m/s).
 T_{pr} = perception/reaction time
= 1.0 s
 g = gravitational acceleration
= 9.81 m/s²
 f = friction factor for wet surfaces
Friction factors will vary depending on speed. Refer to Table 18 for friction factors
 G = grade (m/100 m), positive for uphill and negative for downhill.

Note: When modifying an existing *Signal Timing Sheet* the traffic engineer and / or designer shall ensure the inter-green times have been calculated using the correct friction factor (f). Refer to Table 18 - for Friction Factors.

TRAFFIC SIGNALS

POSTED SPEED (KM/H)	FRICTION FACTOR
40	0.38
50	0.36
60	0.34
70	0.32
80	0.31
90	0.30
100	0.30

Table 16. Friction factors for wet pavement

TRAFFIC SIGNALS

		SIGN DISTANCE (m)					
		0.36 ⁽¹⁾	0.34 ⁽¹⁾	0.32 ⁽¹⁾	0.31 ⁽¹⁾	0.30 ⁽¹⁾	0.30 ⁽¹⁾
GRADE		50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h
D O W N H I L L	-8%	49	71	100	132	170	207
	-7%	48	70	97	127	164	199
	-6%	47	67	94	123	158	192
	-5%	46	66	91	119	153	185
	-4%	45	64	88	116	148	179
	-3%	44	62	86	112	143	173
	-2%	43	61	84	109	139	168
	-1%	42	60	82	106	135	163
	0%	41	58	80	104	131	159
U P H I L L	+1%	41	57	78	101	128	155
	+2%	40	56	76	99	125	151
	+3%	39	55	75	96	122	147
	+4%	39	54	73	94	119	143
	+5%	38	53	72	92	116	140
	+6%	37	52	70	90	114	137
	+7%	37	51	69	89	111	134
	+8%	36	50	68	87	109	131
⁽¹⁾ Friction factor							

Table 17. Advance warning sign distances

- .5 Advance warning signs are mounted overhead on davit style signal poles. For general sign installation details, refer to drawings SP635-3.3.1 to SP635-3.3.20 in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .6 For traffic signal advance warning flasher installation details, refer to drawings SP635-3.3.9 Large Overhead Extruded Aluminum Traffic Signal Advance Warning Sign Installation Details in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .7 For railway advance warning flasher installation details, refer to drawing SP635-3.3.10 Large Overhead Extruded Aluminum Railway Advance Warning Sign Installation Details in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .8 Advance warning signs shall not be illuminated.

- .9 Yellow LED flashers shall be used on advance warning signs. When advance warning signs are positioned immediately downstream of a horizontal curve LED flashers with uniform appearance LED signal heads should be used to ensure a sufficiently wide angle of visibility. The Dialight Uniform Appearance signal head, or equivalent, is acceptable for use.

402.6.11 Prepare to Stop at Railway Crossing Signs

- .1 This sign (W-010-1XXX) is activated by the approach of a train and warns motorists in advance of a railway crossing that the motorist will have to stop. Sign placement and timing will follow the same standards as advance warning flashers (Sub-clauses 402.6.9.).
- .2 Without restricting the intended usage, the W-010-1XXX Sign may be considered at locations where one or more of the following conditions exist:
 - .1 At railway signalized crossings on roadways with a posted speed of 70 km/h or greater.
 - .2 At signalized crossings where the view of the signals is obstructed due to vertical or horizontal alignment, regardless of the legal speed limit, such that a safe stopping distance is not available.
 - .3 At signalized crossings where there is a grade approaching the intersection sufficient to require more than the normal braking effort.
 - .4 At signalized crossings where environmental conditions frequently restrict visibility (e.g., fog or sunset glare).
- .3 Availability of power supply may require the consideration of a different advance warning strategy. Where power is not available, consult the *ministry* Electrical Representative, the Senior Traffic Operations Engineer and the Rail and Navigable Waters Coordinator.
- .4 Where both a W-012-XXX sign and a W-010-1XXX sign are warranted on the same approach road contact the Senior Traffic Operations Engineer to confirm if both are required.

402.6.12 Detectors

- .1 The ministry uses an inductive-loop detector system. For further explanation of this and other detector loop systems refer to the Institute of Transportation Engineers (ITE) *Traffic Detector Handbook*. The ministry will consider video or radar detection in place of inductive detectors where circumstances deem it appropriate. Video or radar detection can be very advantageous where:
 - .1 Stop bar or lane alignment is temporary, or
 - .2 Future paving is imminent, thus wasting inductive loops, or

- .3 Installation requires multiple detours
- .2 Refer to drawing *SP635-2.3.12 Video Detection Installation Detail* in Section 635 of the ministry *Standard Specifications for Highway Construction*. Cameras shall be mounted on special combination Type 2A Arms with extension for the camera or shall be mounted on the signal arms. The designer shall review the site condition, consult the manufacturer and select the most applicable mounting location. When using the special Type 2A Arm the designer shall review the site and confirm clearance from overhead power lines can be maintained. Locating cameras on type 2 shafts in medians is not permitted unless a suitable pole already exists at the location. Installing a new pole to support the camera should not in any way conflict with clear zone or be a potential hazard if knocked down.
- .3 Detector loops are required at all signalized intersections requiring vehicle actuation and counting, as well as at all traffic counter stations which are separate from signalized intersection activation/counting loops.
- .4 It is the ministry policy to count all movements at signalized intersections. Counting detector loops for each lane must have a separate detector input into the controller mainframe. Non-counting loops for a given phase movement may be connected in series if there is a shortage of detector channels. In cases where there are movements to be activated and counted and there is a shortage of detector channels, priority shall be given to counting the through movements, then the left turn movements, and lastly the right turn movements.
- .5 Because loop configurations are complex, a naming convention and definition for each type of loop is required, as well as a colour code to ensure quick and positive identification for construction and maintenance. The naming convention is shown in Figure 40. Specifications are to include both the naming convention and colour code.
- .6 For detector loop installation details, colour code and design information, refer to drawings *SP635-2.8.1 to SP635-2.8.17* in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .7 Due to their longevity, preformed detector loops are becoming more prevalent in ministry installations. Because they are installed before roadway markings are applied, their exact location must be known and documented to ensure the markings are positioned correctly in relation to the loops. Preformed loops are cost-effective provided there is little likelihood they will be dug up by utilities. Preformed loops shall be used at signalized intersections at the discretion of the ministry Manager, Electrical Services and shall be installed as specified in *SP635-2.8.15 to SP635-2.8.17* in Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .8 There are two standard detector loop types:

TRAFFIC SIGNALS

- .1 Diamond or round loops are used for all standard width lanes and free right turn lanes.
- .2 Larger size rectangular loops may be used for counting in free right turn lanes, off ramps, and on ramps where the lane is too wide for a single standard loop. Alternatively, two standard size loops may be used for wide lanes.
- .9 One diamond or round detector loop shall be installed in each through lane on the highway and two detector loops, one behind the other, shall be installed in all left turn lanes and in each lane on the cross street for all other activated movements. If traffic engineers and / or designers cannot determine which road is the highway and which is the cross street, contact the Senior Traffic Operations Engineer.
- .10 At all free right turn lanes, the detector counting loop(s) is positioned in the roadway so that it covers the path of all vehicles through the right turn. At traffic counter stations, only rectangular detector loops are installed in right turn lanes and ramps at interchanges.
- .11 Each detector loop shall be connected in the junction box with 2C No. 18 ministry Standard shielded cable which shall run in conduit to the traffic controller cabinet. The cables where possible, shall be separate from power conductors.
- .12 Loop inductance shall be a minimum of twice the shielded cable inductance. Shielded cable inductance is 0.56 μ h per meter.
- .13 For more information on layout and number of loops and preparation of the loop detector table, refer to Section 700.
- .14 Loop home run conductors from the junction box to the edge of asphalt shall run in a one inch RPVC conduit. Designers shall position one inch RPVC loop home run conduits to minimize the lengths of loop home run slots cut in the asphalt. Where the one inch loop detector conduits are more than ten meter in length, designers shall add an additional junction box.

402.6.13 Detector Loop Applications

- .1 The ministry uses many traffic signal loop configurations at signalized intersections and has developed typical loop locations and standard scenarios to simplify design.
- .2 The various signal loop configurations and scenarios are shown in Figure 40.
 - .1 **Front Stop Bar Loops** are the primary method of actuating the traffic signal. Once they actuate the signal. Further vehicle actuations automatically extend the green time of the signal phase. front stop bar loops shall be installed as follows:

TRAFFIC SIGNALS

- .1 One loop in each lane for through movements where the traffic signal will rest (typically the major movement and street).
- .2 Two loops in each lane of the minor movement (typically minor street).
- .3 Two loops in each left turn lane.
- .4 Only one loop is to be located in all dedicated right turn lanes. By default all dedicated right turn lane loops only count volumes. The Senior Traffic Operations Engineer shall indicate if the loop is to actuate the signal as well.
- .2 **Back Stop Bar Loops** are typically used where a second set of stop bars are used in advance of the primary stop bars. They are typically required where railway tracks are in close proximity to the primary stop bars thus reducing the possibility of vehicles stopping on the tracks.
 - .1 On the main street, the use of back stop bar loops shall be confirmed with the Senior Traffic Operations Engineer. Where back stop bar loops are deemed necessary on the main street, each lane shall have one loop.
 - .2 On the minor street two back stop bar loops shall be installed in each lane.
- .3 **Advance/Extension Loops** are used to extend the green time on the major movement by providing a larger detection zone to determine if there is any approaching traffic. They shall be used in conjunction with advance warning flashers. The use of advance loops shall be confirmed with the Regional Traffic Engineer.
 - .1 If advance/extension loops are required, there shall be one loop per lane, which shall generally be located near the advance warning sign pole. The loops shall be connected together in series at the nearest junction box with only one shielded lead-in cable required in all Regions.
- .4 **Left Turn Set Back Loops** are used to actuate the left turn movements. Left turn set back loops must be active along with the front stop bar loop(s) in the same lane in order to activate the advance left turn arrow.
 - .1 The traffic engineer shall confirm the need for these loops in consultation with the Senior Traffic Operations Engineer and shall determine the need and exact location of the left turn set back loops.
- .5 **Queue Loops** are used to determine the presence of long queues in left turn (or other) lanes, which may adversely impact the safe movement of traffic (i.e., backup of traffic into an adjacent through lane). They are also required for signals on freeway off-ramps to prevent the traffic from queuing onto the freeway creating a safety

- issue. If a queue is detected, the signal shall either enact a pre-emptive phase or extend green time via max plans as determined by the traffic engineer. Consult with the Senior Traffic Operations Engineer to determine the requirement for queue loops.
- .6 **Count Loops** are used to perform volume counts on individual lanes. Typically, through lane stop bar loops also count vehicular volumes for their respective lane. For left turn lanes the rear loops count vehicular volumes for their respective lane.
1. Count loops shall be installed in all free-right turn lanes (lanes that do not form part of the stop bar loops). The count loops shall be rectangular, round or diamond.
- .7 **Bicycle Loops** may be used exclusively for bicycle detection or a paint marking may be added to an existing vehicle detection loop to indicate to the cyclist the location of optimal detection. See the *Standard Specifications for Highway Construction* drawing SP635 2.3.15 for details on bicycle loops and markings.

TRAFFIC SIGNALS

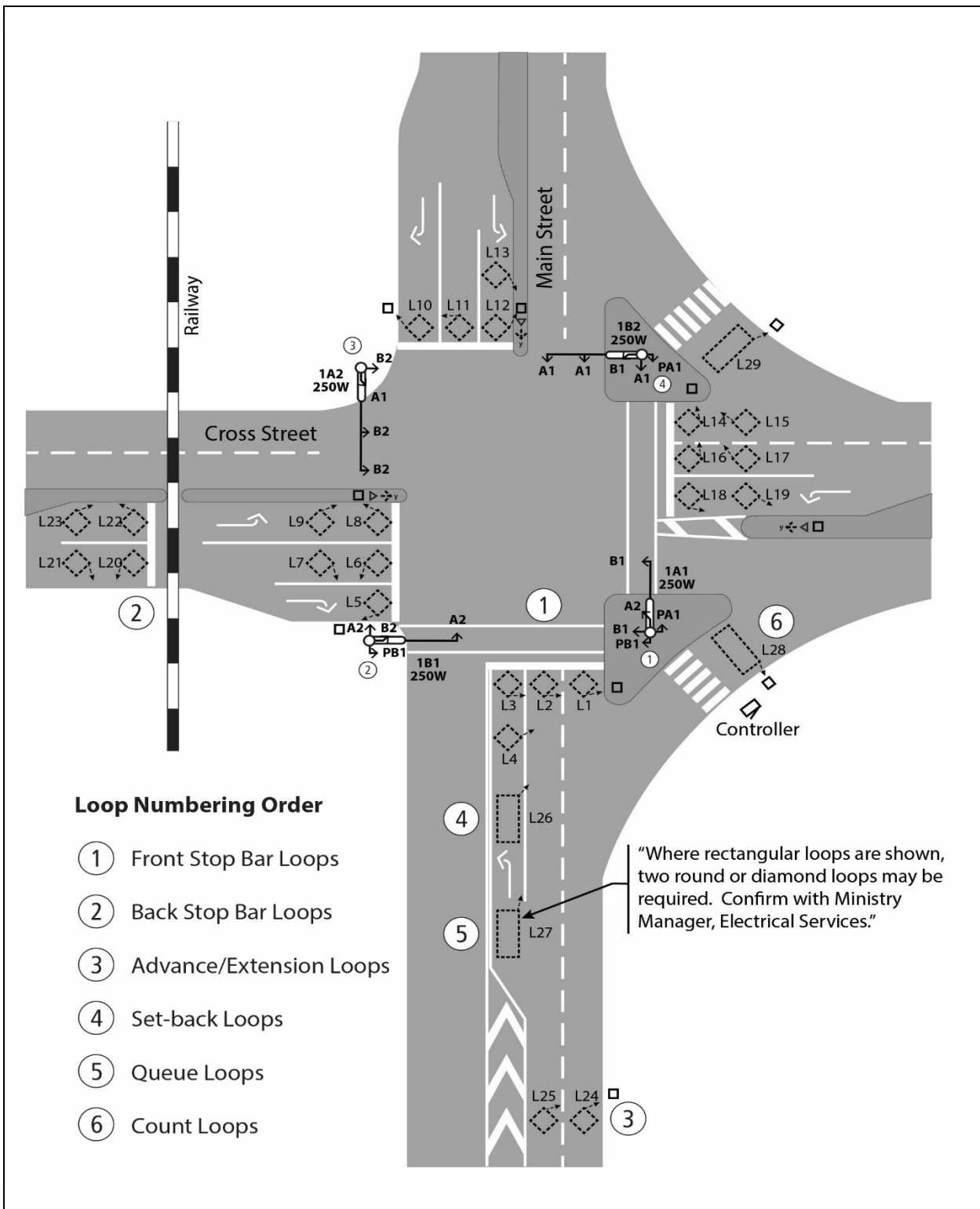


Figure 40. Loop detector numbering and layout

402.6.14 Wheelchair Ramps

- .1 Wheelchair curb ramps are required at all marked crosswalks.
- .2 Designers shall:
 - .1 Show the location and orientation of all wheelchair ramps on the drawings.
 - .2 Avoid placing poles and junction boxes in wheelchair ramps.
- .3 ministry *Standard Specifications for Highway Construction* Standard Drawings SP582-07.02.01 to SP582-07.02.03 show sidewalk details and drawings SP582-07.03 shows island ramp construction details.

402.6.15 Interconnection Signals

- .1 Traffic signals in close proximity to one another may require interconnection; this may be by wireless, wired, or fibre optic link. The type of interconnection shall be confirmed with ministry Electrical and ITS Engineering and the Senior Traffic Operations Engineer.
- .2 Wired interconnect shall be made with a shielded cable installed in a dedicated 50mm RPVC conduit. The signal interconnect cable shall be installed from controller to controller with no splices. In most cases, the controllers are fed from separate electrical services; therefore the bond wire shall not be continuous. Confirm exact signal cable type with the ministry Electrical and ITS Engineering.
- .3 The ministry Electrical Maintenance Contractor will make all connections in the controllers.

402.6.16 Signs on Signal Poles

- .1 Signs mounted on poles that are related to the traffic signal shall be shown on traffic signal pole elevations. It is the responsibility of the designer to confirm the required signing by referencing the ministry's *Manual of Standard Traffic Signs and Pavement Markings* and consulting with the Senior Traffic Operations Engineer.
- .2 Signs typically mounted on a signal pole arm generally include:
 - .1 G-007-2 O/H-x street name sign or for two streets on one sign G-007-3 O/H.
 - .2 R-015-L or -R series turn control signs (including R-015-Tab (time restriction tab), where required).

TRAFFIC SIGNALS

- .3 R-016 or R-017 and R-018 series turn control signs.
- .4 R-109-1L series left turn signal signs.
- .5 R-109-1R series right turn signal signs.
- .6 R-109-1 delayed tab.
- .7 R-110-3 series left turn yield except on green arrow signs.
- .8 R-110-1 or -2 series left turn arrow restriction signs.
- .3 Signs on signal pole arms shall be mounted as shown on the drawings *SP635-3.1.1 to SP635 3.1.22* in Section 635 of the ministry *Standard Specifications for Highway Construction*. Mounting hardware will vary depending on pole type and sign size.
- .4 Signs typically mounted on pole shafts generally include:
 - .1 G-007-2 O/H-x street name sign or for two streets on one sign G-007-3 O/H.
 - .2 R-015-L or -R series turn control signs (including R-015-Tab (time restriction tab), where required).
 - .3 R-016 or R-017 and R-018 series turn control signs.
 - .4 R-109-1L series left turn signal signs.
 - .5 R-109-1R series right turn signal signs.
 - .6 R-109-1 delayed tab.
 - .7 R-110-3 series left turn yield except on green arrow signs.
 - .8 R-110-1 or -2 series left turn arrow restriction signs.
 - .9 R-014R series keep right sign (mounted on all median mount left turn signal posts).
 - .10 W-54 series hazard signs.
- .5 Signs mounted on pole shafts shall be bolted or banded to the shaft.
- .6 The designer shall show all required W-12 signs in accordance with the ministry *Manual of Standard Traffic Signs and Pavement Markings*.
- .7 Where tabs are required on signs, they shall be fabricated as part of the sign as the standard sign mounting hardware is not designed to accommodate two-piece signs.

402.6.17 Bicycle Signal Activation Guidelines

- .1 The ministry Cycling policy was officially implemented in February 2000. It requires that provision for cyclists be made on all new and upgraded provincial highways. All exceptions to this policy must be subject to an evaluation procedure as outlined in the ministry *Cycling Guide* published in April 2000.

TRAFFIC SIGNALS

- .2 The electrical designer shall ensure that provisions for cyclists are made on all new and upgraded traffic signal designs on designated cycling routes.
- .3 Prior to starting the traffic signal design, the designer shall:
 - .1 Become familiar with the current revision of the ministry *Cycling Guide*.
 - .2 Contact the applicable ministry Senior Traffic Operations Engineer or designate and the relevant municipality to:
 - .1 Determine if there are any current cycling issues relating to the project location,
 - .2 Identify the types of treatments currently used in the municipality and,
 - .3 Identify whether any of the roadways are designated cycling routes.
- .4 Contact the Electrical and ITS Engineering Services and the Senior Traffic Operations Engineer for technical direction for accommodating cyclists at the traffic signal based on the responses to the previous two items.
- .5 On designated cycling routes, the design shall incorporate features to accommodate cyclists as specified by the Senior Traffic Operations Engineer, such as additional pushbuttons, curb-side pushbutton posts, vehicle or bicycle detector loops, pavement markings and / or signing.
- .6 On non-designated cycling routes, the design should consider the requirement for the same bicycle features and incorporate these features as specified by the Senior Traffic Operations Engineer.
- .7 All exceptions to this policy must be evaluated and documented as per the ministry *Cycling Guide*. Only designs complying with these procedures will be approved.
- .8 Refer to drawing *SP635-2.3.14 Pushbutton Post Installation Details* for bicycle pushbutton installations and *SP635-2.3.15 Bicycle Detector Loops and Markings* for typical pavement markings and bicycle detection loop placement.

402.6.18 Countdown Pedestrian Signals

- .1 Countdown pedestrian signals can aid in the safe movement of pedestrian traffic. The countdown signals typically fit into a standard pedestrian signal enclosure with LED numerals that can be configured to count down from a pre-set number of seconds to zero in 1 second intervals.
- .2 All new traffic signals shall include countdown pedestrian signals as part of the design.

TRAFFIC SIGNALS

- .3 Existing signals should have countdown pedestrian signals added as funding becomes available through rehabilitation and upgrade programs. The Designer should contact the Senior Traffic Operations Engineer who will then consult with the Manager, Electrical Services and local jurisdictions to prioritize the installation for existing intersections.
- .4 Pedestrian actuation information provided by the cast aluminium PS-015 series signs may continue to be used unless the Senior Traffic Operations Engineer requests the use of the more educational ZPS-015-5 sign.
- .5 Signalized intersections using countdown pedestrian signals shall be designed to operate as follows:
 - .1 Countdown pedestrian signals shall be configured so that the numerical display is enabled and begins counting down simultaneously with the flashing “DON’T WALK” at the start of the pedestrian clearance time. After counting down to zero the numerical display shall be blank and remain blank through all signal phases until the beginning of the next pedestrian clearance interval.
 - .2 If the pedestrian clearance time cannot be provided, which may be the case for many railway pre-emption sequences, a pedestrian countdown signal shall not be implemented.
 - .3 When a signal receives a pre-emption call, the walk indication time may be shortened as required, however the pedestrian clearance time shall not be altered.
 - .4 If the controller pre-empts during the “WALK” indication the controller shall immediately change the “WALK” display to flashing “DON’T WALK” and enable the numerical display which shall begin counting down and reach zero at the same time as the flashing “DON’T WALK” becomes solid.
 - .5 If the controller pre-empts during the flashing “DON’T WALK,” the countdown shall continue to count down without interruption and reach zero at the same time as the flashing “DON’T WALK” becomes solid.
 - .6 The next cycle following the pre-emption event shall use the normal programmed values for the pedestrian timings.
 - .7 When countdown pedestrian signals are to be installed at a signalized intersection they should be installed on all signalized pedestrian legs.
- .6 Signal Display Conventions:
 - ⇒ “WALK” indication = “walking person”
 - ⇒ flashing “DON’T WALK” indication = flashing “upraised hand”
 - ⇒ solid “DON’T WALK” indication = solid “upraised hand”

402.6.19 Uninterruptible Power Supplies (UPS)

- .1 Traffic Signals normally operate using electrical power supplied by the local power utility. When utility power is interrupted, the traffic signal will cease to function and could cause substantial delay to travellers and increased the risk of collisions. Additionally, other traffic control and warning devices become inoperative when power is lost. Standard ministry policy is that all traffic signals and warning systems that form part of the traffic signal shall have a backup power provided by a UPS.
- .2 All UPS, including the cabinet(s), shall be installed and wired by the ministry Electrical Maintenance Contractor.
- .3 All UPS units used with ministry traffic signals shall be listed in the ministry *Recognized Product List*.
- .4 The UPS shall not cause the traffic controller to go into flash when batteries are depleted.

402.7 PRE-EMPTION

402.7.1 General

- .1 This section deals primarily with requests for traffic signal pre-emption from agencies outside the ministry such as municipal, transit, and fire protection authorities.
- .2 For ministry initiated pre-emption (e.g., rail and vehicle queue pre-emption) the designer shall discuss the design requirements with the ministry Rail and Navigable Waters Coordinator or the Senior Traffic Operations Engineer.
- .3 Requests available are (highest to lowest priority):
 - .1 Railway pre-emption (initiated by ministry).
 - .2 Emergency vehicle pre-emption.
 - .3 Vehicle queue pre-emption (initiated by ministry).
 - .4 Transit pre-emption.
 - .5 Transit priority.
- .4 For pre-emption warrants and timing information, refer to 402.5.16, 402.5.17 and 402.5.18.
- .5 For pre-emption drafting presentation standards refer to Section 700.
- .6 The designer shall verify all the following information before beginning a design for pre-emption requests:
 - .1 District Transportation Manager or designate confirms the type of pre-emption technology requested and ensures cost sharing is in place.

- .2 Senior Traffic Operations Engineer receives a completed and signed *Traffic Engineering Checklist*. This will identify the priority of phasing and signal display.
- .3 Controller Group, Electrical and ITS Engineering Services (EEC), confirms the capability of existing controller cabinet to handling new requests.

402.7.2 Railway Pre-emption

- .1 Transport Canada regulates railway crossing safety and has implemented the standard *Railway Signal & Traffic Control Systems Standards 3* describing basic design principles for railway signal and traffic control systems. These are:
 - .1 3.1: Railway signal and traffic control systems shall be designed using fail safe principles.
 - .2 3.2: Railway signal and traffic control systems shall, so far as possible, be arranged so that failure of any part of the system shall cause affected signals to give the most restrictive indications that the condition requires.
 - .3 3.3: All control circuits, the functioning of which affects safety of train operation, shall be designed on the closed-circuit principle.
 - .4 3.4: Railway signal and traffic control systems shall be so interconnected that aspects to proceed cannot be displayed simultaneously for conflicting movements, except that opposing signals may indicate "proceed at restricted speed" at the same time for switching movements only.

This standard has been enacted to ensure traffic signals interconnected to railway signals do not conflict with train movements when any components of the systems fail (railway crossing signal, interconnection cables/components or the traffic controller). This will allow the traffic controller to clear traffic from the crossing prior to going into four-way flash at the traffic light. This type of interconnection is to be implemented at all new or reconstructed interconnected traffic signals where it is suitable for traffic operations and the railway signal system will accept this type of interconnection.

TRAFFIC SIGNALS

- .2 Project Traffic Engineers shall contact the appropriate railway signal designers when undertaking a traffic design involving a traffic signal/railway signal interconnect to ensure designs are coordinated and shall show the requirement for six wire double break and supervisor circuits on all *Traffic Engineering Checklist* and *Signal Timing Sheets*. These circuits are detailed in section 504.5.12 of this manual.
- .3 Traffic controllers shall be equipped with two relays and internally wired as noted in the schematic in section 504.5.12 of this manual. Railway controllers shall be equipped with one relay and wired as noted in the schematic in section 504.5.12 of this manual.
- .4 Traffic signals designers shall specify interconnect wiring as noted on the attached table in section 504.5.12 of this manual.

For ministry railway pre-emption:

- .5 This request will terminate the current phase and cannot be overridden by any other pre-emption request.
- .6 The railway pre-emption request for traffic signals contains the following components:
 - .1 Traffic Controller Assembly (TCA) pre-emption interface.
 - .2 LED "No Left Turn" and/or "No Right Turn" signs (as required).
 - .3 Hard wire connection from the railway signal controller.

402.7.3 Emergency Vehicle Pre-emption

- .1 This request will terminate the current phase and implement emergency pre-emption on a first come, first served basis. This request will not override railway pre-emption.
- .2 Emergency pre-emption requests at traffic signals contain the following components:
 - .1 Pre-emption sensors, associated electronics, cabinet and wiring.
 - .2 Traffic Controller Assembly pre-emption interface. Traffic Controller Assembly interface equipment may vary depending on pre-emption type and cabinet assembly type.
 - .3 Pre-emption indicating lights (optional).

402.7.4 Vehicle Queue Pre-emption

- .1 Although this priority will not override emergency or railway pre-emption, it will terminate the current phase and implement a queue pre-emption.
- .2 Vehicle queue pre-emption does not require specialized equipment or input from non-ministry agencies.
- .3 Vehicle queue pre-emption utilizes vehicle detection (e.g., detection loops) which is part of the signal operation system.

402.7.5 Transit Pre-emption (Low Priority)

- .1 Although this priority will not override emergency or railway pre-emption, it will terminate the current phase and implement a transit pre-emption.
- .2 Transit pre-emption requests at traffic signals contain the following components:
 - .1 Transit sensors.
 - .2 Traffic Controller Assembly pre-emption interface.
 - .3 Pre-emption indicating lights (optional).
- .3 Note: Transit Signal Priority (TSP) is not available in the LMD 8000 controllers.

402.7.6 Transit Priority

- .1 This request may provide additional movements or extra green time for transit vehicles.
- .2 Transit priority requests at traffic signals contain the following components:
 - .1 Transit sensors.
 - .2 Traffic Controller Assembly pre-emption interface.
 - .3 Priority indicating lights (optional).

402.7.7 Railway, Emergency, or Transit Pre-emption Systems

- .1 Pre-emption sensors, electronics, and cabinet.
 - .1 The ministry permits the installation of various types of technologies for initiating emergency pre-emption at traffic signals.
 - .2 Current pre-emption technologies are as follows:
 - .1 Siren activated (emergency vehicle pre-emption).
 - .2 Radio activated. (emergency vehicle and transit pre-emption/priority).

TRAFFIC SIGNALS

- .3 Digital cellular (CDPD). (emergency vehicle and transit pre-emption/priority).
- .4 Vehicle Detector Loops (transit pre-emption/priority).
- .5 Hard wire connections (rail, emergency vehicle and transit pre-emption/priority).
- .6 GPS activated (emergency and transit pre-emption/priority).
- .3 Pre-emption sensors (use with emergency vehicle and transit pre-emption/priority pre-emption) - detect when pre-emption should occur, and which direction of pre-emption is being requested. The pre-emption electronics are housed in a standard cabinet (pre-emption controller cabinet).
- .4 A hardwire interconnection is used between the signal controller and fire hall or rail controller. Connection to a fire hall is accomplished using either dedicated wire or telephone lines. Railway pre-emption is provided by a direct hard wire connection from the railway controller to the signal controller.
- .5 The municipality in consultation with their emergency response personnel generally selects the type of pre-emption technology. The ministry attempts to accommodate all requests by using a standardized interface to the different types of pre-emption equipment. The ministry does not allow any manufacturer-specific equipment inside the traffic controller cabinet.
- .6 The sensors (where required) are generally installed on the signal or luminaire pole and wired to the pre-emption controller cabinet. The pre-emption controller takes the sensor information and converts it to electronic signals that select the direction of pre-emption being requested. These signals are then sent to the traffic controller cabinet via hardwire (4 pair cable) to initiate pre-emption. One pair is used per direction of pre-emption.
- .7 The pre-emption controller is housed in a standard 12"x16"x20" CSA 4X pole mount cabinet as shown in the ministry Electrical & Signing Material Standard Drawings MS1102.1 to MS1102 .6. Pre-emption cabinets are supplied by the ministry and are made available to the pre-emption equipment manufacturer for installation of the card and rack, terminal blocks and testing of the system.
- .8 For pre-emption cabinet installation reference drawing *SP635-2.4.2 100A – Service Panel Installation Details for Overhead Drop Service* from section 635 of the *Standard Specifications for Highway Construction*.
- .2 Traffic Controller Assembly (TCA) Pre-emption Interface
 - .1 Cables from the pre-emption controller cabinet, from the railway controller, or directly from the fire hall are fed into the traffic

TRAFFIC SIGNALS

controller cabinet through the conduit system and are connected to a pre-emption interface card (legacy equipment) or isolators installed in the controller cabinet (NEMA TS1).

- .2 Interface cards are installed in the TS1 controller cabinet to ensure the signals received are electronically isolated from the Traffic Controller Assembly unit.
- .3 The number of Traffic Controller Assembly interface cards required will affect the type of controller cabinet chosen. As shown in Table 20, each card is capable of three pre-emption's, two all-purpose pre-emption's and one railway pre-emption. A Type M rack cabinet can accommodate one card while a Type S can accommodate two cards. Interface cards also control the emergency blue and white indicating lights and tie into the conflict monitor in the Traffic Controller Assembly. This applies only to legacy equipment (NEMA TS1). NEMA TS2-1 P6 cabinets use the 6-wire interconnect system and do not connect directly to the blue/white priority indication lights.
- .4 Installing complex pre-emption equipment in older shelf mount cabinets is not recommended because a significant amount of rewiring is required to update the cabinet. An assessment of the suitability of the cabinets must be made prior to finalizing the design.

TRAFFIC SIGNALS

PRE-EMPTION TYPE	PRE-EMPTION #		TYPICAL PHASES
	M CABINET	S CABINET	
Card 1 - All purpose	1	1	A1, A1/A2, or A1/A1→
Card 1 - All purpose	2	2	A2 or A2/A2→
Card 1 - Rail	3	3	Rail
Card 2 - All purpose	N/A	4	B1, B1/B2, or B1/B1→
Card 2 - All purpose		5	B2 or B2/B2→
Card 2 - Low priority		6	Low Priority

Table 18. Pre-emption card capabilities of type M and S cabinets.

PRE-EMPTION TYPE	PRE-EMPTION #	TYPICAL PHASES
Rail	1	Rail
Rail	2	Rail
Emergency	3	A1, A1/A2, or A1/A1→
Emergency	4	A2 or A2/A2→
Emergency	5	B1, B1/B2, or B1/B1→
Emergency	6	B2 or B2/B2→
Transit or Low Priority	7-10	Transit/Low Priority

Table 19. Pre-emption capabilities for P6 cabinets

.3 Signal Traffic Controller Assembly Programming

- .1 The Traffic Controller Assembly unit is programmed to accept a number of pre-emption inputs and to implement a pre-defined phase sequence. The traffic engineer in consultation with the municipality, railway authority or other authority defines the phase sequence. The ministry performs the programming.

.4 Pre-emption Indicating Lights

- .1 Pre-emption indicating lights:

TRAFFIC SIGNALS

- .1 Indicate to the emergency or transit vehicle driver the current status of the pre-emption at the signal.
- .2 Are normally mounted on signal or luminaire poles.
- .3 Are optional.
- .2 The designer should consult with the municipality to determine which system they are supplying.
- .3 The options for emergency indicating lights are described as follows:
 - .1 One pair (set) of omni-directional lights as follows:
 - .1 They are located in one quadrant of the intersection. The lights are turned on when the controller is displaying the requested phase after the pre-emption signal has been received. The light is not displayed while the controller is sequencing to find the applicable pre-emption phase. These indicating lights are applicable for an intersection where only one direction of pre-emption is required (refer to drawing *SP635-2.3.9 Fire Signal Indication Light Installation Detail* in Section 635 of the ministry *Standard Specifications for Highway Construction*)
 - .2 The omni-directional lights shall be placed so they are visible to the movement of emergency vehicles. Usually the best location is the same pole that the primary signal heads for that movement are mounted on.
 - .2 A pair of blue and white lights mounted facing each approach as follows:
 - .1 The pre-emption equipment manufacturer supplies this style of indicating lights.
 - .2 Using this option, there can be up to four sets of lights for a four leg intersection. Vehicles requesting pre-emption for a particular approach trigger the white light to start flashing for that direction and the blue light to flash for all other directions. When the controller has sequenced to the applicable phase, the flashing white light turns to a steady white light and remains white until the pre-emption call drops off, the MAX time programmed in the controller times out, or the MAX time built into the interface card times out. The blue lights remain flashing throughout the pre-emption sequence.

- .3 White lights mounted facing each approach as follows:
 - .1 This style of indicating lights are supplied by the manufacturer.
 - .2 Using this option, there can be up to four white lights for a four-leg intersection. Vehicles requesting pre-emption on an approach, trigger the white light to start flashing for that direction. When the controller has sequenced to the applicable phase, the flashing white light turns to a steady white light and remains white until the pre-emption call drops off, the MAX time programmed in the controller times out, or the MAX time built into the interface card times out. The lights for the other directions are off.
- .5 "LED "No Left Turn" Sign
 - .1 LED "no left turn" signs may be used in conjunction with rail pre-emption at intersections where it is possible for vehicles to turn left and then stop and block the intersection because a train is crossing. They are not required where a protected left turn signal exists for that movement.
 - .2 These signs should be considered at intersections where traffic making the left turn onto the railroad tracks has a minimal storage area on the crossing approach and may queue into the intersection.
 - .3 The Senior Traffic Operations Engineer and the ministry Rail and Navigable Waters Coordinator Electrical and ITS Engineering Services shall determine the requirement for LED "no left turn" signs.
 - .4 Immediately upon receiving a rail pre-emption call, the traffic controller shall turn on the "no left turn" blank-out sign except for signals with protected/permissive left turn phases. Signals with protected/permissive left turn phases shall serve the minimum green time and the associated yellow time as per pre-emption entry timing standards, before the "no left turn" blank-out sign is activated. The sign shows a symbolic "No Left Turn" message, a white left turn arrow surrounded by a red circle with a red slash through it, and the message "TRAIN XING" in white text flashing underneath.
- .6 LED "No Right Turn" Sign
 - .1 LED "no right turn" signs may be used in conjunction with rail pre-emption at intersections where the railway crossing signal is not visible from the right turn lane and where the volume of right turning vehicles towards the rail crossing is such that vehicles will queue

through the storage between the rail crossing and the intersection and impede the highway through movement.

- .2 The Senior Traffic Operations Engineer and the ministry Rail and Navigable Waters Coordinator shall determine the requirement for LED "no right turn signs".
- .3 Immediately upon receiving a rail pre-emption call, the traffic controller shall turn on the "no right turn" blank-out sign except for signals with protected/permissive left turn phases. Signals with protected/permissive left turn phases shall serve the minimum left turn green time and the associated yellow time before the "no right turn" blank-out sign is activated. The sign shows a symbolic "no right turn" message with a white right turn arrow surrounded by a red circle with a red slash through it and the message "TRAIN XING" in white text flashing underneath.

402.7.8 Approval Process and Division of Responsibilities

- .1 The ministry generally does not initiate the installation of signal pre-emption for emergency or transit pre-emption.
- .2 The municipality, transit authority or other designated authority shall make all applications for the installation of traffic signal pre-emption equipment.
- .3 All requests for the installation of pre-emption equipment shall be made to the District Transportation Manager. Contact the District Transportation Manager for the application form.
- .4 The requesting authority shall provide the proposed pre-emption technology, pre-emptive phasing and schedule for installation. The ministry will evaluate the request and, if acceptable, will provide approval to proceed.
- .5 The ministry will prepare the signal design and will coordinate the installation of the pre-emption equipment. The division of responsibility for the supply, installation and maintenance of various types of pre-emption equipment is contained in Table 22 and Table 23.
- .6 The requesting authority is responsible for the testing, commissioning and maintenance of the pre-emption equipment once the contractor has completed the installation.

TRAFFIC SIGNALS

RAILWAY PRE-EMPTION			
COMPONENT:	WHO SUPPLIES?	WHO INSTALLS?	WHO MAINTAINS?
ELECTRONICS:			
Interface in controller	Contractor	Contractor	EMC
Railway advance warning sign and controller	Contractor	EMC	EMC
Electronics in railway cabinet	Railway	Railway	Railway
HARDWARE:			
Interface in controller	Contractor	Contractor	EMC
LED "no left turn" or "no right turn" sign	Contractor	EMC	EMC
Mounting hardware	Contractor	EMC	EMC
WIRING:			
Control cable from railway control cabinet and to controller	EMC	EMC	EMC

Table 20. Railway activated pre-emption and advance warning sign responsibilities.

TRAFFIC SIGNALS

SIREN ACTIVATED (EMERGENCY ONLY)			
COMPONENT:	WHO SUPPLIES?	WHO INSTALLS?	WHO MAINTAINS?
ELECTRONICS:			
Electronics in pre-emption cabinet	Municipality	Municipality	Municipality
HARDWARE:			
Pre-emption cabinet	Ministry	Ministry	Ministry
Spring hanger and signal housing	Ministry	Ministry	Ministry
Microphones	Municipality	Ministry	Municipality
Pre-emption indicating lights	Municipality	Ministry	Municipality
WIRING:			
120VAC wiring from pre-emption cabinet to pre-emption indicating lights	Ministry	Ministry	Ministry
Control cable from sensor to pre-emption cabinet	Municipality	Ministry	Ministry
Control cable from pre-emption cabinet to controller	Ministry	Ministry	Ministry

Table 21. Siren activated pre-emption responsibilities.

403 PEDESTRIAN SIGNALS

403.1 GENERAL

- .1 Pedestrian signals only serve pedestrian traffic and are installed in locations with high pedestrian traffic, such as schools. Pedestrian traffic signals are generally installed at intersections. The installation of mid-block signals should be avoided, where possible. Cross street traffic is controlled by stop signs. The Traffic Engineer shall confirm the need for cyclist activation.
- .2 Refer to the ministry's *Pedestrian Crossing Control Manual* for pedestrian signal warrants and additional information.

403.2 DATA REQUIRMENTS

- .1 A physical layout of the site conditions should be prepared, and the following inputs considered when undertaking warrant analysis:
 - .1 Intersection geometry.
 - .2 Channelization.
 - .3 Grades.
 - .4 Sight-distance restrictions.
 - .5 Bus stops and routings.
 - .6 Parking conditions.
 - .7 Signs and pavement markings.
 - .8 Street lighting.
 - .9 Driveways.
 - .10 Location of nearby railroad crossings.
 - .11 Distance to nearest signals.
 - .12 Utility poles and fixtures.
 - .13 Adjacent land use.

403.3 WARRANT

- .1 Refer to the ministry's *Pedestrian Crossing Control Manual for British Columbia* for details on Warrants.

403.4 PHASING

403.4.1 Signal Operation

- .1 Pedestrian signals rest on the highway flashing green. Once the pedestrian pushbutton is pressed and the minimum flashing green time is exceeded, the

PEDESTRIAN SIGNALS

signal displays solid green for 5 seconds. The yellow and red clearance interval is displayed on the highway and the pedestrian phase is serviced. The signal then returns to the highway flashing green once the pedestrian phase has timed its clearance.

403.4.2 Phase Assignment

- .1 Pedestrian signals have two phases which operate as shown in Figure 41.

PEDESTRIAN SIGNALS



Figure 41. Pedestrian signal phasing

403.5 TIMING

- .1 All signal timings shall meet the approval of the Senior Traffic Operations Engineer. Traffic engineers and / or designers shall provide all background data and calculations as required by the Senior Traffic Operations Engineer.
- .2 Signal timings shall be submitted on a ministry *Signal Timing Sheet*. An example of the *Signal Timing Sheet* is located in Appendix 400. Refer to 403.5.1 to 403.5.5 for the timing information required on the *Signal Timing Sheet*.

403.5.2 Pedestrian Walk Intervals

- .1 A pedestrian walk interval is the time during which a "WALK" indication is displayed on a pedestrian signal head. During this time, pedestrians may start to walk across traffic lanes in a crosswalk. The "WALK" indication should be displayed for a minimum amount of time, allowing pedestrians time to notice and react to the signal.
- .2 A walk interval of 7 seconds should be used.

403.5.3 Pedestrian Clearance Times

- .1 Crosswalks:
 - .1 Longer than 24 meters, pedestrian refuges may be considered.
 - .2 Which cross pedestrian refuges can be considered as two separate crosswalks.
- .2 To be considered a pedestrian refuge (as defined in the ministry *BC Supplement to TAC Geometric Design Guidelines*), central islands or medians shall:
 - .1 Provide pedestrian signal heads and pushbuttons for both directions.
 - .2 Have a level wheelchair accessible area of at least 1.2 m x 1.2m. This does not include any ramps.
- .3 Pedestrian clearance time is defined as the time required for a pedestrian entering a crosswalk at the end of the walk interval to comfortably reach the safety of a pedestrian refuge or the other side of the road.
- .4 Refer to 402.5.7 for a discussion of calculating pedestrian clearance times.

403.5.4 Vehicle Phase Green

- .1 The default flashing green time is 20 seconds. This may be increased or decreased at the discretion of the Senior Traffic Operations Engineer.

PEDESTRIAN SIGNALS

- .2 For purposes of the controller timing sheet, the flashing green on the highway is achieved by setting the WALK to flash and setting RECALL to CNA. The flashing time is entered as the highway WALK time and the solid green 5 seconds is entered as the pedestrian clearance for the highway phase.

403.5.5 Vehicular Clearance and Yellow/Red Split

- .1 These are calculated in the same manner as for traffic signals, except that for pedestrian signals the all-red interval for the vehicular movement is always 2.0 seconds. The yellow time shall be the calculated intergreen time minus the 2.0 second red. Refer to 402.5.3 for details.

403.5.6 Coordination

- .1 Pedestrian signals may be part of a coordinated system. Refer to 402.5.12 through 402.5.15 as references, along with the following.
- .2 When calculating the coordination timing the pedestrian phase determines the minimum phase timings as shown in Equation 16 and Equation 17. Refer to Figure 42.

$$P_{PB-min} = W + PC + Y \quad \text{Equation 16}$$

where

P_{PB-min} = minimum phase time on pedestrian phase (s)
W = walk time (s)
PC = pedestrian clearance time - flashing orange hand (s)
Y = solid orange hand (s). Cross street inter-green time

$$P_{A-min} = W + PC + AW + Y + R \quad \text{Equation 17}$$

where

P_{A-min} = minimum phase time on vehicle phase (s)
W = minimum vehicle flashing green time (s)
PC = vehicle solid green time (s)
= 5 s.
AW = advance warning (s)
Y = yellow time (s)
R = all red time (s)

PEDESTRIAN SIGNALS

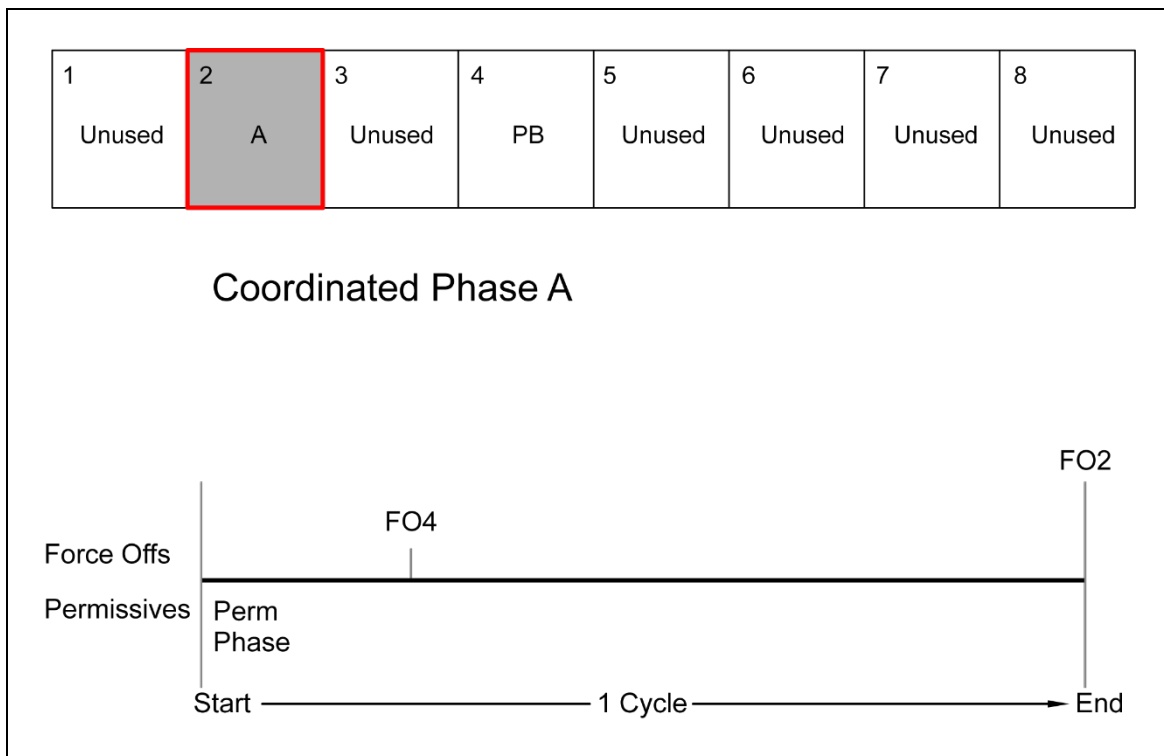


Figure 42. Pedestrian signal in coordination

- .3 The force-off is calculated using Equation 18, the start permissive is 0 and the end permissive is calculated using Equation 19.

$$FO = G_{solid} + I + AW + W + PC \quad \text{Equation 18}$$

where

FO = force-off of pedestrian phase
 G_{solid} = solid green time on vehicle phase (s)
 = 5s
 I = vehicular clearance time (s)
 AW = advance warning of vehicle phase (s)
 W = pedestrian walk time (s)
 PC = pedestrian clearance time (s).

- .1 To calculate a pedestrian permissive, a vehicle permissive shall be calculated first even though no vehicle phase exists. The start of pedestrian permissive period = 0 at the beginning of the cycle.

$$EP_{ped} = FO - PC - W - Y_c - R_c - AW_c \quad \text{Equation 19}$$

where

EP_{ped}	= end of pedestrian permissive period (s)
FO	= force-off of vehicle phase (s)
PC	= pedestrian clearance time (s)
W	= pedestrian walk time (s)
Y_c	= yellow time (s) of coordinated vehicle phase
R_c	= all red time (s) of coordinated vehicle phase
AW_c	= advance warning time of coordinated vehicle phase (s).

403.6 DESIGN

403.6.1 General

- .1 Refer to 402.6.1 for general traffic signal information which applies to pedestrian signals.
- .2 Refer to Sample Drawings in Appendix 700 for a typical pedestrian signal design.

403.6.2 Traffic Signal Indications and Signal Heads

- .1 Refer to 402.6.2 for this information.

403.6.3 Flashing Signal Indication

- .1 The flashing green indication shall flash at a rate of 60 flashes per minute.
- .2 The “don’t walk” flashing hand indication during the pedestrian clearance interval shall flash at a rate of approximately 60 flashes per minute.

403.6.4 Signal Head Locations

- .1 Refer to Figure 43 for pedestrian head and pole locations.
- .2 Refer to 402.6.4 for further information.

PEDESTRIAN SIGNALS

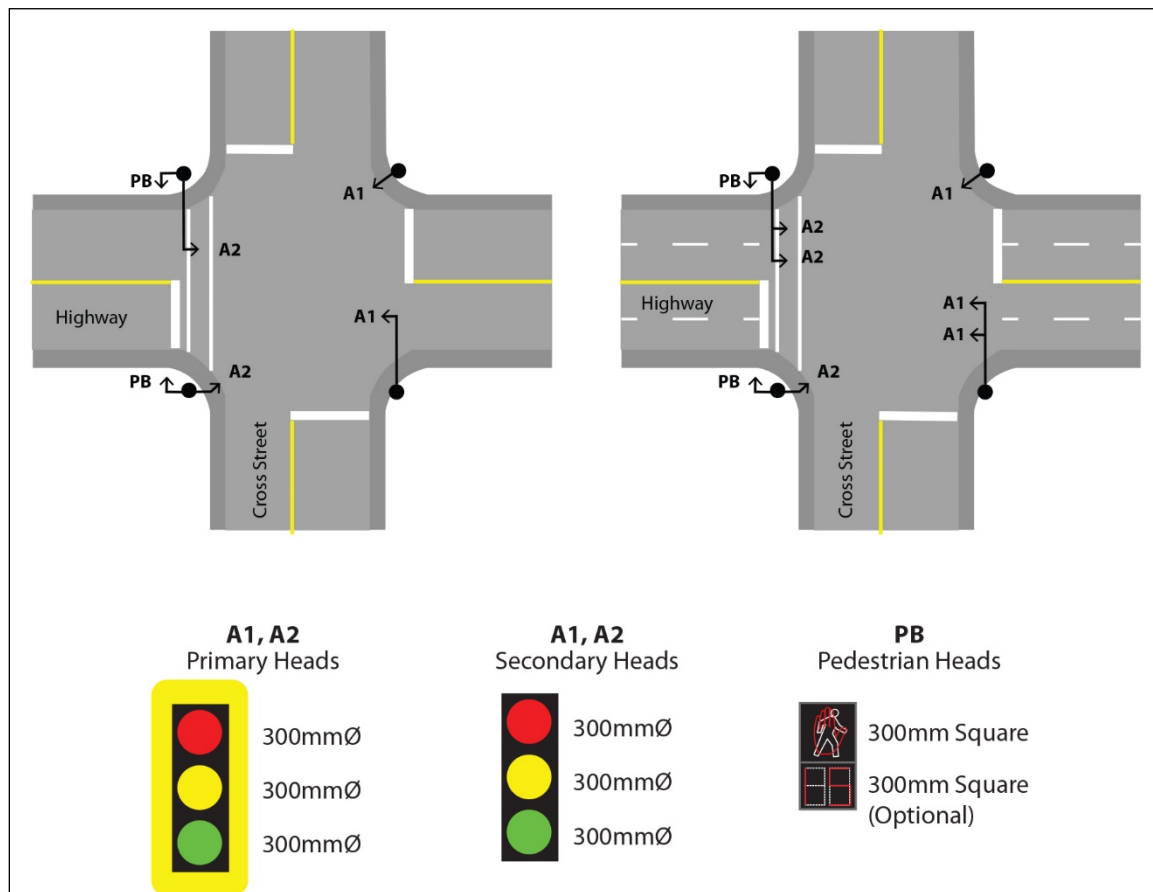


Figure 43. Standard pole location for pedestrian signal.

403.6.5 Pedestrian Signal Equipment

- .1 Pedestrian signals are designed and constructed using similar design principles and equipment to traffic signals. Refer to 402.6.4 through 402.6.12 for more information which may apply to a pedestrian signal.
- .2 Where cyclist activation is required, the separate cyclist push button shall be mounted as per drawing *SP635-2.3.14 Pushbutton Post Details* from Section 635 of the ministry *Standard Specifications for Highway Construction*.
- .3 Base mount Type P6 cabinets are used to control pedestrian signals. Traffic Controller Assemblies are supplied by the ministry at the expense of the project.
- .4 Stop signs shall be used on the cross street. The requirement for stop bars and cross walk markings should be reviewed by the traffic engineer.
- .5 Stop bars shall be installed on the Highway.
- .6 Advance warning signs shall be installed where warranted.

404 ONE-WAY BRIDGE SIGNALS

404.1 GENERAL

- .1 One-way bridge signals allocate the right of way of traffic across single lane bridges or single lane alternating roadways. The scope of this section covers permanent one-way bridge traffic signals only. For temporary one-way bridge controller installations, refer to the ministry *Traffic Management Manual* available at the following link:

https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/traffic-engineering-and-safety/traffic-engineering/traffic-management-and-traffic-control/tcm-work-on-roadways/tcm_consolidated.pdf

404.2 FEATURES

- .1 One-way bridge controllers have the following features:
 - .1 Four phase traffic controller operation.
 - .2 Selectable red/yellow manual flash.
 - .3 Pushbutton activated extended green time (2X regular green).
 - .4 Remote vehicle detection/advance warning cabinet, where applicable.
 - .5 Pushbutton manual reversible lane control.
 - .6 Manual “hold” in any phase movement.
 - .7 Fixed time or fully actuated.

404.3 OPERATION

- .1 One way bridge controllers have two modes of operation - fixed time or actuated.

404.4 FIXED TIME CONTROLLERS

- .1 Fixed time controllers have a programmable max time on all used phases. Each phase is serviced to its maximum value as per the *Signal Timing Sheet*, with the controller cycling continuously. The operation of the controller is not responsive to vehicle demand. The controller makes use of four phases and it cycles as follows:
 - .1 Phase 1 directs traffic across the common roadway. The green interval is timed to its maximum value, and then it terminates.
 - .2 Phase 2 provides the timing for the "all-red" bridge clearance period to clear vehicles off the right of way. This is accomplished utilizing the phase timings without field indicators thus causing an "all-red" bridge clearance period. The phase then terminates.

ONE-WAY BRIDGE SIGNALS

- .3 Phase 3 then directs traffic across the common roadway in the opposite direction. The green interval is timed to its maximum value, and then it terminates.
- .4 Phase 4 provides the timing for the "all-red" bridge clearance period for the opposite direction to clear vehicles off the right of way. This is accomplished utilizing the phase timings without field indicators thus causing an "all-red" bridge clearance period. The phase then terminates.

404.5 ACTUATED CONTROLLERS

- .1 Actuated controllers service phases based on vehicle detection. Vehicle detection is provided on both approaches. If no vehicles are detected, the controller rests with red displayed in both directions (Phases 2 & 4). Minimum and max times are set as per the *Signal Timing Sheet*.
 - .1 When a phase is called and serviced, it always times the minimum green with extensions up to the maximum green based upon vehicle detections.
 - .2 The controller automatically advances to the next bridge clearance phase, times out (all red in the field), and rests if no vehicles are detected. If no vehicles are detected, the controller rests in the next "all-red" bridge clearance phase after the last phase serviced.

404.6 TIMING

- .1 All one-way bridge controller timings shall be approved by the Senior Traffic Operations Engineer.
- .2 The timing of the one-way bridge controller is significantly influenced by the bridge clearance phase time (phases 2 and 4). The bridge clearance phase time is based on the maximum speed allowed on the bridge and the distance between stop bars.
- .3 The yellow time is always 4 seconds.
- .4 The all-red clearance times across the bridge are a function of the distance between stop bars and the travel speed. The red clearance times are determined by using Equation 20.

$$R = \frac{3.6D}{V}$$

Equation 20

where

R = all-red clearance time (s)

V = travel speed across the bridge (km/h)

ONE-WAY BRIDGE SIGNALS

D = distance between stop bars (m)

NOTE: Red times are always rounded up to the nearest second.

- .5 One-way bridge signals should be timed to achieve the same Level of Service (LOS) for both approaches. This is further explained as follows:
 - .1 The capacity (vehicles per hour) of a movement at a one-way bridge signal is determined in a large extent to the saturation flow rate and the cycle length chosen. It is recommended that lower saturation flow rates be used on one-way bridge signals because typically there are narrow lanes and substantial side friction.
 - .2 It is possible to conduct capacity analysis of one-way bridge signals using traffic engineering design software such as Highway Capacity Software or Synchro. The one-way bridge can be modeled as an intersection where the cross street phases are in fact the clearance phases. The one-way bridge is east-west. Note that for north-south cross street setting the green + yellow + red = bridge red time. In the printout, the north-south measures of effectiveness (MOE's) can be disregarded. However the east-west MOE's will give an accurate average delay and LOS for the bridge traffic.
- .6 Fixed time controllers require the following timings:
 - .1 Phase 1 (green indicator) minimum green time shall equal the maximum green time.
 - .2 Phase 2 ("all-red" bridge clearance) minimum green time is based on the maximum speed allowed on the bridge at any time during construction. Historically, this has varied from 25 to 50 km/h. No max green time is programmed.
 - .3 Phase 3 (green indicator) minimum green time shall equal the maximum green time.
 - .4 Phase 4 ("all-red" bridge clearance) minimum green time is based on the maximum speed allowed on the bridge at any time during construction. Historically, this has varied from 25 to 50 km/h. No max green time is programmed.
 - .5 Extended green time shall equal two times the maximum green time. This is entered in the WALK field for that phase. Note that this time is only for clearing queues and is called via Phase A and Phase B pushbuttons on the controller.
 - .6 Advance warning times if required.
- .7 Actuated controllers require the following timings:
 - .1 Phase 1 (green indicator) minimum green time (default value = 10 seconds).

ONE-WAY BRIDGE SIGNALS

- .2 Phase 1 passage time.
- .3 Phase 1 maximum green time.
- .4 Phase 2 ("all-red" bridge clearance) minimum green time is based on the maximum speed allowed on the bridge at any time during construction. Historically, this has varied from 25 to 50 km/h. No max green or passage time is programmed.
- .5 Phase 3 (green indicator) minimum green time (default value = 10 seconds).
- .6 Phase 3 passage time.
- .7 Phase 3 maximum green time.
- .8 Phase 4 ("all-red" bridge clearance) minimum green time is based on the maximum speed allowed on the bridge at any time during construction. Historically, this has varied from 25 to 50 km/h. No max green or passage time is programmed.
- .9 Extended green time shall equal two times the maximum green time. This is entered in the WALK field for that phase. Note that this time is only for clearing queues and is called via Phase A and Phase B pushbuttons on the controller.
- .10 Advanced warning time if required.

404.7 SELECTABLE FLASHING OPERATION

- .1 When in flash, a one-way bridge signal shall flash all-red. If the bridge is in two-way operation, it shall flash yellow. Signal heads should be sacked if not energized.
- .2 As the travel speed across the bridge will change in relation to the work on the bridge, the clearance times and green times may need to be updated periodically.

404.8 DESIGN

- .1 All one-way bridge controllers, communications equipment, uninterruptible power supplies and remote detector units are based on the standard ministry designs and equipment. Each ministry Manager, Electrical Services has one one-way bridge controller in their inventory. The Manager, Electrical Services can be contacted for availability. If the controller is not available, alternate products may be required.
- .2 There are three configurations of one-way bridge controllers depending on the site:
 - .1 Configuration 1:
 - .1 Is actuated with a remote detector unit.
 - .2 Is used for bridges over 100 meters.

ONE-WAY BRIDGE SIGNALS

- .2 Configuration 2:
 - .1 Is actuated without a remote detector unit.
 - .2 Is used for bridges under 100 meters.
- .3 Configuration 3:
 - .1 Is non-actuated (fixed-time).
- .3 Generally, Type M controllers on a structural steel frame with an uninterruptible power supply (UPS) and a dial-up modem are used for one-way bridge signals. The choice of one-way bridge controller type shall be approved by the Senior Traffic Operations Engineer and the ministry Electrical Representative.
- .4 All actuated one-way bridge controllers have count capability.

405 DRAWBRIDGE/SWINGBRIDGE SIGNALS

405.1 GENERAL

- .1 Signals are used on the approaches to drawbridges and swing bridges, permitting or prohibiting access to cross the bridge. The signals are interconnected with the bridge mechanism. A green indication may be given when the bridge is open to traffic and a red indication is given when the bridge is closed to traffic. Refer to the Transportation Association of Canada (TAC), *Manual of Uniform Traffic Control Devices (MUTCD)* Section B5.5 for further information on Traffic Control Signals at Opening Bridges.

405.2 OPERATION

- .1 The operation of swing bridges varies. Each swing bridge will have a unique procedure for the opening and closing of the bridge. Consult the operations manual for operational details.

405.3 TIMING

- .1 All drawbridge and swing bridge controller timings shall be approved by the Senior Traffic Operations Engineer.
- .2 Clearance times are calculated using Equation 21.

$$I = T_{pr} + \frac{V}{2(f + AG)g} + \frac{D_c}{V} \quad \text{Equation 21}$$

where

I	= clearance time (s).
T _{pr}	= perception/reaction time (s) = 1.0 s
V	= 85th percentile or posted speed (m/s)
f	= friction factor on wet pavement. Refer to Table 18
AG	= approach grade (m/100 m), positive if approach traffic is Climbing, negative if approach traffic is descending
g	= 9.81 m/s ²
D _c	= clearance distance (m).

- .3 The yellow time is always 4 seconds. The balance of the clearance time is all-red.
- .4 Advance warning flashers may be required. Refer to Sub-clause 402.6.9.

DRAWBRIDGE/SWINGBRIDGE SIGNALS

- .5 Traffic signals located within 150 m of a drawbridge and swing bridge signal shall be fitted with pre-empt interconnected with the bridge signal to avoid a significant queue build up between signals.

405.4 DESIGN

- .1 Traffic signal displays shall be placed on both the left and right side of the roadway, at either end of the moveable span. The signals shall not be less than 15 m nor more than 30 m from the end of the moveable span. Refer to 402.6 for further information.
- .2 Pedestrian signals are required if there are sidewalks or other pedestrian facilities on the bridge.
- .3 Where the bridge is close to a railway grade crossing, special advance signals may be necessary to ensure that vehicles are not forced to stop on the tracks. Advance signals should be located at least four meters away from the nearest rail of a railway or the nearest pavement edge of an intersecting street on the side most distant from the bridge.
- .4 Prior to proceeding with a drawbridge and swing bridge signal design, the designer shall meet with the ministry Electrical and ITS Engineering and the Senior Traffic Operations Engineer to discuss layout, operation and equipment.

406 FIRE SIGNALS

406.1 GENERAL

- .1 Fire signals are used at fire truck entrances either mid-block or at intersections where full traffic signals are not warranted but, due to high traffic volumes, lack of visibility, collision experience, high speeds, excessive delay to fire truck entry or a high frequency of fire truck entry, a traffic control device is required. Refer to the Transportation Association of Canada, *Manual of Uniform Traffic Control Devices* (MUTCD) Section B5.4, for further information on Fire Signals.

406.2 OPERATION

- .1 The signals shall not operate until activated from the fire station. This activation shall be provided by the way of a palm button, or ministry approved alternative, in the fire station.
- .2 A fire signal shall have signal heads with red and yellow displays.
- .3 Operation shall be as follows:
 - .1 Upon activation the yellow signal indication shall flash along with advance warning signs, if installed.
 - .2 A steady yellow signal display shall follow the flashing yellow to advise motorists that the red signal will be displayed.
 - .3 A flashing red indication shall be displayed for the duration of the activation.
- .4 Advance warning flashers shall be installed if warranted by the criteria detailed in this manual in section 402.6.10 *Advance Warning Flashers*.

406.3 TIMING

- .1 The flashing yellow time shall be the same as the advance warning if the signal warrants advance warning. Otherwise, the flashing yellow shall be five seconds.
- .2 Solid yellow clearance intervals shall be calculated as per the through vehicle calculations in section 402.5.4.
- .3 The duration of the flashing red and any delay timings between activating the fire signal and receiving the electrical signal from the fire hall shall be determined in consultation with the Senior Traffic Operations Engineer and the Fire Department.

406.4 DESIGN

- .1 A fire signal requires a hardwire interconnection from the controller to the palm button in the fire hall. This interconnection shall be made with a 2C No. 18 ministry standard shielded cable installed in conduit. A normally closed relay is required in the fire hall to isolate the signal. The type and location of the palm button and relay in the fire hall shall meet the approval of the Fire Department and the ministry Electrical and ITS Engineering. The designer shall detail the installation of this equipment on the electrical drawings.
- .2 Fire signal heads consist of a 300 mm diameter red signal indication, a 300 mm diameter yellow signal indication and a special backboard, showing a fire truck symbol mounted overhead on signal poles as shown in Section B5.4 of the Transportation Association of Canada (TAC), *Manual of Uniform Traffic Control Devices* for Canada (MUTCD).
- .3 Refer to Section 500 and the ministry *Standard Specifications for Highway Construction* for information on concrete bases, poles, luminaires, service equipment, junction boxes, conduit and small overhead signs.
- .4 Orient signal heads over the lanes as detailed in 402.6.4. Secondary heads shall be mounted on the right side pole shafts at 2.5 m above finished grade, complete with special backboard.
- .5 A 300 mm red flashing single-section signal head oriented toward the fire hall exit shall be used to advise the emergency vehicles that the signal is in a flashing red state. The signal head shall be:
 - .1 Mounted on the closest signal pole to the fire hall.
 - .2 Oriented so it is visible to the emergency vehicle driver.
- .6 In some situations, fire indicating lights may be required rather than the single-section signal head described in 406.4.5 above. Operating fire indicating lights are intended to show the driver of the fire truck the signal has gone into pre-emption. Fire indicating light installation details are shown on drawing SP635-2.3.9 *Fire Signal Indication Light Installation Detail* in Section 635 of the ministry *Standard Specifications for Highway Construction* and explained further in Sub-Paragraph 402.7.7.4. If indication lights are specified a traffic signal controller is required. The controller is supplied by the ministry at the project's expense. Fire indication lights shall be:
 - .1 Installed on a fire signal pole nearest the fire hall.
 - .2 Oriented so they are visible to the fire truck driver.
- .7 Controllers shall be ministry standard pole or pad mount. If indicating lights are not required a ministry accepted fire signal controller shall be used. See the ministry *Recognized Products List* for accepted fire signal controllers.

FIRE SIGNALS

- .8 Refer to the ministry *Manual of Standard Signs and Pavement Markings* for signing and pavement markings.
- .9 Refer to Figure B5-2 in *Transportation Association of Canada (TAC), Manual of Uniform Traffic Control Devices for Canada (MUTCD)* for a typical fire signal layout. The designer shall place stop bars so the fire truck turning radius can be maintained.
- .10 Fire signal head backboards shall include 75mm reflective (ASTM 9 or 11) yellow tape around the perimeter.

407 SPECIAL CROSSWALKS

407.1 GENERAL

- .1 Special crosswalks may be installed mid-block at pedestrian crosswalks or school crosswalks.
- .2 A typical special crosswalk is shown in the ministry *Pedestrian Crossings Control Manual*.

407.2 DATA COLLECTION AND WARRANTS

- .1 Refer to the ministry *Pedestrian Crossings Control Manual* for data collection and warrant information.

407.3 DESIGN

- .1 Special crosswalk equipment consists of internally illuminated pedestrian crosswalk signs complete with down-lighter and push-button activated alternating flashing yellow signal heads mounted on a ministry signal pole.
- .2 See the ministry *Recognized Products List* for accepted pedestrian signal controllers.
- .3 Refer to the ministry *Pedestrian Crossings Control Manual* for further information on special crosswalks.
- .4 Refer to Section 500 for information on concrete bases, poles, luminaires, service equipment, junction boxes, conduit and small overhead signs.
- .5 For rural two-lane roadways a single pole may be used to mount overhead signs.
- .6 Supplemental street lighting in advance of each crosswalk approach shall be installed to meet IES crosswalk illumination requirements.
- .7 Rectangular Flashing Beacons (RFB) may be used at the discretion of the Senior Traffic Operations Engineer. The RFB system must be listed on the ministry *Recognized Products List*.

408 INTERSECTION FLASHING BEACONS AND WARNING SIGNS

408.1 GENERAL

- .1 Flashing beacons are displays typically used to emphasize caution or stop conditions. The use of flashing beacons shall be reviewed with the Senior Traffic Operations Engineer and the ministry Electrical and ITS Engineering prior to proceeding with the design.

408.2 WARRANTS FOR INTERSECTION FLASHING BEACONS

- .1 Beacons with flashing red and yellow indications may be used to emphasize the need for caution when at least two reportable collisions a year for at least three years have occurred and where any of the following conditions exist:
 - .1 Intersections - At intersections where full signalization is not warranted.
 - .2 Overhead Signs - On overhead warning signs as noted in the ministry *Manual of Standard Traffic Signs and Pavement Markings*.
 - .3 Post Mounted Flashers - Shall be mounted on posts to indicate hazards as noted in the ministry *Manual of Standard Traffic Signs and Pavement Markings*.
- .2 Flashing beacons with red indications are equivalent to stop signs and therefore may be used to reinforce the operation of the stop sign. Generally overhead flashing beacons at intersections flash yellow on the highway and red on the cross street.

408.3 OPERATION

- .1 Flashing beacon operation shall be approved by the Senior Traffic Operations Engineer and ministry Electrical and ITS Engineering.

408.4 DESIGN OF INTERSECTION FLASHING BEACONS

- .1 Overhead flashing beacons shall be mounted on a signal pole and placed over the centre of the intersection as shown in Figure 44. Refer to drawing *SP635-2.3.6 Four-Way Overhead Flashing Signal Head Installation Details* in Section 635 of the ministry *Standard Specifications for Highway Construction* for flashing beacon mounting details.
- .2 Stop signs shall be used on the cross streets with the flashing red indications. Generally, overhead flashing beacons at intersections flash yellow on the highway and red on the cross street.
- .3 Flashing beacons shall flash 24 hours a day at a rate of 60 flashes per minute.

INTERSECTION FLASHING BEACONS AND WARNING SIGNS

- .4 Flashing beacons used to control intersections shall be ministry standard 300 mm signal head sections complete with backboards.
- .5 Where a separate service is required for only the flashing beacon signal, a ministry standard 30A service panel may be used.
- .6 A flasher control unit mounted inside the service panel shall control the flashing beacon.
- .7 In cases where a full signal is proposed to be installed within two years, consider placing the flashing heads on signal poles positioned to accommodate the full signal.
- .8 Refer to Section 500 for information on concrete bases, poles, luminaires, service equipment, junction boxes and conduit.

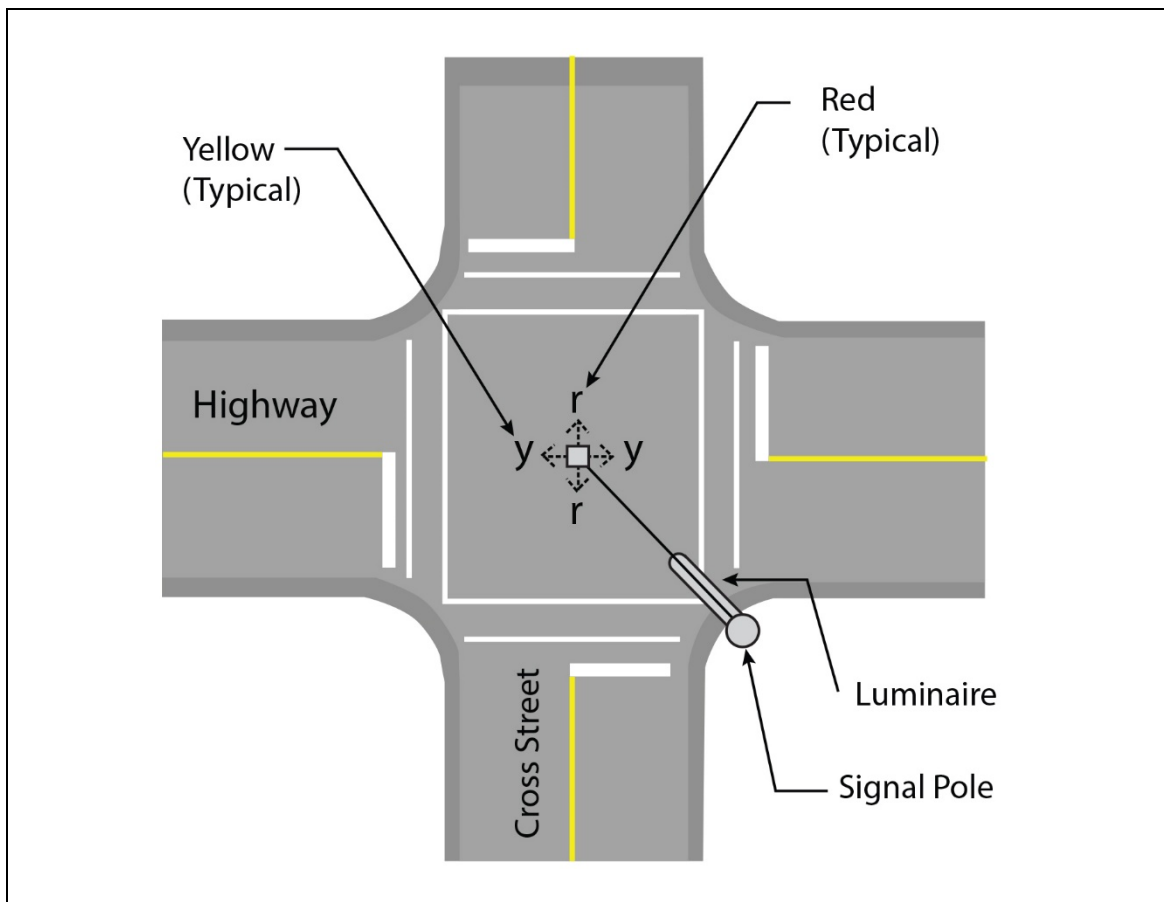


Figure 44. Standard pole location for overhead flashing beacon installations at an intersection

408.5 DESIGN OF FLASHING BEACONS ON OVERHEAD SIGNS

- .1 When flashing beacons are warranted on special curve-warning or intersection-ahead signs, they shall be mounted in a similar fashion as advance warning signs. Flashing beacons installed on curve-warning signs and on intersection-ahead signs shall flash yellow.
- .2 Flashing beacons shall flash 24 hours a day at a rate of 60 flashes per minute.
- .3 Flashing beacons mounted on overhead signs shall be ministry standard 300 mm signal head sections.
- .4 Special curve warning signs shall be 1.22 m (H) x 2.44 m (W) and be manufactured out of extruded aluminum.
- .5 Unlike advance warning signs, flashing beacons shall flash simultaneously.
- .6 A flasher control unit shall be mounted inside the service panel to control the flashing beacon.
- .7 Refer to the current version of the *Standard Specifications for Highway Construction* and Section 500 of this manual for information on concrete bases, sign poles, junction boxes, conduit and large sign mounting.

409 LANE CONTROL SIGNALS

409.1 GENERAL

- .1 Lane control signals are used to control the direction of traffic movements on individual lanes of a roadway. The most common application of this control is in reversible lane control systems where one lane may serve different directions of traffic during different time periods. Refer to the Transportation Association of Canada (TAC), *Manual of Uniform Traffic Control Devices* (MUTCD) *Section B5.6* for further information on Lane Control Signals.
- .2 For general guidelines on lane control system design, refer to the TAC publication *Guidelines for the Planning, Design, Operation and Evaluation of Reversible Lane Systems*. This document can be purchased online at:
<http://www.tac-atc.ca/en/publications/ptm-reverse>

409.2 DESIGN

409.2.1 General

- .1 Prior to starting a lane control system design, the designer shall meet with the ministry Electrical and ITS Engineering and the Senior Traffic Operations Engineer to review the operation, equipment locations and control equipment.

409.2.2 Signal Indications

- .1 Steady Green Arrow Indication: The signal is pointing down over the centre of the traffic lane. The vehicle may travel in the indicated lane.
- .2 Steady Red "X" Indication: The signal is oriented over the centre of the traffic lane. The vehicle cannot travel in the lane indicated.
- .3 Flashing Yellow "X" Indication: The signal is oriented over the centre of the traffic lane. The vehicle must move into a lane with a green arrow as soon as practical. A lane control change is being made.
- .4 Diagonal Yellow Flashing Arrow Indication: The signal is pointing downward towards the left lane or the right lane. The vehicle must merge into the lane to which the arrow is pointed. This indication may be used in special applications where a lane ends.
- .5 Lane control signals shall be visible from the distances noted in the Transportation Association of Canada, *Manual of Uniform Traffic Control Devices* (MUTCD).

409.2.3 Equipment

- .1 Lane control signals shall display a red "X", a green arrow, a yellow "X" and sometimes a diagonal yellow arrow. Displays are normally LED.
- .2 Display signal heads shall meet the minimum requirements of the latest Institute of Transportation Engineers (ITE) standards for Lane-Use Traffic Control Signal Heads.
- .3 Generally, the lane control signal displays are 300mm x 300mm for lane control systems having a speed limit of 60 km/h or less. Display symbols may be 450mm x 450mm on lane control systems with speed limits 70 km/h or greater.
- .4 Lane control signals are normally mounted on ministry standard signal poles or monotube sign bridge structures using special mounting brackets.
- .5 For reversible traffic flow applications displays shall be located at both points of entry to the lane under reversible control. Displays located between points of entry shall be located so that at least one indication is clearly visible to motorists at all times.

409.2.4 Standards

- .1 The ministry requires that designers follow ministry standards for Special Projects as well as deliver thorough documentation when designing reversible lane control systems.
- .2 The required documentation consists of the following manuals:
 - .1 **System Overview Manual** - A document that describes the purpose, features and operation of the reversible lane control system.
 - .2 **System Users Manual** - A document that provides detailed instructions to the operator on the use of the computer software that controls the system.
 - .3 **Operational Policy Manual** - A document that defines policies governing the operation and maintenance of the system. This document is primarily used by the operator.
 - .4 **Incident and Fault Management Manual** - A document that provides procedures for all parties responding to incidents such as motor vehicle collisions or fires. It also defines the operator response to electrical faults in the system.
 - .5 **System Maintenance Manual** - A document that defines preventive maintenance schedules and procedures, and corrective maintenance response times and procedures for ministry maintenance personnel. This document shall contain all system drawings and Original Equipment Manufacturer (OEM) manuals.

- .6 **Incident Response Field Manual** - An abbreviated form of the Incident and Fault Management Manual. It is used by field personnel, such as wrecker operators, when responding to an incident.

410 INSTALLATION OF MICELLANEOUS DEVICES

410.1 GENERAL

- .1 This section describes the policies and procedures for deploying devices that may be used for various functions relating to traffic management and road safety. This includes signs augmented with LED displays, such as LED Chevron signs and LED Wildlife Warning signs, and other devices such as Speed Reader signs, Rapid Flashing Beacons, and Microwave (Wi-Fi) Radios. Similar devices that may fall within scope of this section should follow the same general policies and procedures whether or not they are listed here.

410.2 GENERAL POLICY

- .1 There is no formal warrant process for these devices.
- .2 These devices should only be installed in locations approved by the Senior Traffic Operations Engineer or Electrical and ITS Engineering.
- .3 Installations shall be documented on electrical drawings with TE numbers assigned by ministry Electrical and ITS Engineering. Designs shall be in accordance with this manual, the ministry *Standard Specification for Highway Construction*, and all applicable codes and standards.
- .4 The drawings shall detail all electrical information including the location, configuration, mounting details, and power source.
- .5 The device(s) shall be connected to an electrical service supplied by a power utility unless approved by ministry ITS and Electrical Engineering.
- .6 Only products approved by ministry Electrical and ITS Engineering or listed on the ministry *Recognized Products List* shall be used.
- .7 New devices shall have a performance based maintenance specification developed by ministry Electrical and ITS Engineering and the Manager, Electrical Services and be entered into the ministry electrical inventory.

410.3 PROCEDURE

- .1 A request shall be made to the ministry Senior Traffic Operations Engineer or Electrical and ITS Engineering for approval to install the device.
- .2 If approved, ministry Electrical and ITS Engineering will provide requirements for design, documentation, and drawings.
- .3 Sign design and installation details shall be in accordance with the appropriate sections of the ministry *Manual of Standard Traffic Signs and Pavement Markings*.

INSTALLATION OF MISCELLANEOUS DEVICES

- .4 The ministry Manager, Electrical Services shall notify the appropriate power authority of the increased load if the device is connected to a non-metered electrical service.

410.4 DEVICES

- .1 Listed below are some of the devices that are currently used. Similar devices, even though they are not listed here, should follow the procedures listed above.

410.4.2 LED Chevron Signs

- .1 The LED Chevron sign is a W-062 Series Chevron Alignment Marker sign with LED's around the perimeter of the black arrow. The LED's enhance the visibility of the sign and help to maintain its effectiveness during adverse weather conditions.

410.4.3 Speed Reader Signs

- .1 Speed Reader signs are electronic signs that use radar to detect the speed of an approaching vehicle and display the speed on an LED variable message display. The speed display is typically combined with a static (non-electronic) display that includes the text "Your Speed" or similar.

410.4.4 Rectangular Flashing Beacons

- .1 Rectangular Flashing Beacons (RFB's) are intended for use at special pedestrian crosswalks as an alternative to circular flashing beacons. Studies have shown, compared to circular beacons, the RRFB increases the likelihood that motorists will yield at an occupied crosswalk. The RRFB has an asymmetric wig-wag flash pattern that follows the MUTCD flash requirement of 70 – 80 periods of flashing per minute. During each flash cycle, one rectangular beacon emits two rapid pulses of light and the other emits three rapid pulses of light.

410.4.5 Illuminated Bollards

- .1 Illuminated Bollards are used to enhance the visibility of various types of roadway infrastructure such as pedestrian crossings and traffic islands.

410.4.6 Microwave Radios

- .1 Microwave Radios provide a cost effective means of communications where high data rates are required, and can be used as an effective alternative to a

hard-wired data link. Microwave Radios are used in many applications including intelligent transportation systems, public safety communications, and public utilities. These radios operate in the 2.4, 4.9, and 5.8 GHz frequency bands and do not require licensing by Industry Canada.

410.4.7 Bluetooth Readers

- .1 Bluetooth Readers are radio receivers installed on ministry infrastructure in close proximity to roadways. They are used to gather traffic flow information by logging the ID (MAC address), time, and location of Bluetooth devices in passing vehicles. Each time a device is detected the information is logged and compared to previous reads; this information is then used to derive the travel time along specific corridors. Many devices are read and the information averaged to give an indication of general traffic conditions such as speed, volume, and occupancy.

The information obtained from the Bluetooth device is restricted to the MAC address for the device and does not identify the user or include any personal information of any kind.

410.4.8 Radar Vehicle Detection Sensors

- .1 Radar Vehicle Detection Sensors have many applications in the transportation sector including monitoring traffic for volume, speed, and occupancy. They may also be used as an alternative to inductive loops for intersection vehicle detection and stop bar detection.