MARCH 2021

Signals 101
MANUAL

DEPARTMENT OF TRANSPORTATION

OFFICE OF TRAFFIC ENGINEERING

Contents

1. WHY?

This chapter will address why a traffic signal is installed, including:

- Who initiates a traffic signal?
- Traffic signal warrants
- Intersection Control Evaluation (ICE) reports
- Associated manuals

1.1 Who initiates a traffic signal?

A traffic signal may be initiated in many ways. If a study shows such a signal is justified, then the signal must be programmed, i.e. budgeted for and put into the letting schedule. A signal can be initiated by a developer, city/county, politician, the public, or the State.

1.2 Signal Warrants

Traffic control signals should not be installed unless one or more of the signal warrants in the Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD) are met. Warrants can be found in Chapter 4C of the MN MUTCD, available at the following link: www.dot.state.mn.us/trafficeng/publ/index.html.

However, the satisfaction of a warrant or warrants is not in itself justification for a signal. In addition to meeting a warrant, to be justified a signal should meet perceived safety or operational needs. Information should be obtained by means of engineering studies and compared with the requirements set forth in the warrants. An Intersection Control Evaluation (ICE) report is required; details on this are found later in this section.

There are nine warrants contained in the MN MUTCD:

- Warrant 1: Eight-Hour Vehicular Volume
- Warrant 2: Four-Hour Vehicular Volume
- Warrant 3: Peak Hour
- Warrant 4: Pedestrian Volume
- Warrant 5: School Crossing
- Warrant 6: Coordinated Signal System
- Warrant 7: Crash Experience
- Warrant 8: Roadway Network
- Warrant 9: Intersection Near a Grade Crossing

Several of the warrants are less strong and require careful justification to avoid placing signals that cause more problems than they solve. For instance, consider Warrant 3. If only one hour is met for Warrant 3, then a signal could be installed that is only needed 1 hour out of the day.

Another example is Warrant 7. Note that the language states "Five or more reported crashes, of types susceptible to correction by a traffic control signal, …". A rear-end collision is not considered to be an accident that could be corrected by a signal (in fact, this collision type often increases with the installation of a traffic signal).

Let's review an example of Warrant 1, which requires a minimum of eight hours of traffic data. To meet Warrant 1, at least eight distinct hours must meet the threshold volumes. For this example, we will assume 2 or more lanes on the major and minor street under 100% conditions.

The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic signal. The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and where the traffic volume

on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

To be warranted, one of the following must occur:

1. Condition A or B is met for at least 8 hours a day as shown on the 100% column.
2. Condition A or B is met for at least 8 hours a day as shown on the 70% column if the posted or 85th percentile speed on the mainline exceeds 40 MPH or the intersection lies within the built-up area of an isolated community having a population of less than 10,000.

Condition A - Minimum Vehicle Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1.....	1.....	500	400	350	280	150	120	105	84
2 or more...	1.....	[illegible]	480	420	336	[illegible]	120	105	84
2 or more...	2 or more...	600	480	420	336	200	160	140	112
1.....	2 or more...	500	400	350	280	200	160	140	112

	Vehicles Per Hour		Minimum Required		
Time	Total of Both Major Street. Approaches	Higher Minor Street Approach	Total of Both Major Street. Approaches	Higher Minor Street Approach	Hour Satisfied?
6:00 to 7:00	650	205	600	200	Yes
7:00 to 8:00	690	250	600	200	Yes
8:00 to 9:00	640	201	600	200	Yes
9:00 to 10:00	600	190	600	200	No
10:00 to 11:00	550	100	600	200	No
11:00 to 12:00	560	120	600	200	No
12:00 to 1:00	600	160	600	200	No
1:00 to 2:00	590	130	600	200	No
2:00 to 3:00	580	180	600	200	No
3:00 to 4:00	600	190	600	200	No
4:00 to 5:00	630	220	600	200	Yes
5:00 to 6:00	700	250	600	200	Yes
6:00 to 7:00	680	230	600	200	Yes
7:00 to 8:00	550	200	600	200	No
8:00 to 9:00	450	190	600	200	No
9:00 to 10:00	400	100	600	200	No

Warrant not met for Condition A (6 of 8 hours met)

For this example, 6 of 8 hours met the requirements for Warrant 1 Condition A, so Warrant 1 was not met. This example only considered Condition A of Warrant 1.

1.3 Intersection Control Evaluation (ICE)

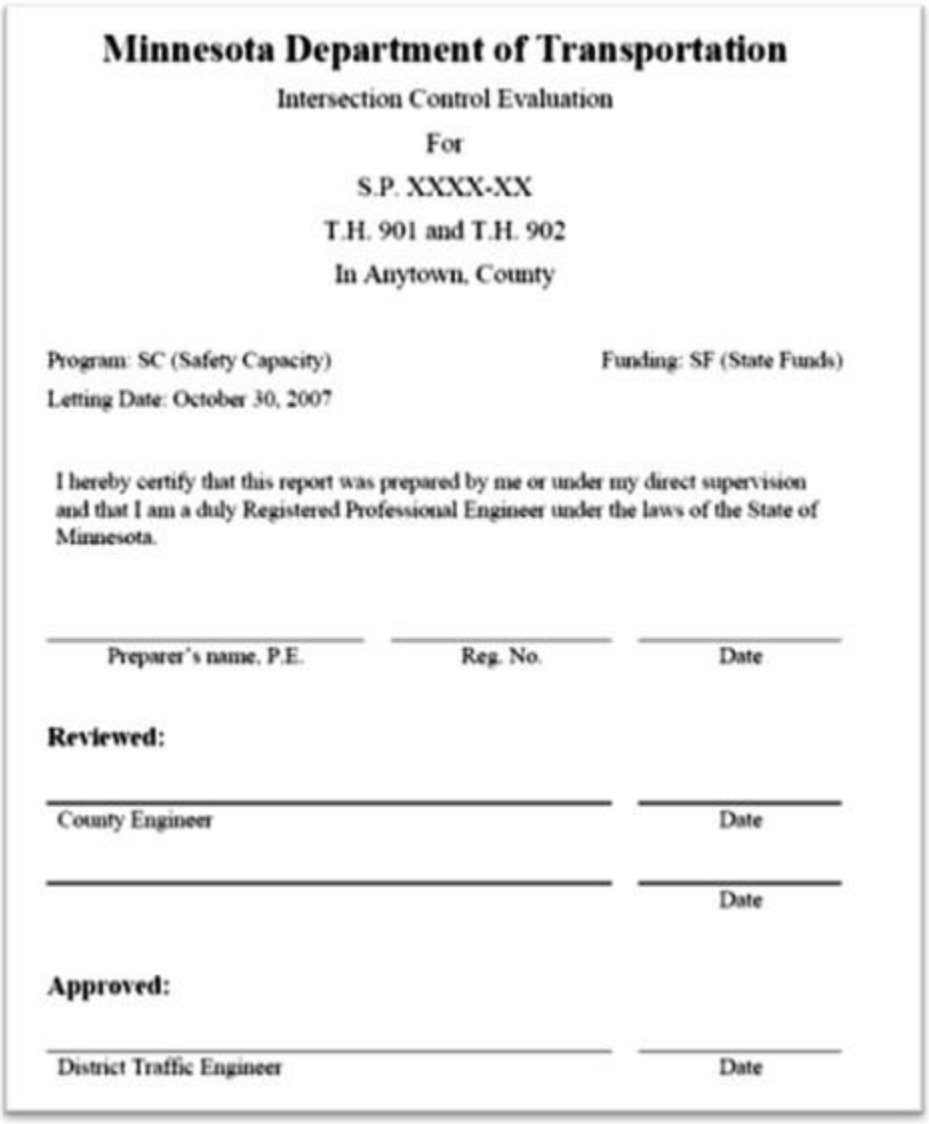
In the past, the only perceived solution to traffic delay and safety problems for at-grade intersections was the installation of a traffic signal, based on Signal Justification Reports (SJR). A SJR had to be completed before a new signal or significant modification of a signal could proceed (MnDOT Traffic Engineering Manual). The SJR is straightforward but does not consider other alternatives forms of intersection control. Other options including stop control, roundabouts, and unconventional reduced-access intersections, may also be acceptable alternatives.

An Intersection Control Evaluation (ICE) is a process that identifies the best intersection control through a comprehensive analysis and documentation of the technical (safety and operational), economic, and political issues of viable alternatives.

The purpose of the ICE is to evaluate various intersection designs; select the optimal control for an intersection based on an objective analysis of the existing conditions and future needs; and document all technical, financial, and political issues in the ICE report (in lieu of the SJR).

The deliverable depends on scope and location of the project, and could be an ICE Report, ICE Letter, SJR, or Signal Justification Letter (SJL).

Below is a sample ICE report cover sheet. The ICE report must be completed under the direct supervision of a Minnesota Professional Engineer (PE). It is also to be reviewed by appropriate agencies and approved by the District Traffic Engineer (DTE).



Minnesota Department of Transportation

Intersection Control Evaluation

For

S.P. XXXX-XX

T.H. 901 and T.H. 902

In Anytown, County

Program: SC (Safety Capacity) Funding: SF (State Funds)

Letting Date: October 30, 2007

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Preparer's name, P.E. Reg. No. Date

Reviewed:

County Engineer Date

Date

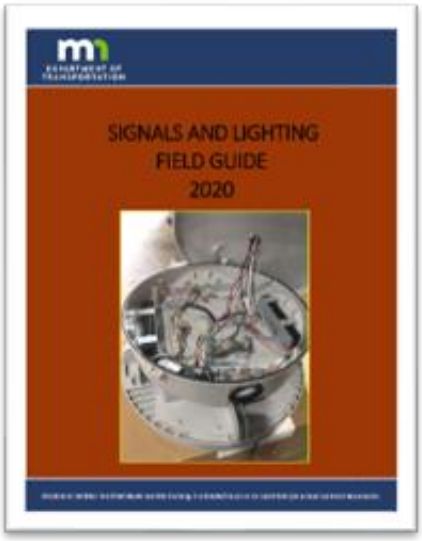
Approved:

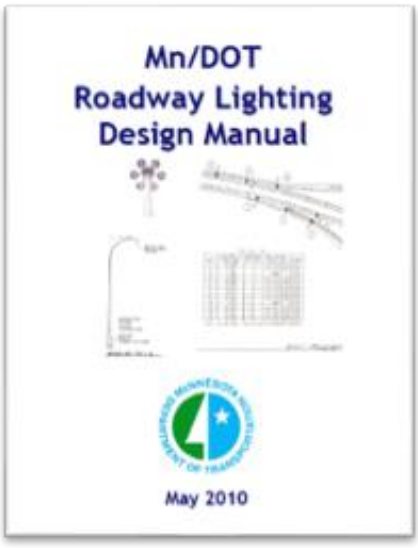
District Traffic Engineer Date

1.4 Manuals

The MN MUTCD provides a uniform system of traffic control devices on all streets, highways, bikeways, and private roads open to public travel within the State of Minnesota. Chapter 4 of the MN MUTCD focuses on traffic signals.

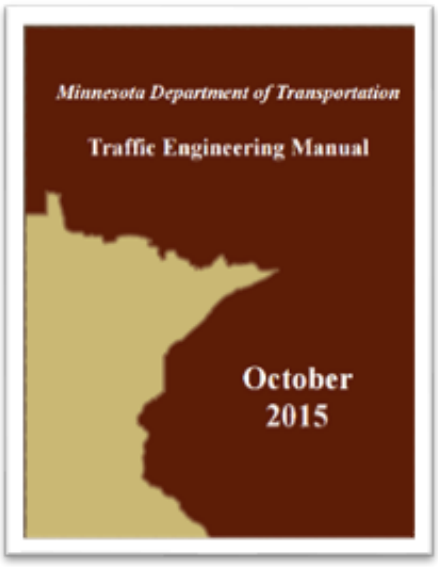
The Signal and Lighting Certification Field Guide is for those who are involved in the construction and maintenance of traffic signals and lighting systems.





The Roadway Lighting Design Manual (offered again in 2022) covers the design of roadway lighting systems.

The Standard Specifications are used for all types of construction. Refer to Chapter 13 of this manual for more details.



The Traffic Engineering Manual (TEM) contains a variety of information related to traffic signals.

The Traffic Signal Timing and Coordination Manual (training offered again in 2022) is a manual for how to operate a traffic signal or a network of signals.

The Traffic Control Signal Design Manual (training to be offered again in 2021) covers the design of signal systems.

For up-to-date information, visit the Office of Traffic Engineering (OTE) website (http://www.dot.state.mn.us/trafficeng) for a wide range of resources. Many of the references used in this manual can be downloaded via the Publications tab.

2. SIGNAL AGREEMENTS

This chapter will cover agreements, including:

- Signal agreements
- Cost splits
- Type of agreements written in the OTE
- Agreements for State let and city/county let projects
- What is covered under agreements, and items that may be covered

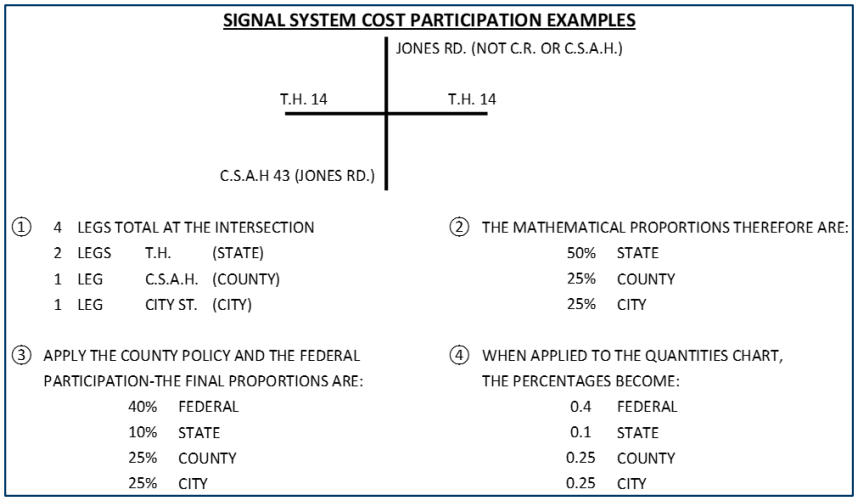
2.1 Signal Agreements

An Agreement is a contract between the State and another entity defining who pays for what. Cooperative agreements specify the sharing of costs, maintenance, and operation of signals. The State will not participate financially in a traffic signal that is not justified (see Chapter 1 regarding Intersection Control Evaluation).

2.2 Cost Split

The cost of constructing and maintaining a traffic signal shall be shared by the State and other municipal agencies.

The construction cost is usually divided in the same ratio as the number of legs of the intersection under each jurisdiction. If a leg is split by a division boundary, that leg should be equally divided. A private entrance leg should be divided as a municipal leg.



2.3 Types of Agreements

There are different types of agreements written in the OTE, including:

- Traffic Control Signal
- Flashing Beacon
- Emergency Vehicle Preemption (EVP)
- Roadway Lighting

The costs for the signal may include intersection roadway lights, intersection roadway signs, EVP as well as the cost of construction, engineering, inspection, and maintenance. Agreements are written for both State let and city/county let projects.

For State let projects, agreement classifications include:

- Receivable
- Payable/receivable
- Maintenance
- Reimbursable maintenance
- State force account

For city/county let projects, agreement classifications include:

- Payable/receivable
- Payable
- Receivable
- Maintenance
- Reimbursable maintenance
- City force account
- City/State force account
- Agency

Traffic signal plans handled by MnDOT for other agencies, with or without the State Aid process, are handled differently depending on whether the project has federal funding participation, and whether or not the intersection involved is located on or off the trunk highway system.

If a signal at a trunk highway intersection is being built or revised by any other agency, the District/Division Traffic Engineer shall approve the final plans before bids are opened on the project. The Traffic Engineer shall approve the plans whether or not there is any federal funding participation.

If a proposed signal is not at a trunk highway location, and the job involves federal funding participation, the District Traffic Engineer will indicate concurrence with the design by means of a memorandum to the State Aid Office.

If a proposed signal is not at a trunk highway location, and the project does not have federal funding participation, the District Traffic Engineer may indicate approval by means of a memo to the State Aid Office; however, the District/Division may recommend approval of such a project if the plans have been certified by both a master electrician and licensed engineer.

2.4 What Agreements Cover

Agreements cover costs (construction costs and splits), maintenance, operation (timing), and electrical energy (power). Agreement terms (cost participation, power supply, design responsibilities, operation responsibilities and major/minor maintenance responsibilities) should be defined as early as possible within any project - regardless of whether the project is going to be administered by the Department or a local agency. Agreement terms for any project are a byproduct of appropriate and timely local agency and Department coordination.

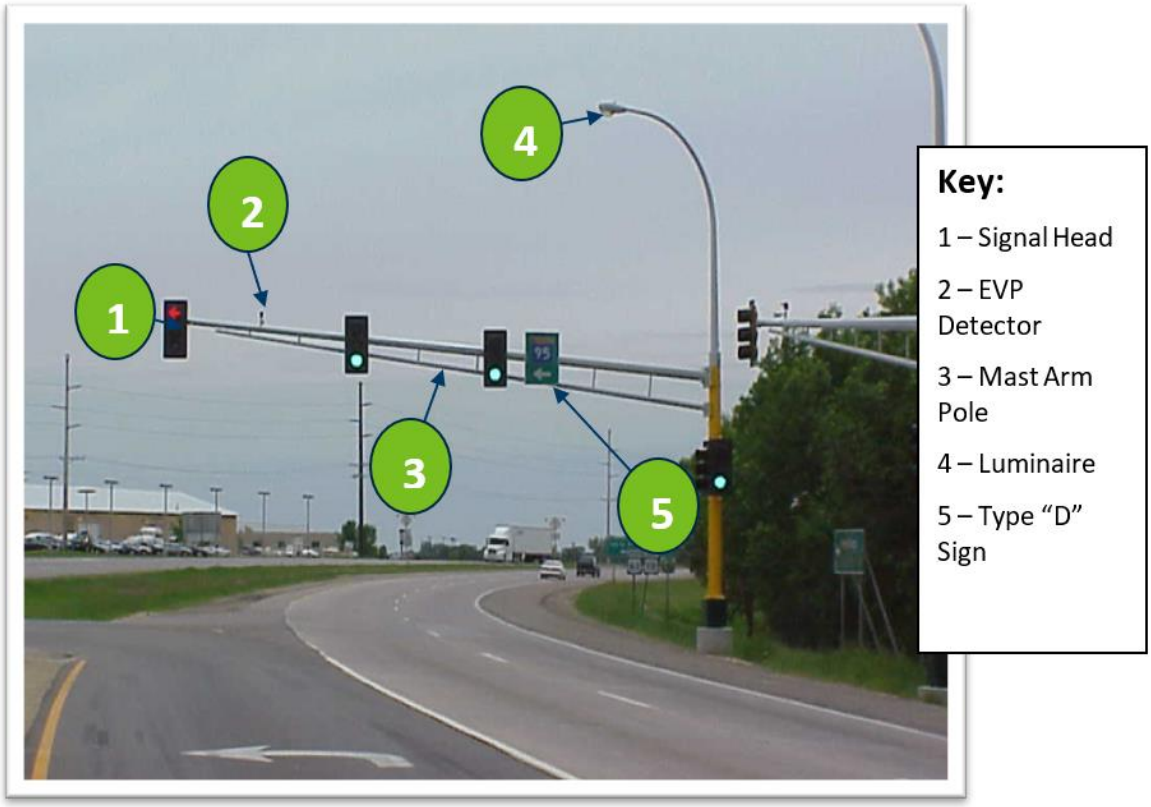
Additionally, agreements may cover signals, roadway lighting, advanced warning flashers, signal ahead flashers, interconnect, emergency vehicle preemption, Type "D" signs, internally lit signs, crosswalk markings, intersection improvements, beacons, preliminary engineering, engineering and inspection, State furnished materials (cabinet, controller, video cameras), and city/county furnished materials. The cost is also a split by leg for interconnect (communications devices for adjacent intersections in a signal system).

3. FIELD COMPONENTS

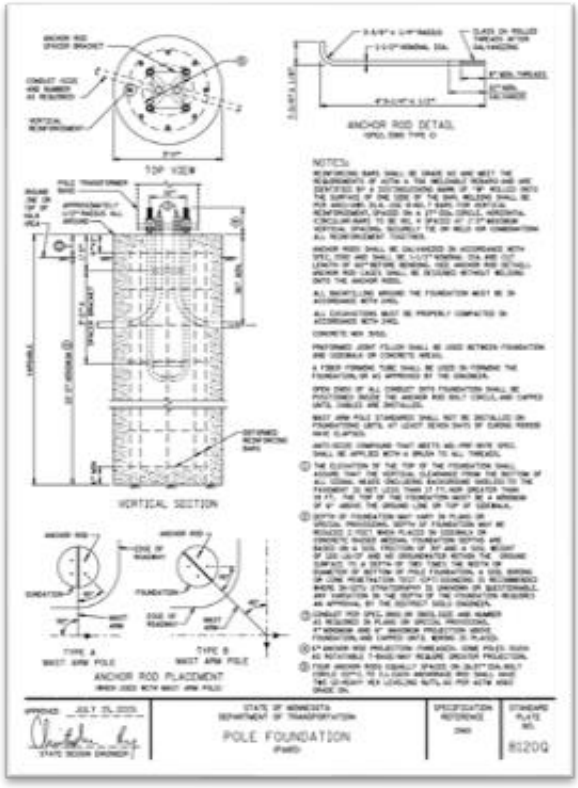
In this chapter, you will be introduced to some common field components used with traffic signals. MnDOT standard plans and standard plates are available at the link below. Standard plates are for items that will be fabricated off-site and brought to the project site for installation, while standard plans are used for the layout and construction of items that will be constructed on-site.

https://www.dot.state.mn.us/library/standards.html

Below is a picture of a signalized intersection, as well as an image identifying a mast arm pole and some of the common components found on it. These include EVP detector, traffic signal heads (protected and permitted), a luminaire for lighting the roadway and a Type "D" guide sign.



3.1 Foundations



On the right is Standard Plate No. 8120, Pole Foundation for Type PA85 Poles. Standard Plate No. 8126 is for foundation PA90 and PA100 Poles (i.e. longer mast arms) and 8133 is for Type BA Poles. See page 19 for information on mast arm lengths.

Refer to the Standard Plates for the most current version.

The picture below shows an anchor bolt, and the bottom image shows a steel foundation cage (reinforcing bars). See Standard Plate 8120 for details.

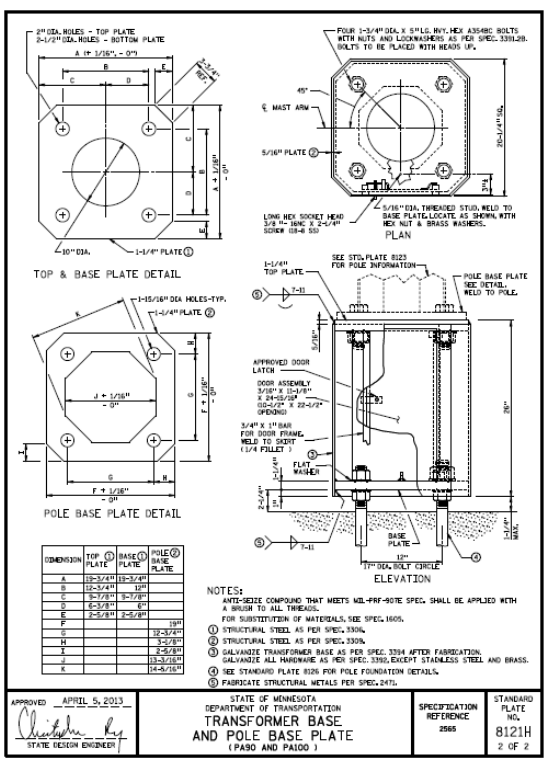
The image below shows the foundation at grade level for a PA series pole and for a BA series pole being constructed. Notice the anchor rods where the signal transformer base attaches.

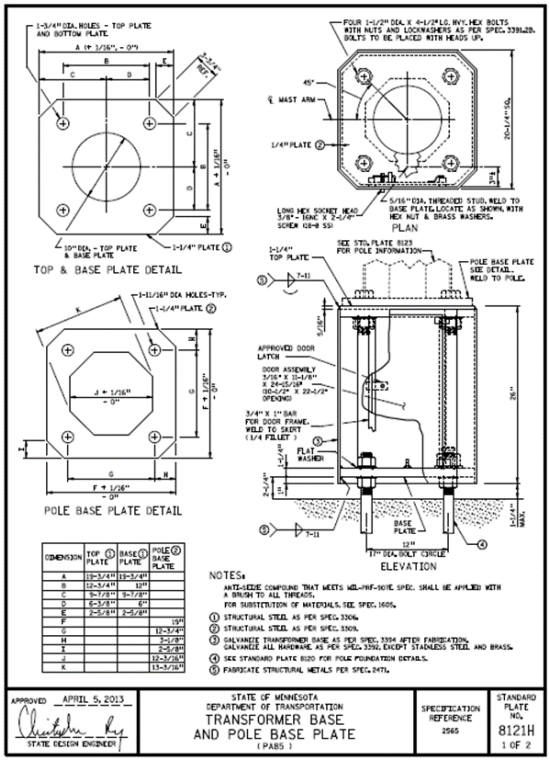
Foundation (BA series)

Foundation (PA series)

3.2 Transformer Base

Below is Standard Plate No. 8121 (page 1 and 2), Transformer Base and Pole Base Plate.





The pictures below show a pole base and transformer. See Standard Plate 8121 for details.

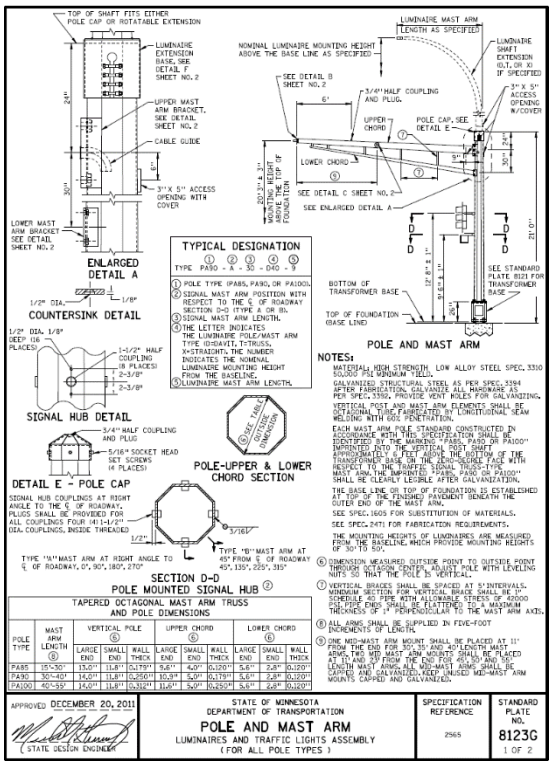
Below are examples of transformer base access panels. The picture on the left is on a pedestal pole and the picture on the right is for a mast arm (with access panel open). See Standard Plate 8121 for details.

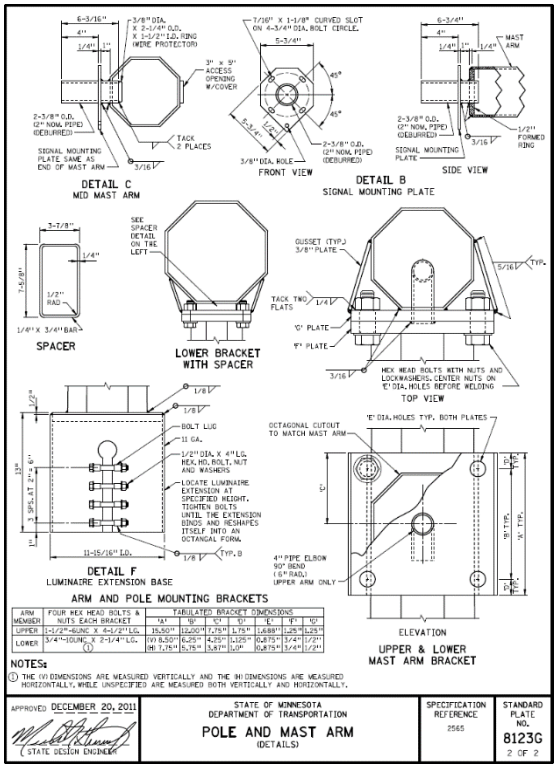
3.3 Pole and Mast Arms

Standard Plate No. 8123 (page 1 and 2), Pole and Mast Arm, is included below. Notice that there are 3 types that are used:

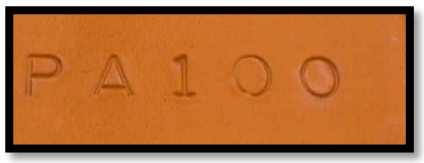
1. PA85 (15-30' long mast arms)
2. PA90 (30-40' long mast arms)
3. PA100 (40-55' long mast arms)

The length of the arm is specified on the signal layout plan sheets (see Chapter 4). Standard Plate No. 8133 covers Type BA Poles (60-80’ mast arms).





This picture shows the vertical pole (yellow post shown in the picture on the left) and a stamp indicating that this is a Pole Type PA100 (image below). See Standard Plate 8123 for details.



3.4 Signals

MnDOT and several other jurisdictions were among some of the first jurisdictions in the United States to implement the 4-section Flashing Yellow Arrow (FYA) protected-permissive left turn signal indication at intersections where in the past 5-section protected-permissive circular green signal indications were used. Both types of signal indications direct motorists to turn left after yielding to oncoming traffic, but a national study demonstrated that drivers found FYA indications more understandable than traditional yield-on-green ball indications.

Refer to the MnDOT OTE link for additional details on flashing yellow arrows.
www.dot.state.mn.us/trafficeng/signals/flashingyellowarrow.html

On the following page is a figure with descriptions of the function for each section of the 4-section FYA indication.

Steady Red Arrow: Drivers turning left must stop and wait.

Steady Yellow Arrow: Drivers are warned that the left-turn signal is about to go to red and they should prepare to stop or prepare to complete their left turn if they are within the intersection.

Flashing Yellow Arrow: Drivers are allowed to turn left after yielding to oncoming traffic and pedestrians. (Oncoming traffic has a green light.) Drivers must determine if there is an adequate gap before turning!

Solid Green Arrow: Left turns have the right of way. Oncoming traffic has a red light.

Below are pictures of 4-section FYA indications, both at the end of the mast arm and mounted to the pole. Also depicted in the photos below is yellow retroreflective sheeting around the border of the signal indication backplate.

Below are pictures of a 3-section protected left turn signal. In a protected left, all three indications are arrow type. Vehicles are only allowed to move during the green indication (no permissive left turn movement is allowed).

The pictures below show a protected/permissive left turn signal. Left turn vehicles are allowed to operate as a protected movement during the green arrow and as a permissive movement (yield to oncoming traffic) during the green ball. Notice the supplemental 'Left Turn Yield on Green' sign.

The picture below shows a No Right Turn blankout sign mounted on a mast arm pole. These may be use where a railroad is running parallel with the highway and the train crossing is active, or if a pedestrian trail crossing push button call has been placed.

3.5 Mast Arm Pole

The picture below on the left shows a Type PA mast arm pole. See Standard Plate 8123 for details. Type PA mast arm poles are supplied in 5' increments from 15' to 55'.

The picture on the right shows a Type BA mast arm pole. See Standard Plate 8133 for details. Type BA mast arm poles are supplied in 5’ increments from 60’ to 80’. The longer mast arms have been implemented at several locations. Type BA mast arm poles are approximately three times the cost of Type PA mast arm poles.

The foundation can be a drilled shaft or spread footing design. The preferred method is the drilled shaft.

3.6 Chord Spacing

The picture below shows the chords (vertical braces) on a mast arm pole. The chords are spaced at 5' intervals. See Standard Plate 8123 for details.

3.7 Other Field Components

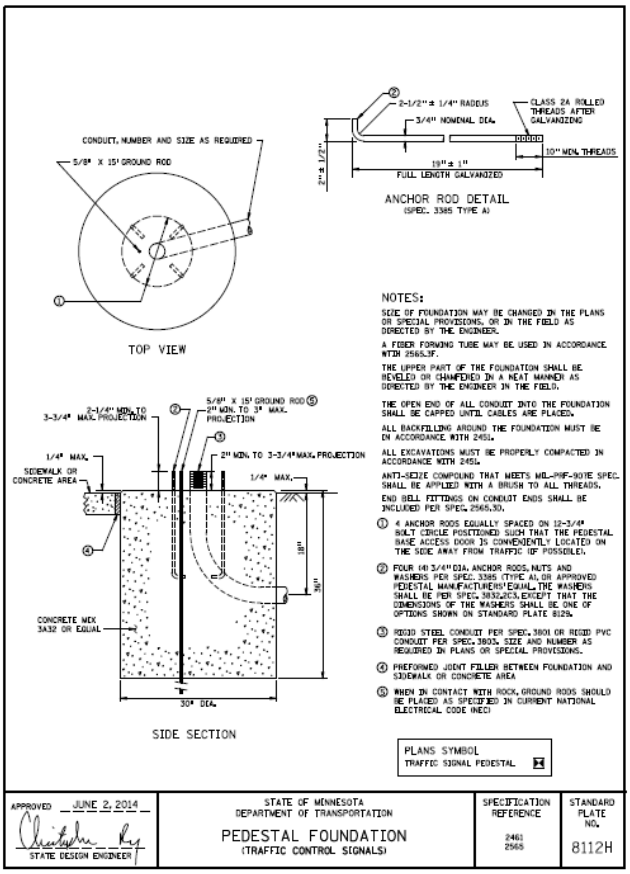
The pictures on the top show a typical Type "D" guide sign (front and back). The pictures on the bottom show a close-up view of an EVP detector and confirmatory light. See Chapter 11 for more information on EVP.

The pictures on the top show a typical signal head-mounting bracket. The picture on the bottom shows a hinge where the mast arm is mounted to the pole. The hinge allows the mast arm to be rotated if it is on a house-moving route.

The picture on the left shows the luminaire shaft extension. The picture on the right is the luminaire head. Generally, there are at least two luminaires at an intersection. Four luminaires will continue to become more prominent. The photoelectric cell is located within the signal cabinet.

3.8 Signal Pedestal

To the left is Standard Plate No. 8112, Pedestal Foundation. The picture to the right is a close-up of the pedestal base.



The picture on the top left is the concrete pedestal foundation and anchor rods. The picture on the right shows the base and wind collar. See Standard Plate 8112 for details on the pedestal foundation.

The picture below shows 3-section left turn signals mounted on top of a pedestal pole.

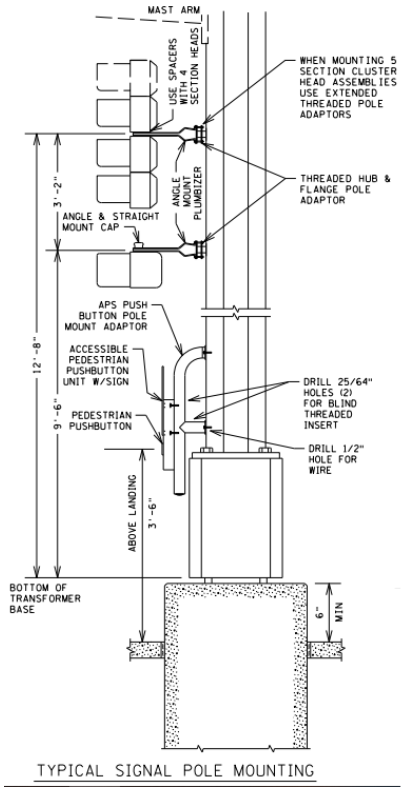
The pictures below show the old style of mounting assemblies for traffic signal heads on a pedestal pole.

Long Pole w/ Bracketing

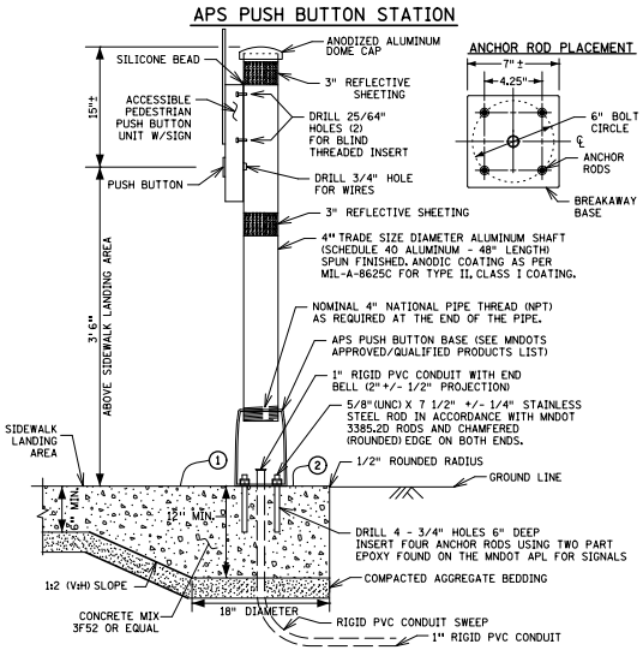
Pedestal Bracket

Pedestal Bracket

Below is an image of a one-way signal and pedestrian indication bracket and mounting detail.



Below, the image on the left shows the Accessible Pedestrian Signal (APS) push button station detail from the plan set. The picture on the right shows an APS push button station at an intersection.



3.9 Pedestrian Hybrid Beacons

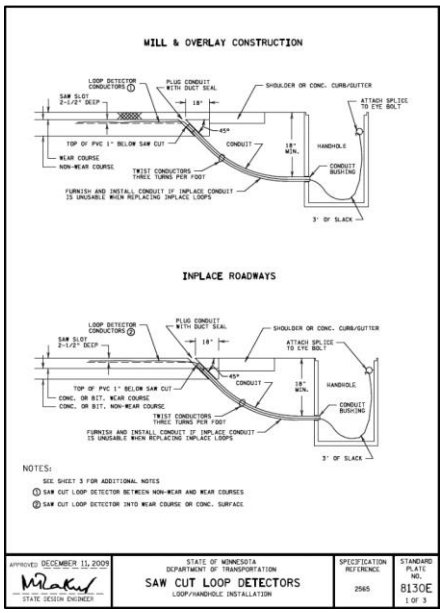
From the 2009 Edition of the Federal Manual on Uniform Traffic Control Devices, "A pedestrian hybrid beacon is a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk."

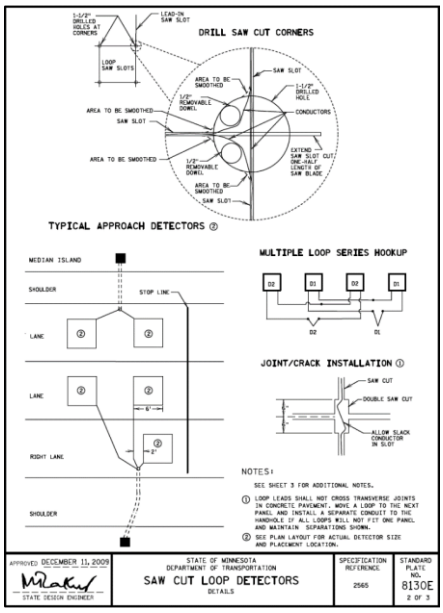
This type of signal is commonly referred to as a HAWK signal. "HAWK" stands for **H**igh-intensity **A**ctivated Cross-**W**al**K**. There are at least 10 HAWK systems installed in Minnesota.

For more information, go to www.dot.state.mn.us/d3/hottopics/hawk.html

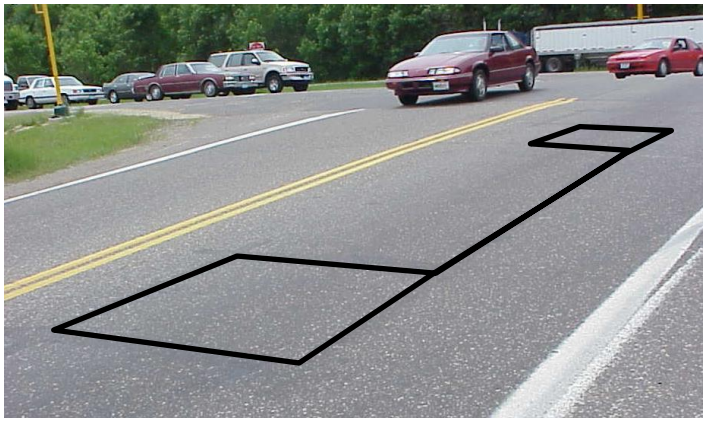
3.10 Saw Cut Loop Detectors

This is Standard Plate No. 8130, Saw Cut Loop Detectors.



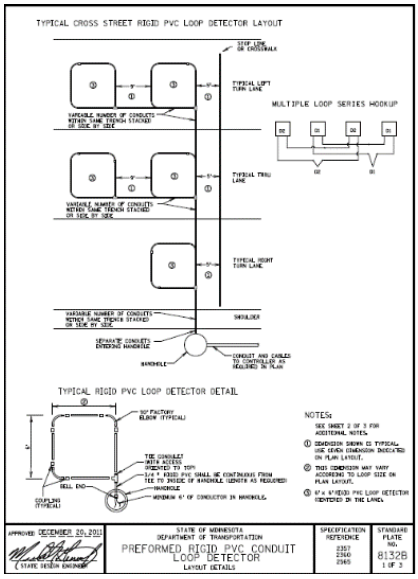


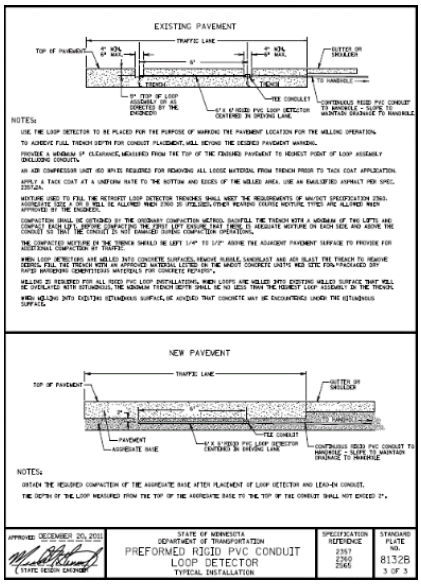
The photos below show loop detectors that are placed in the roadway by sawcut. The detectors have been outlined for these pictures only. Conductor wire is placed in the saw cuts and covered with epoxy filler. The loops are used to detect vehicles. For details, see Standard Plate 8130.



3.11 Non-Metallic Loop Detectors

This is Standard Plate No. 8132, Preformed Rigid PVC Conduit Loop Detector.





Below are pictures of a Non-Metallic Conduit (NMC) loop conduit. Conductor wire is placed in the conduit and the loop assembly is placed in or under the roadway. The NMC loop is used to detect vehicles.

When loop detectors are not used, other forms of vehicle detection may be installed, including video, microwave, and sonic detection. Below are some examples of these other forms of detection. Typically, these detectors are installed overhead.

Video Detection (mast arm, standard camera)

Sonic Detection

Video Detection (davit, fisheye camera)

Microwave Detection

3.12 Handholes

The picture on the left shows the handhole structure prior to installation. The picture on the right show the installed handhole with wire being pulled through. A handhole is used as an access to conduit and wire. The lid can be removed. See the Standard Specifications, Special Provisions and Approved Products List (APL) for details.

3.13 Other Field Components

The picture on the left shows typical crosswalk markings. These indicate where pedestrians cross the roadway. The picture on the right shows a typical pedestrian curb ramp installation (note that the APS push button station depicted is not the correct location based on current design standards).

Below are some pictures showing a typical traffic signal cabinet and service cabinet installation. See Chapter 5 for further details.

These pictures below show an example of the source of power (SOP) for a traffic signal. Depending on the configuration of power infrastructure in various areas, the SOP may either be an overhead transformer on a wood pole or a ground mounted transformer on a concrete foundation.

3.14 Enforcement Lights

The bright blue lights, placed at 90-degree angles on the poles, activate when the signal turns red. It is visible to police officers parked nearby but not to approaching traffic. Law enforcement uses the light to spot red-light runners.

3.15 Signal Ahead Sign

Below is a picture of a signal ahead sign. This sign is installed on approaches to a traffic signal that is not visible for a sufficient distance to permit the road user to react to it.

3.16 Advance Warning Flasher (AWF)

Below an image showing a typical Advance Warning Flasher installation. It is used in lieu of the signal ahead sign on higher speed corridors where motorists need longer deceleration distances. See Chapter 10 for further details.

3.17 Span Wire Signal

Below is a picture of a typical span wire signal. Generally, these are temporary installations to be used during roadway construction, but some may be long-term as an interim solution prior to a larger future roadway project where geometry is changed significantly. Generally, the traffic signal wires are installed overhead instead of underground.

Additionally, below are some images showing close-ups of span wire signal heads.

3.18 Approved/Qualified Products

For a list of pre-approved products to use on MnDOT projects, visit http://www.dot.state.mn.us/products. Click on the Signals link for traffic control signal products.

4. INTRODUCTION TO TRAFFIC SIGNAL PLANS

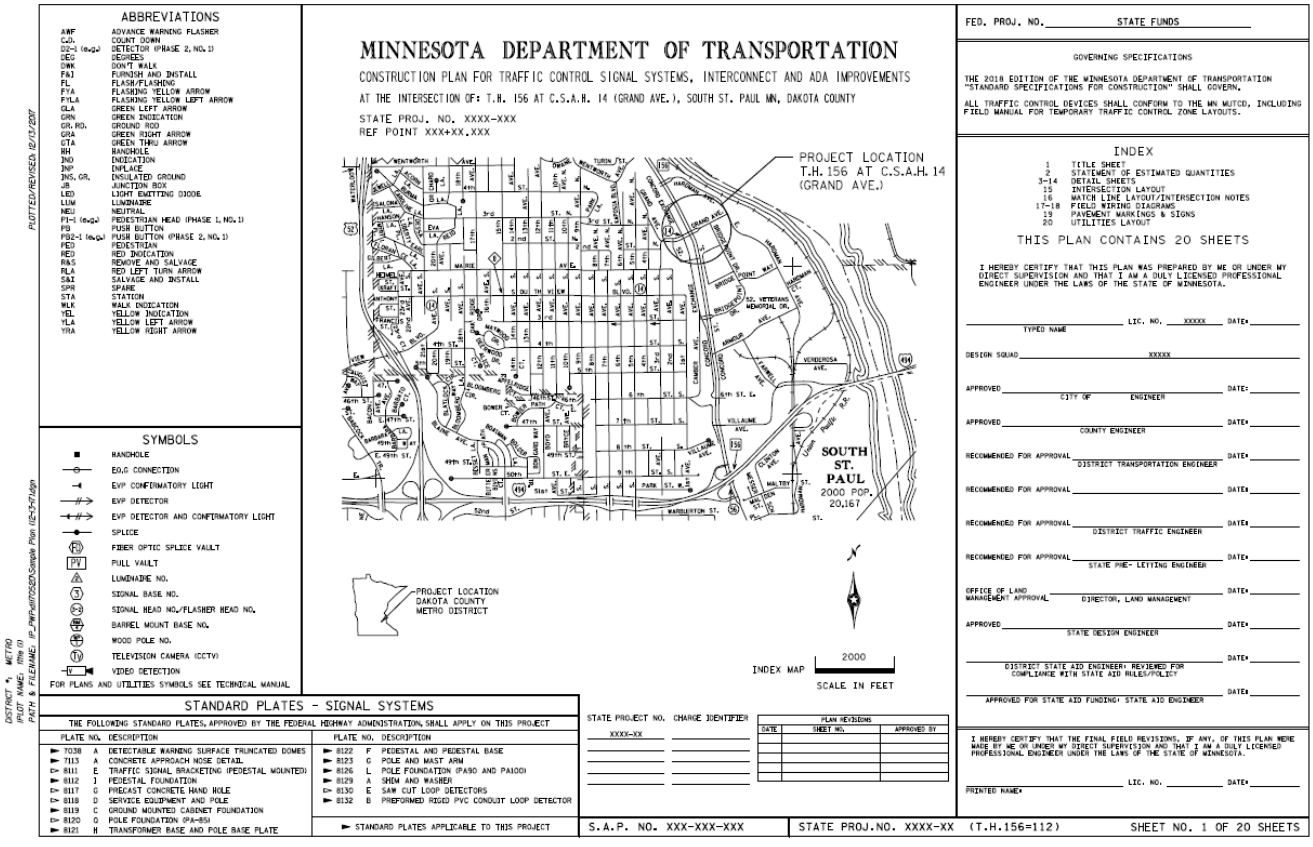
In this chapter you will be introduced to a traffic signal plan sheet layout and wiring diagram and be given an overview of the typical items that are found in these plan sets. The current sample plan set is available at the following link: http://www.dot.state.mn.us/trafficeng/signals/signalplansheets.html.

There are multiple reasons a traffic signal plan is needed, including:

- Building the traffic signal
- Bidding
- Tort claims
- Maintenance
- Locates

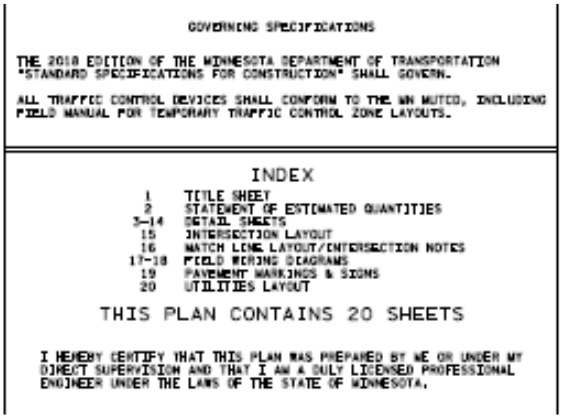
4.1 Title Sheet – Front Page

The title sheet is required for all traffic signal plans. It includes information such as the title block, project location, governing specifications, etc.



4.1.1 Governing Specs and Index of Sheets

This defines the governing specifications for the project, the project funding, and the index of the sheets contained within the plan set.



GOVERNING SPECIFICATIONS

THE 2018 EDITION OF THE MINNESOTA DEPARTMENT OF TRANSPORTATION "STANDARD SPECIFICATIONS FOR CONSTRUCTION" SHALL GOVERN.

ALL TRAFFIC CONTROL DEVICES SHALL CONFORM TO THE MN MUTCD, INCLUDING FIELD MANUAL FOR TEMPORARY TRAFFIC CONTROL ZONE LAYOUTS.

INDEX

1	TITLE SHEET
2	STATEMENT OF ESTIMATED QUANTITIES
3-14	DETAIL SHEETS
15	INTERSECTION LAYOUT
16	MATCH LINE LAYOUT/INTERSECTION NOTES
17-18	FIELD WIRING DIAGRAMS
19	PAVEMENT MARKINGS & SIGNS
20	UTILITIES LAYOUT

THIS PLAN CONTAINS 20 SHEETS

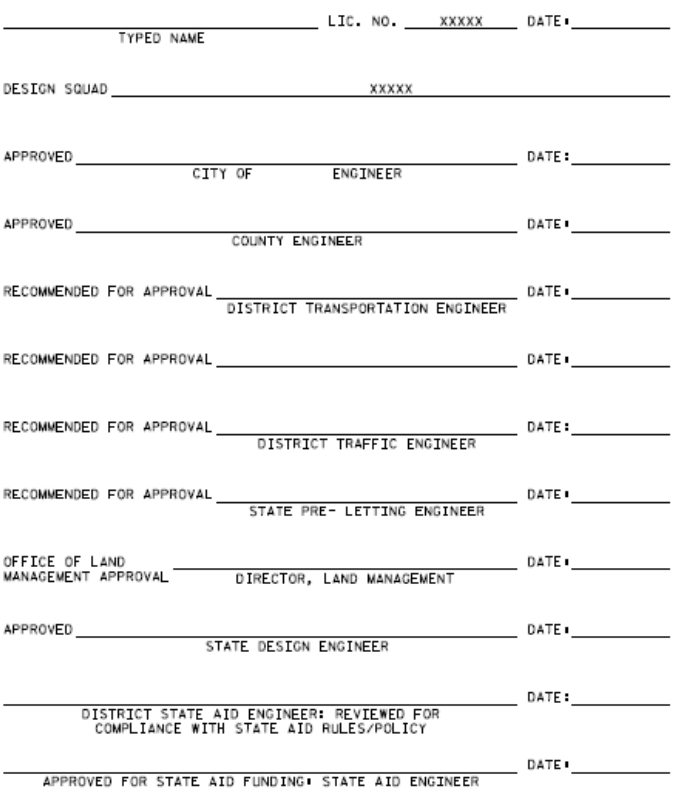
I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

4.1.2 Signature Block

The designer should consult with the MnDOT project manager to ensure that the appropriate signature block is used. The signature block is contained on the title sheet and varies depending on the type of project.

The plan preparation certification note identifies:

- Who the plan set was developed by (or under the direct supervision of)
- That individual's state registration information



_____ LIC. NO. XXXXX DATE: _____
TYPED NAME

DESIGN SQUAD _____ XXXXX _____

APPROVED _____ DATE: _____
CITY OF ENGINEER

APPROVED _____ DATE: _____
COUNTY ENGINEER

RECOMMENDED FOR APPROVAL _____ DATE: _____
DISTRICT TRANSPORTATION ENGINEER

RECOMMENDED FOR APPROVAL _____ DATE: _____

RECOMMENDED FOR APPROVAL _____ DATE: _____
DISTRICT TRAFFIC ENGINEER

RECOMMENDED FOR APPROVAL _____ DATE: _____
STATE PRE- LETTING ENGINEER

OFFICE OF LAND MANAGEMENT APPROVAL _____ DATE: _____
DIRECTOR, LAND MANAGEMENT

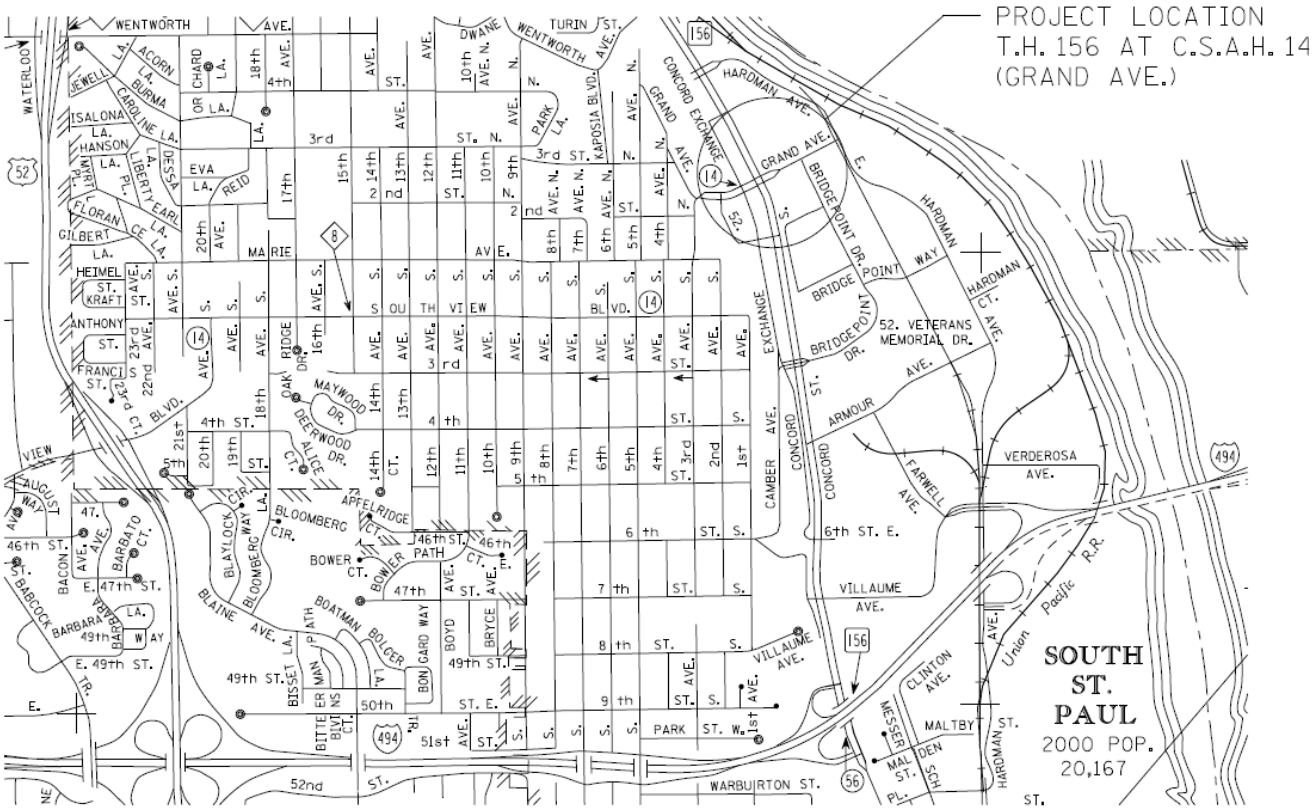
APPROVED _____ DATE: _____
STATE DESIGN ENGINEER

_____ DATE: _____
DISTRICT STATE AID ENGINEER: REVIEWED FOR COMPLIANCE WITH STATE AID RULES/POLICY

_____ DATE: _____
APPROVED FOR STATE AID FUNDING: STATE AID ENGINEER

4.1.3 Index Map

The index map is used to identify the location of the project(s). The project numbers and sheet numbers are shown in the lower right-hand corner of the title sheet and on all other sheets. For revisions to the plan made after project advertisement, an "R" shall be used after the sheet number.



4.1.4 Standard Plates Summary and Estimated Quantities

This identifies the list of Standard Plates that are applicable to this project. The estimated quantities may be included on a separate sheet or shown on the title sheet (if there is room). Traffic control interconnection, emergency vehicle preemption system, and other items such as conduit and handholes for a future signal system may be itemized separately from the signal system due to cost participation. The appropriate specification item numbers, item descriptions, and units using the State's computerized pay item list shall be included.

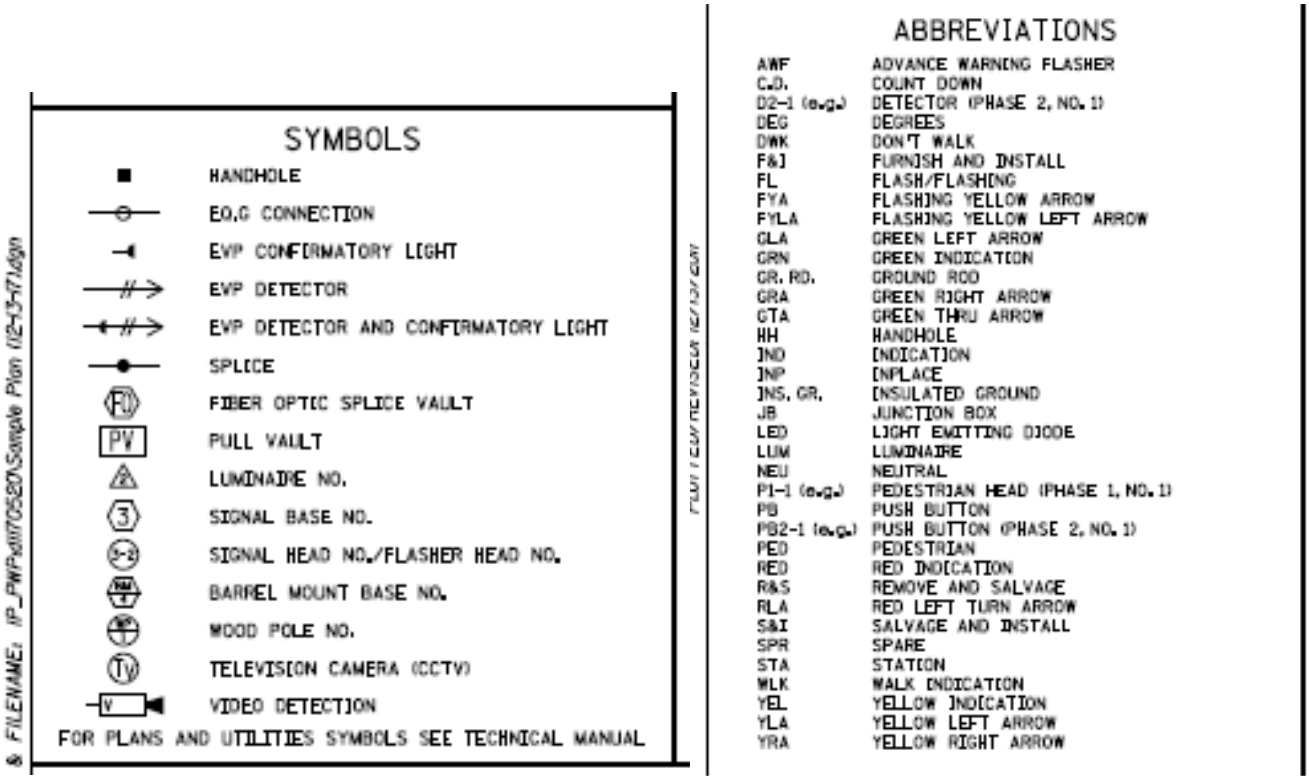
STANDARD PLATES - SIGNAL SYSTEMS

THE FOLLOWING STANDARD PLATES, APPROVED BY THE FEDERAL HIGHWAY ADMINISTRATION, SHALL APPLY ON THIS PROJECT

	PLATE NO.		DESCRIPTION		PLATE NO.		DESCRIPTION
►	7038	A	DETECTABLE WARNING SURFACE TRUNCATED DOMES	►	8122	F	PEDESTAL AND PEDESTAL BASE
►	7113	A	CONCRETE APPROACH NOSE DETAIL	►	8123	G	POLE AND MAST ARM
▽	8111	E	TRAFFIC SIGNAL BRACKETING (PEDESTAL MOUNTED)	►	8126	L	POLE FOUNDATION (PA90 AND PA100)
►	8112	I	PEDESTAL FOUNDATION	►	8129	A	SHIM AND WASHER
▽	8117	G	PRECAST CONCRETE HAND HOLE	▽	8130	E	SAW CUT LOOP DETECTORS
▽	8118	D	SERVICE EQUIPMENT AND POLE	►	8132	B	PREFORMED RIGID PVC CONDUIT LOOP DETECTOR
►	8119	C	GROUND MOUNTED CABINET FOUNDATION				
▽	8120	Q	POLE FOUNDATION (PA-85)				
►	8121	H	TRANSFORMER BASE AND POLE BASE PLATE	► STANDARD PLATES APPLICABLE TO THIS PROJECT			

4.1.5 Plan Symbols and Abbreviations

These are some of the common symbols and abbreviations used in a signal plan set.



4.2 Title Sheet – Page 2

Page 2 of the title sheet is the quantity sheet. Earthwork summary tabulations may be included if the signal project is part of a construction project.

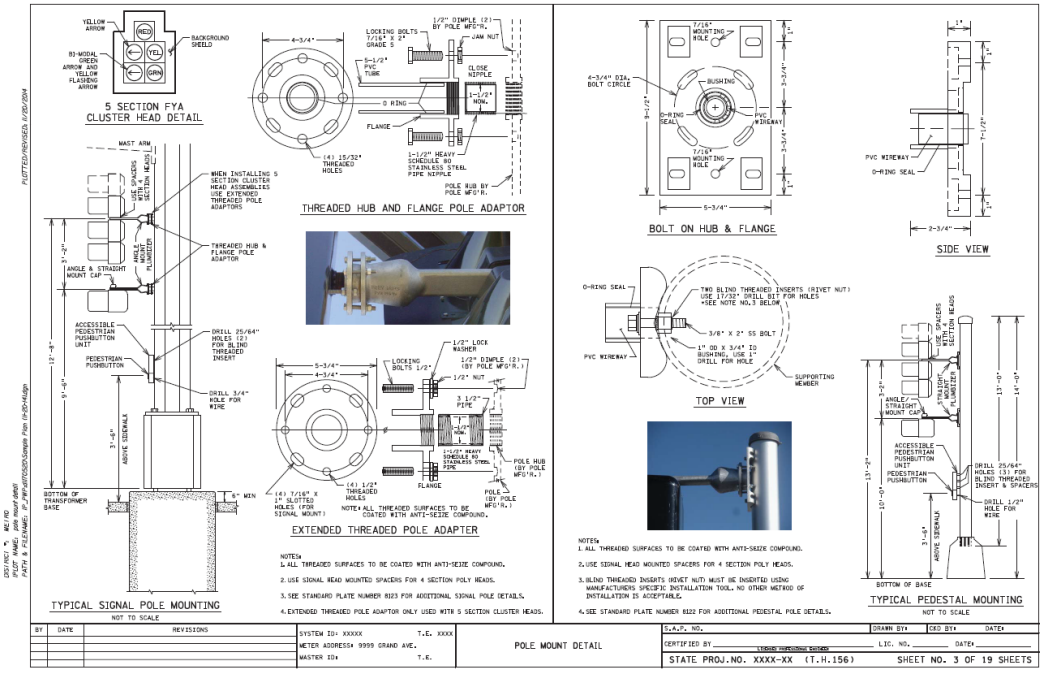
STATEMENT OF ESTIMATED QUANTITIES				COST BREAKDOWN			
ITEM NO.	DESCRIPTION	UNIT	TOTAL ESTIMATED QUANTITIES	STATE SP XXXX-XX	COUNTY SAP XXX-XXX-XXX	FEDERAL SP XXXX-XX	CITY SAP XXX-XXX-XXX
2021.501	MOBILIZATION	LUMP SUM					
2104.501	REMOVE CURB AND GUTTER	LIN FT					
2104.503	REMOVE CONCRETE WALK	SQ FT					
2104.503	REMOVE BRICK MEDIAN	SQ FT					
2104.503	REMOVE BRICK SIDEWALK	SQ FT					
2104.603	REMOVE AND REPLACE BITUMINOUS PAVEMENT	LIN FT					
2104.618	SALVAGE BRICK PAVERS	SQ FT					
2232.603	MILL AND PATCH BITUMINOUS PAVEMENT	LIN FT					
2521.618	CONCRETE WALK	SQ FT					
2531.603	CONCRETE CURB AND GUTTER	LIN FT					
2565.511	CONCRETE CURB DESIGN V	LIN FT					
2531.618	TRUNCATED DOMES	SQ FT					
2563.601	TRAFFIC CONTROL	LUMP SUM					
2565.511	TRAFFIC CONTROL SIGNAL SYSTEM	SIG SYS					
2565.601	EMERGENCY VEHICLE PREEMPTION SYSTEM	LUMP SUM					
2565.601	TRAFFIC CONTROL INTERCONNECTION	LUMP SUM					
2565.616	REVISE SIGNAL SYSTEM	SYSTEM					

4.3 All Sheets

The title block is required on all sheets. For the intersection layout sheet, the signal system ID, meter address, and TE number should be included.

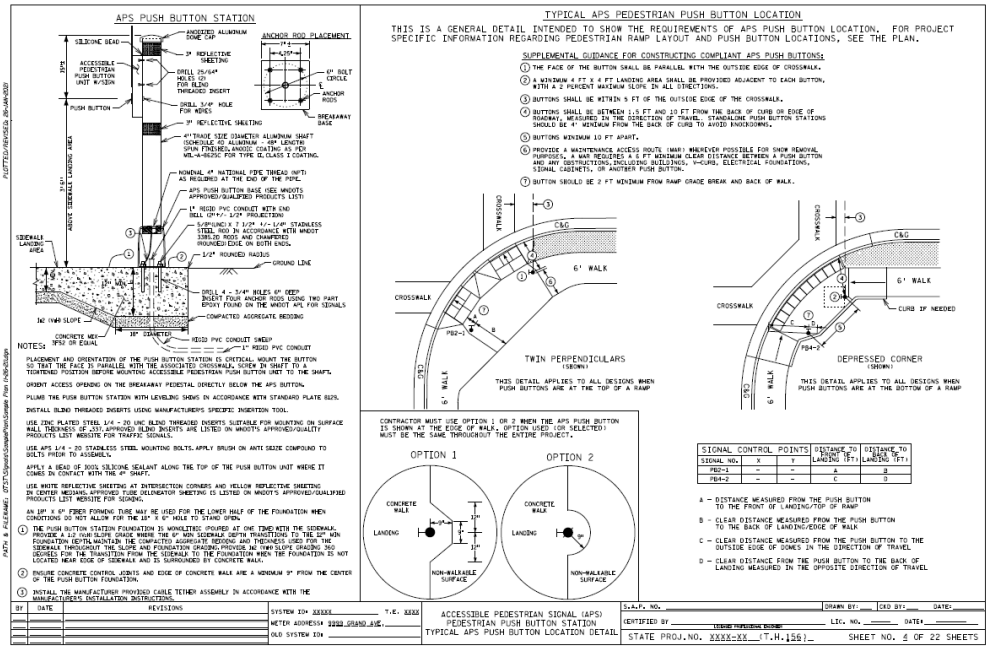
4.4 Pole Mount Detail – Page 3

The pole mount details for angle and straight mounts are pictured below.



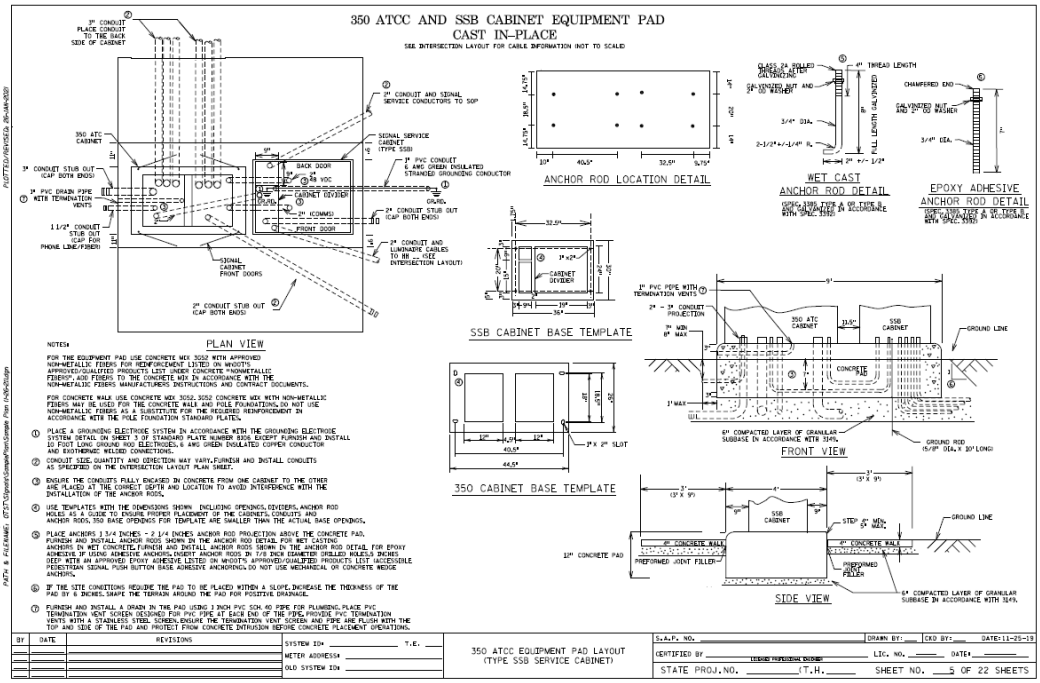
4.5 APS Push Button Station – Page 4

This detail shows the accessible pedestrian signal (APS) push button (PB) details.



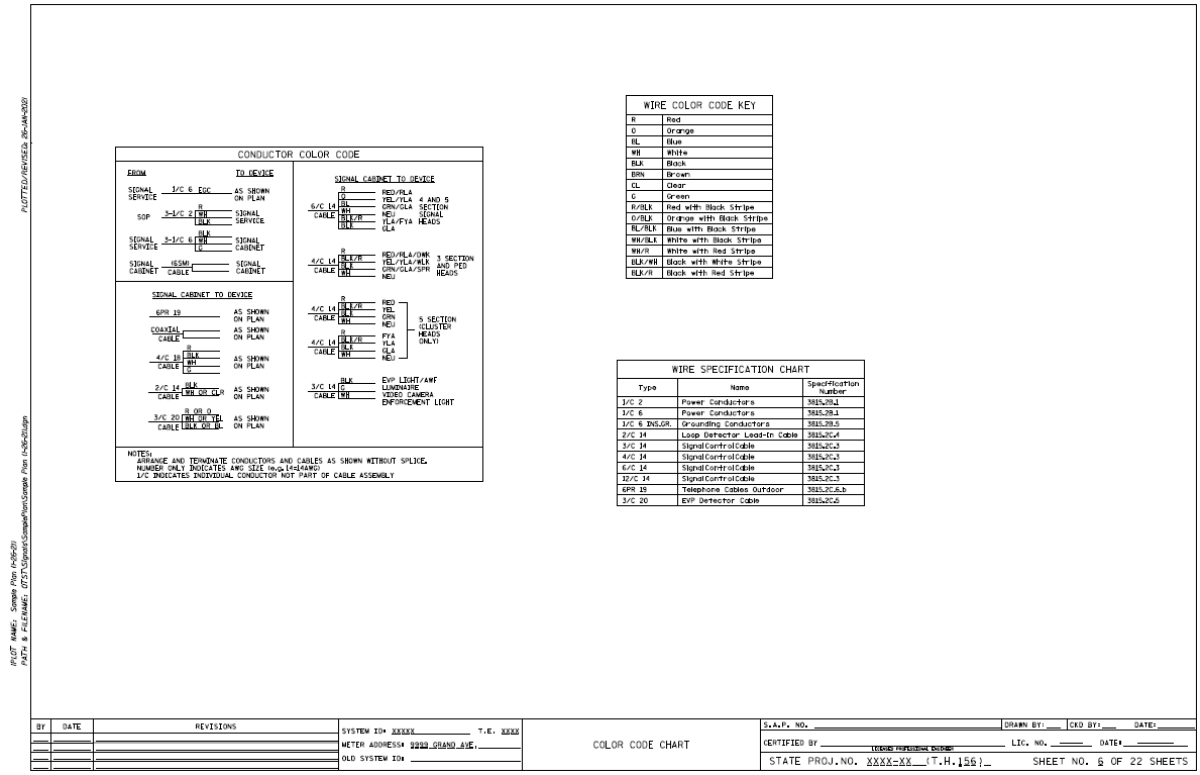
4.6 Equipment Pad – Page 5

The equipment pad layout sheet shows the details for the equipment pad. The concrete pad in the picture is the equipment pad for the traffic signal controller and service cabinet. This photo on the next page shows the traffic signal controller cabinet and service cabinet.



4.7 Color Code Chart – Page 6

This detail sheet includes the conductor color code, wire color code, and wire specification charts.



CONDUCTOR COLOR CODE

FROM	TO DEVICE
SIGNAL SERVICE — 3/C 6 EGC	AS SHOWN ON PLAN
SSP — 3-3/C 2 WH BLK	SIGNAL SERVICE
SIGNAL SERVICE — 3-3/C 6 WH BLK GL	SIGNAL CABINET
SIGNAL CABINET — CABLE (ESM)	SIGNAL CABINET

SIGNAL CABINET TO DEVICE

6PR 19	AS SHOWN ON PLAN
COAXIAL CABLE	AS SHOWN ON PLAN
4/C 18 CABLE R BLK WH G	AS SHOWN ON PLAN
2/C 14 CABLE BLK WH OR CLR	AS SHOWN ON PLAN
3/C 20 CABLE R OR O WH OR YEL BLK OR GL	AS SHOWN ON PLAN

SIGNAL CABINET TO DEVICE

6/C 14 CABLE R O BL GRN WH BLK/R BLK — RED/YLA; YEL/YLA 4 AND 6 SECTION GRN/GLA SIGNAL MDU; BLK/R YLA/FYA HEADS; GLA	
4/C 14 CABLE R BLK/R GLA WH — RED/YLA/GRN 3 SECTION; YEL/YLA/WLK AND PED; GRN/GLA/SPR HEADS; MDU	
4/C 14 CABLE R BLK/R YEL GRN WH — RED; YEL; GRN; MDU — 5 SECTION (CLUSTER HEADS ONLY)	
4/C 14 CABLE R BLK/R GLA WH — FYA; YLA; GLA; MDU — 5 SECTION (CLUSTER HEADS ONLY)	
3/C 14 CABLE BLK O WH — BLK: EVP LIGHT/AMF LUMINAIRE; WH: VIDEO CAMERA ENFORCEMENT LIGHT	

NOTES:
ARRANGE AND TERMINATE CONDUCTORS AND CABLES AS SHOWN WITHOUT SPLICE.
NUMBER ONLY INDICATES AWG SIZE (e.g. 14=#14AWG)
I/C INDICATES INDIVIDUAL CONDUCTOR NOT PART OF CABLE ASSEMBLY

WIRE COLOR CODE KEY

R	Red
O	Orange
BL	Blue
WH	White
BLK	Black
BRN	Brown
CL	Clear
G	Green
R/BLK	Red with Black Stripe
O/BLK	Orange with Black Stripe
BL/BLK	Blue with Black Stripe
WH/BLK	White with Black Stripe
WH/R	White with Red Stripe
BLK/WH	Black with White Stripe
BLK/R	Black with Red Stripe

WIRE SPECIFICATION CHART

Type	Name	Specification Number
1/C 2	Power Conductors	3825.2B.1
1/C 6	Power Conductors	3825.2B.1
1/C 6 INS.GR.	Grounding Conductors	3825.2B.5
2/C 14	Loop Detector Lead-In Cable	3825.2C.4
3/C 14	Signal Control Cable	3825.2C.3
4/C 14	Signal Control Cable	3825.2C.3
6/C 14	Signal Control Cable	3825.2C.3
12/C 14	Signal Control Cable	3825.2C.3
6PR 19	Telephone Cables Outdoor	3825.2C.6.b
3/C 20	EVP Detector Cable	3825.2C.6

BY	DATE	REVISIONS

SYSTEM ID= XXXXX T.E. XXXX
METER ADDRESS= 9999 GRAND AVE.
OLD SYSTEM ID=

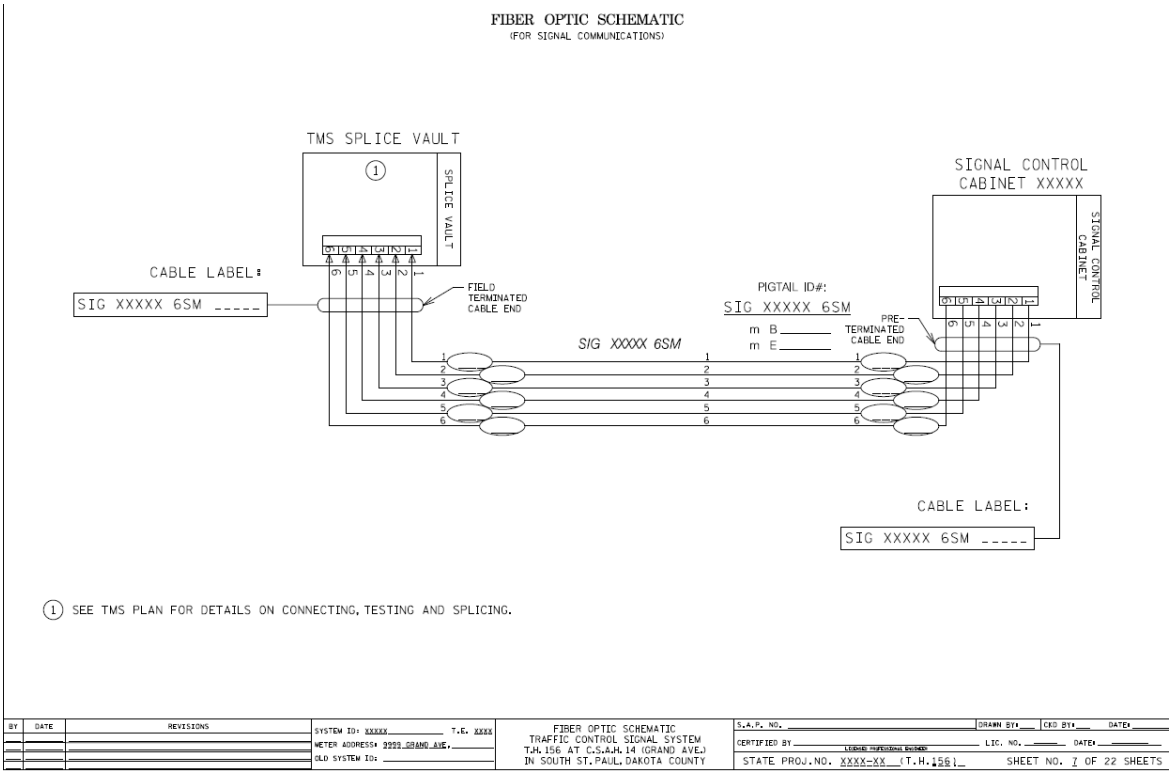
COLOR CODE CHART

S.A.F. NO. DRAWN BY: CKD BY: DATE:
CERTIFIED BY (LICENSED PROFESSIONAL ENGINEER) LIC. NO. DATE:
STATE PROJ. NO. XXXX-XX (T.H.156) SHEET NO. 6 OF 22 SHEETS

PLOTTED/REVISED: 05-MAY-2021
PLOT NAME: Sample Plan Pg06.dgn
PATH & FILENAME: C:\TS\Sample\Sample Plan Pg06.dgn

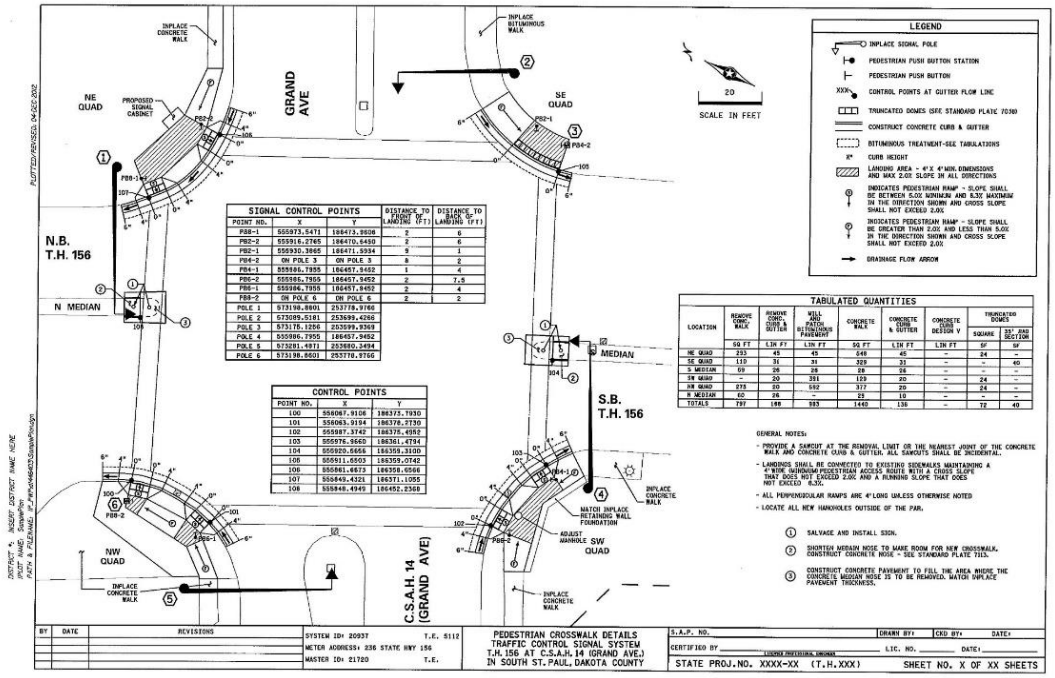
4.8 Fiber Optic Schematic – Page 7

This is the fiber optic schematic detail sheet (if applicable).



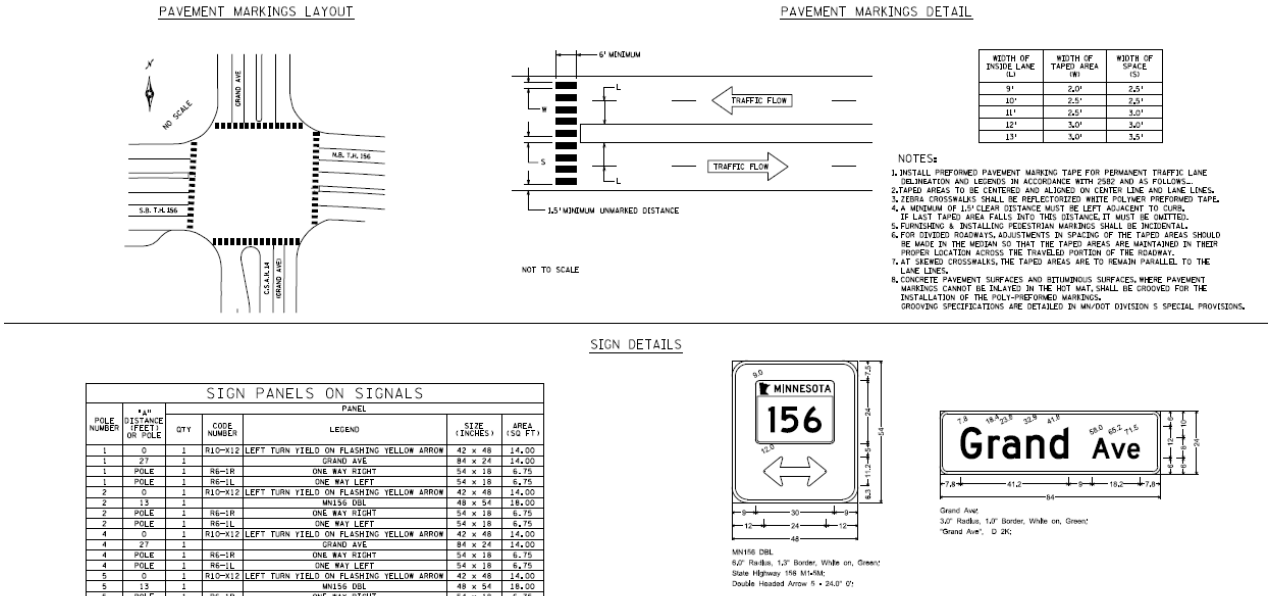
4.9 Pedestrian Crosswalk Details – Page 8

The image below shows the layout of the pedestrian curb ramps and push buttons.



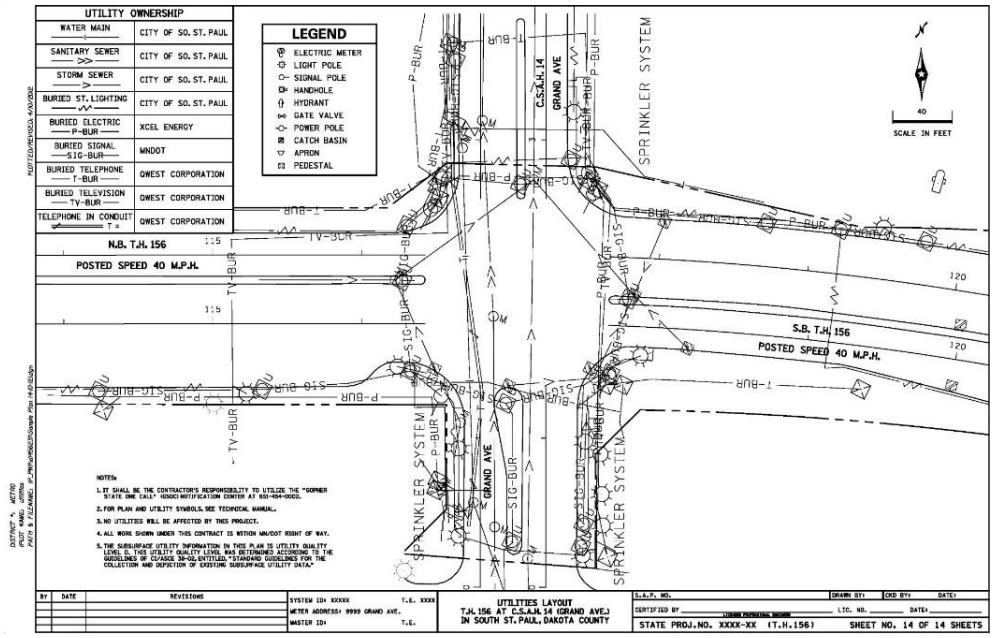
4.10 Pavement Markings and Signs – Page 19

Below is the detail sheet for pavement markings and signing.



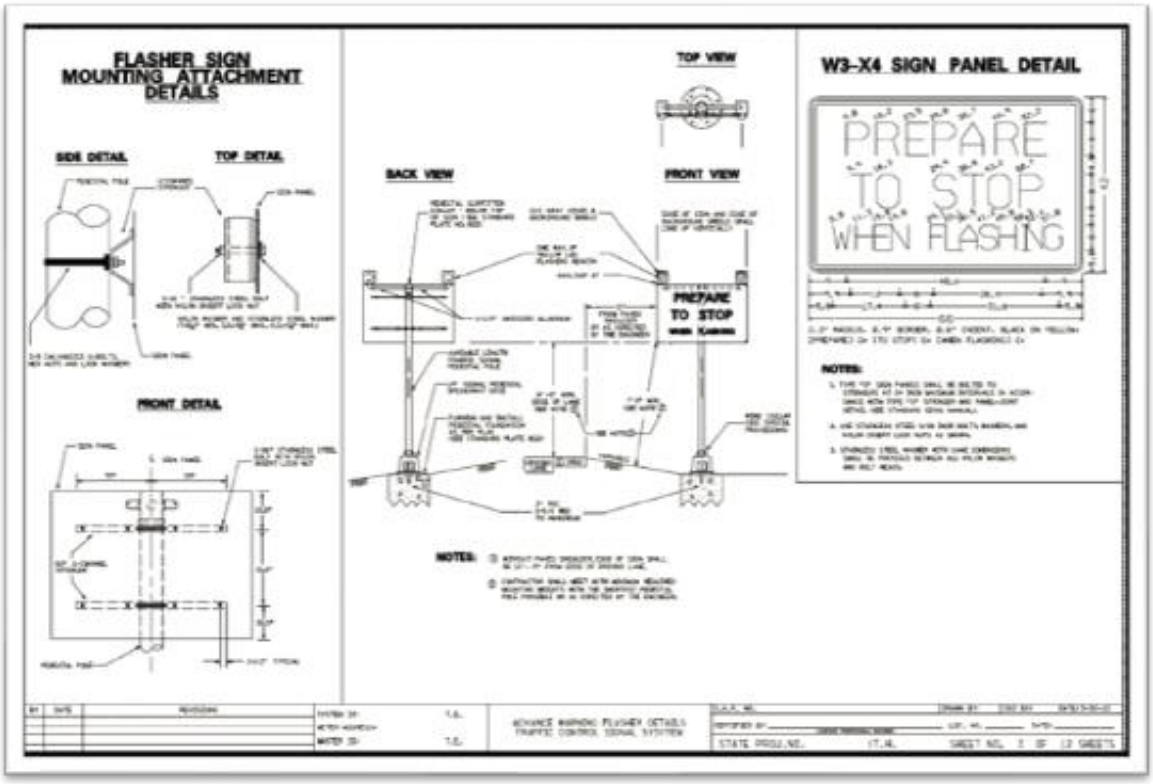
4.11 Utilities Layout – Page 22

Below is the plan sheet view of existing utilities.



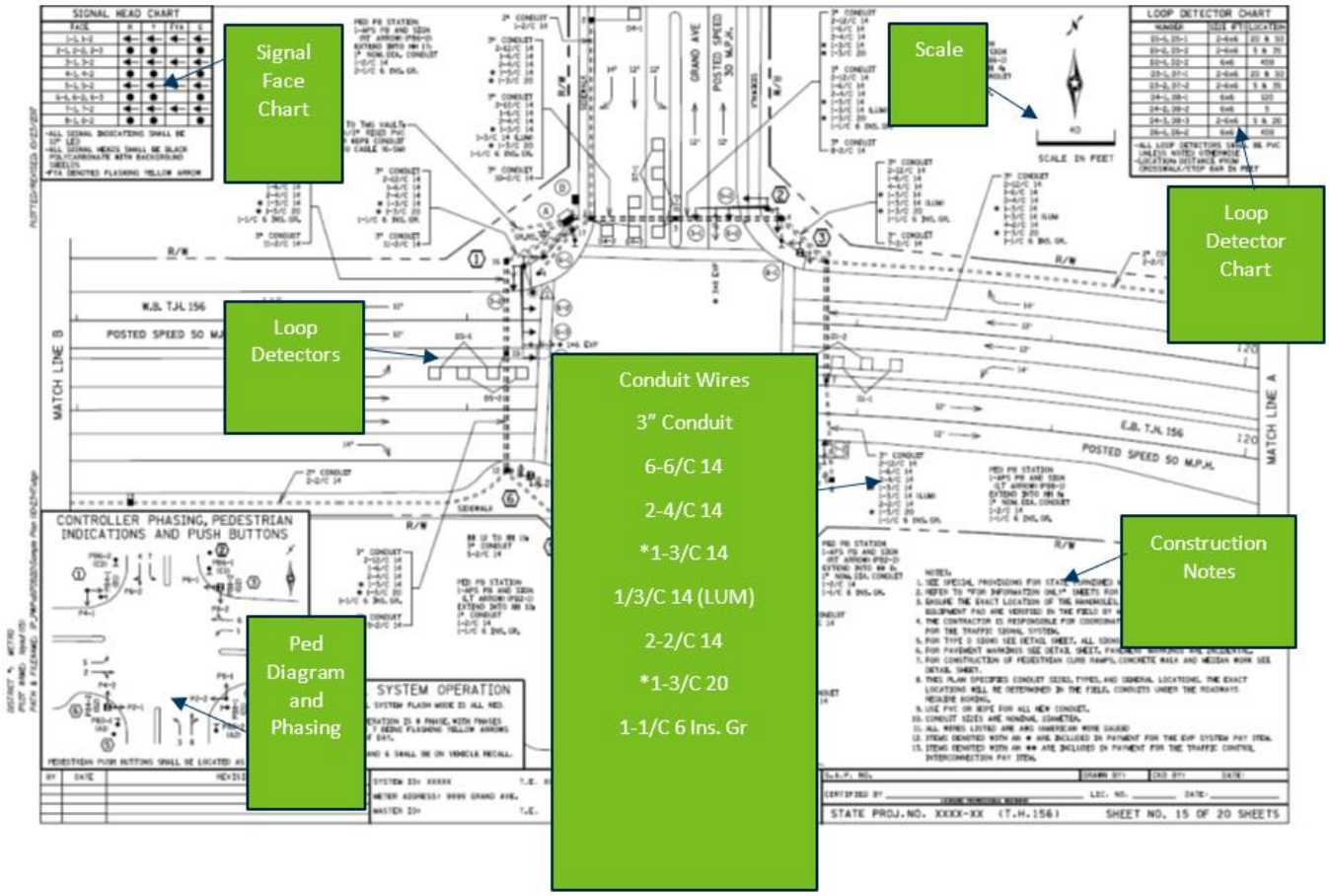
4.12 Advanced Warning Flasher Detail - Not Part of Example Plan

This is the detail sheet for the advance warning flasher. The pictures show some typical AWF installations. See Chapter 10 for more information on AWF. The current detail is available at the following link: http://www.dot.state.mn.us/trafficeng/signals/signalplansheets.html



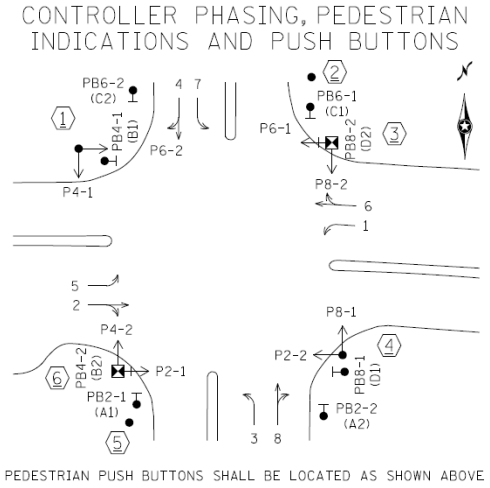
4.13 Signal Layout - Page 15

This is the typical plan sheet signal layout.



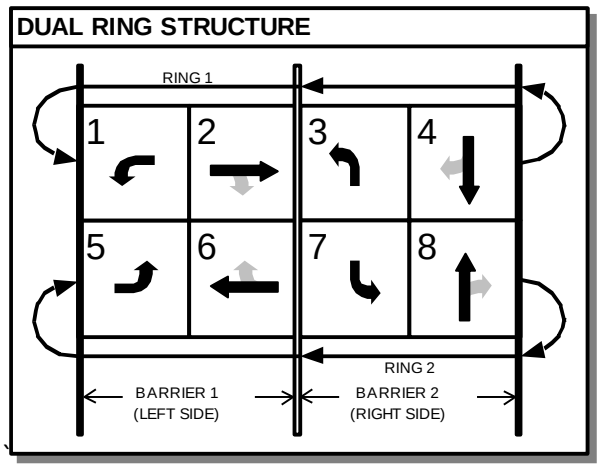
4.14 Intersection Layout – Page 15

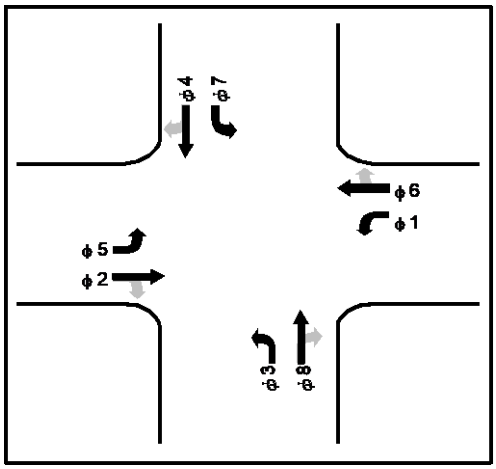
Below is an 8 phase NEMA Controller.



4.14.1 Controller Operations

Below are images showing the dual ring and concurrent group controllers and phasing schematic. Refer to Chapter 7 for additional details.

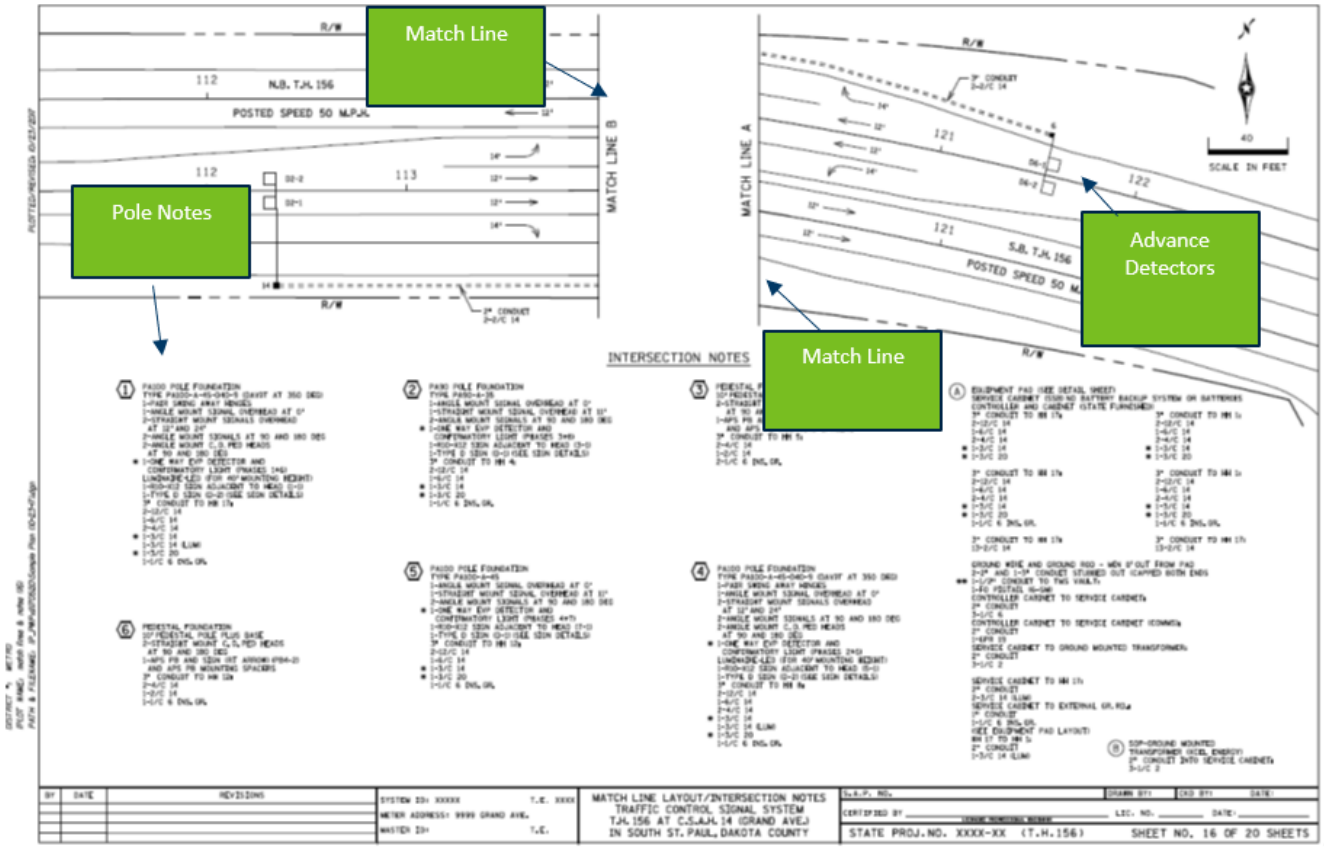




4.15 Signal Layout – Page 16

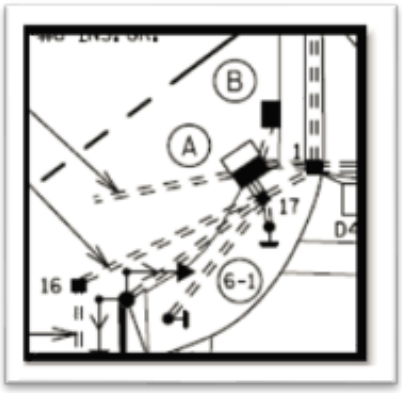
On the following page is the match line sheet of the signal layout. This sheet shows the advance detectors. The intersection layout sheet includes, at a minimum, the following:

- Intersection geometrics
- All graphics depicting signal system components
- Controller phasing diagram
- Signal system operation notes
- Signal faces table
- Loop detectors table
- Signal pole notes
- Equipment pad notes
- Source of power notes
- Construction notes
- Signal system ID, meter address and TE number
- A scale
- A north arrow
- Speed limits
- Street names
- DO NOT show utilities on the layout sheet, include additional sheet(s) for utilities



4.16 Intersection Layout – Page 15 and 16

The images below show the equipment pad and SOP Notes. Label, in a circle, the controller cabinet or equipment pad "A" and the source of power "B". A solid (filled) symbol identifies new equipment and an open symbol identifies in-place equipment.



4.17 Intersection Layout – Page 15

4.17.1 Mast Arm and Pole Symbols

The signal bases and pole notes are shown in a hexagon. The signal bases are labeled clockwise around the intersection with number 1 being adjacent to or near the controller cabinet. A solid filled symbol identifies new equipment and an open symbol identifies in-place equipment. The vehicle signal face is identified with the filled triangle (proposed). The faces are labeled from right to left as you approach the intersection. Signal faces are numbered with the controller phase first, followed by the face number (for example 2-1, 2-2, etc.).

Key:

1: Signal Head Indication

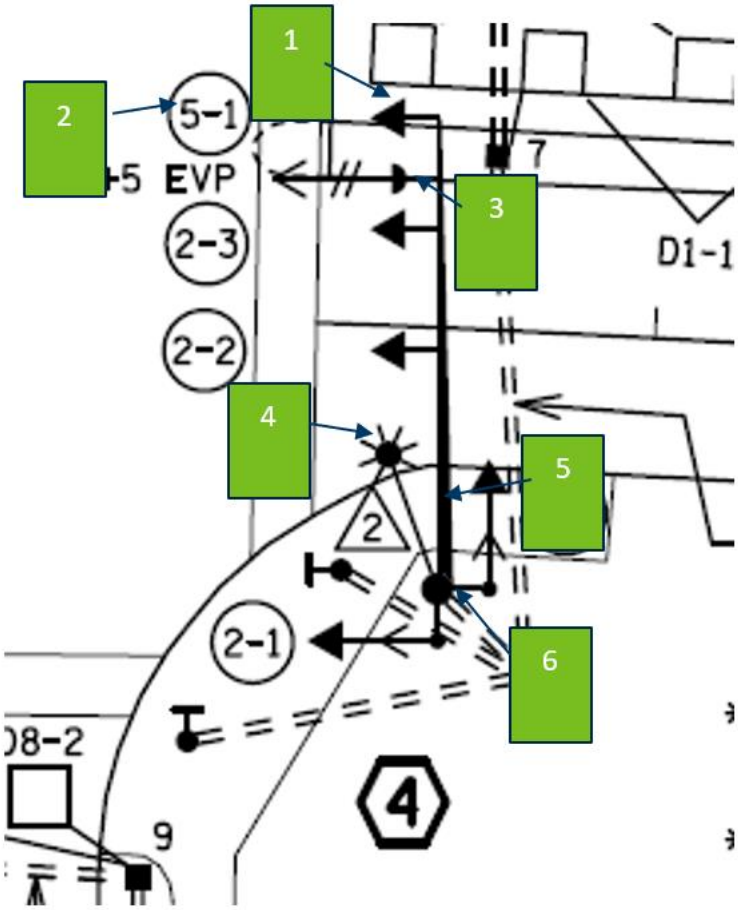
2: Signal Head Number

3: Emergency Vehicle Preemption

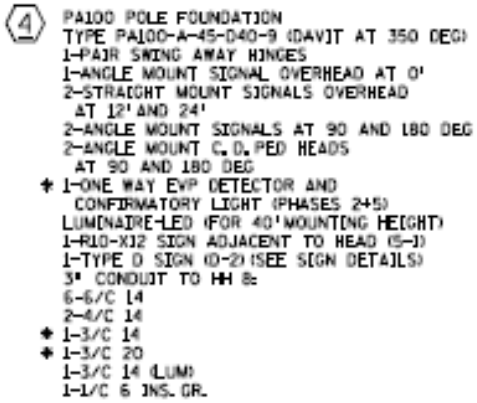
4: Luminaire

5: Mast Arm

6: Signal Pole Base



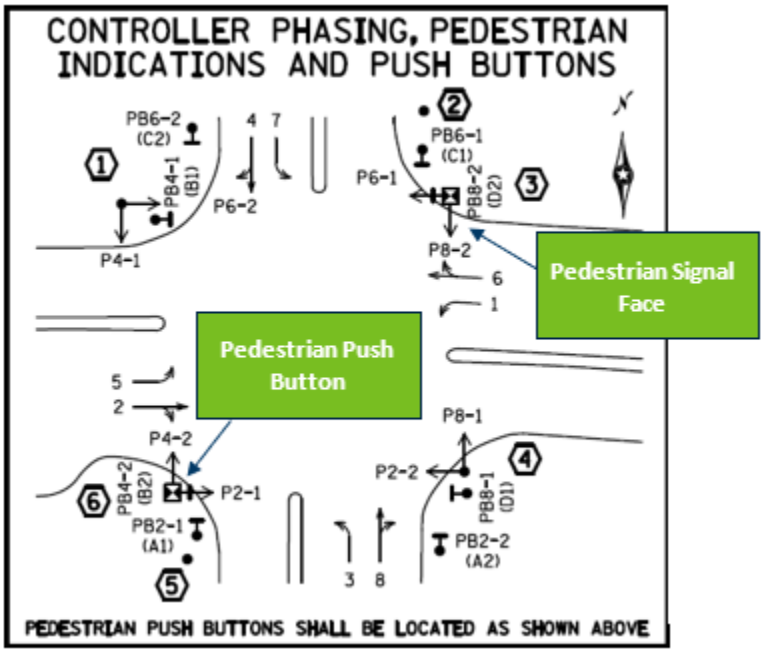
Below are the signal pole notes for pole 4. The mast arm is at 0 degrees. Items referenced with angles are in relation to the mast arm pole in the clockwise direction.



4.17.2 Pedestrian Signal Face and Push Button

The pedestrian signal face is illustrated with an arrow. The face is numbered as you approach the intersection with Number 1 being the first on the right and Numbers 2, 3, and 4 as you proceed through the intersection. The labels are preceded by a P with the controller phase number (for example P4-3, P4-4, etc.).

The pedestrian push button is labeled with a PB and the controller phase number.



4.17.3 Signal Faces Table

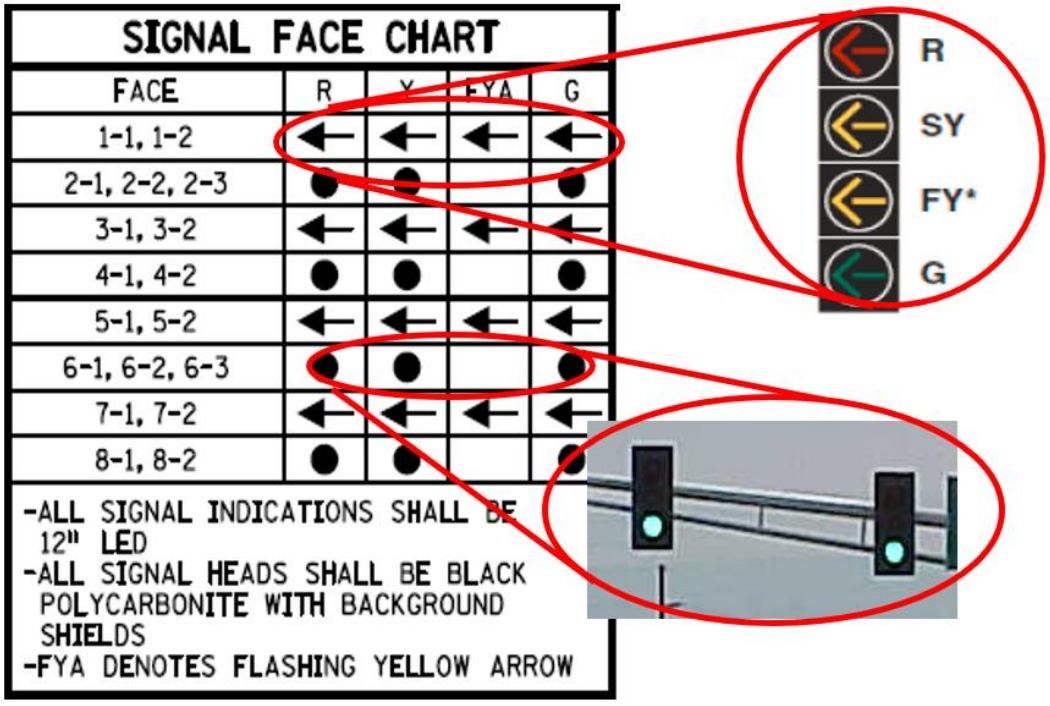
The signal indications table identifies the face configuration for the signals shown on the plan sheet. The face identification number refers to the signal face identifier number (circled number such as 2-1) shown on the plan sheet.

R = Red indication

Y = Yellow indication

G = Green indication

LED = Light Emitting Diode indication



4.17.4 Loop Detectors Table

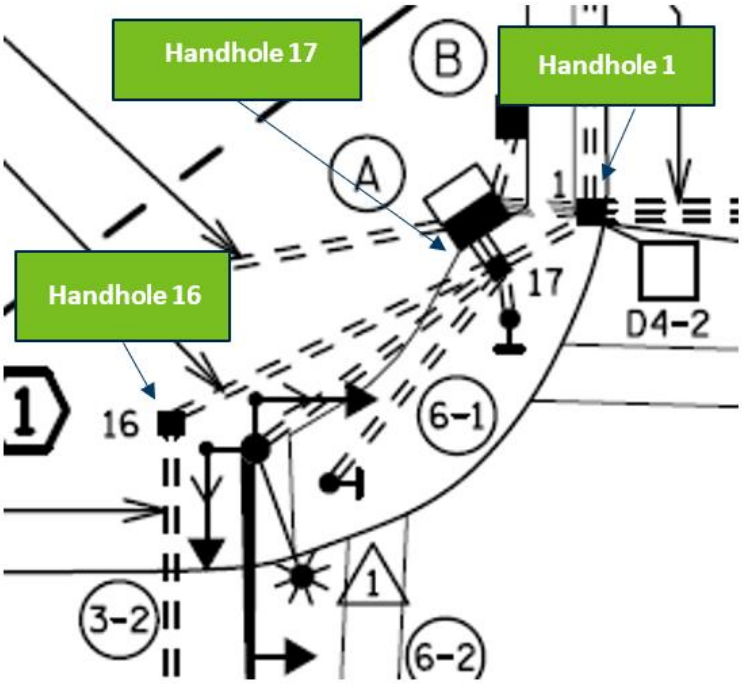
Loop detectors are shown with a square or rectangle. The detectors are normally labeled as you approach the intersection and from right to left with number 1 usually a detector back from the stop line and number 2 to the left. These numbers are proceeded by a D and the controller phase number (for example D8-1, D8-2, etc.).

The loop detector table identifies the size, number, and location of the detector shown on the plan sheet. The detector number refers to the detector shown on the intersection plan sheet. The location shows the distance from the stop line to the detector.

LOOP DETECTOR CHART		
NUMBER	SIZE (FT)	LOCATION
D1-1, D5-1	2-6x6	20 & 50
D1-2, D5-2	2-6x6	5 & 35
D2-1, D2-2	6x6	400
D3-1, D7-1	2-6x6	20 & 50
D3-2, D7-2	2-6x6	5 & 35
D4-1, D8-1	6x6	120
D4-2, D8-2	2-6x6	0 & 15
D4-3, D8-3	2-6x6	5 & 20
D6-1, D6-2	6x6	400
-ALL LOOP DETECTORS SHALL BE PVC UNLESS NOTED OTHERWISE -LOCATION: DISTANCE FROM CROSSWALK/STOP BAR IN FEET		

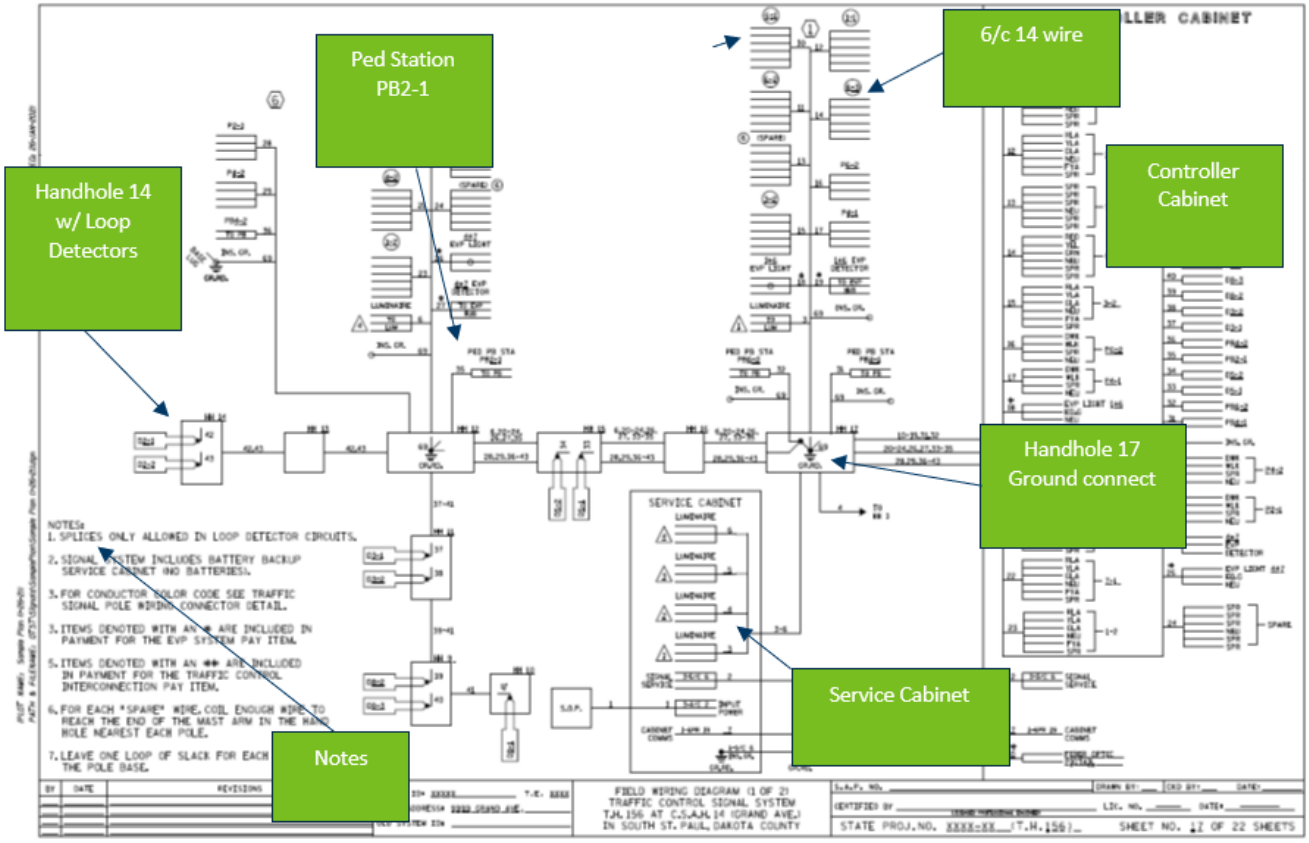
4.17.5 Handhole Labeling

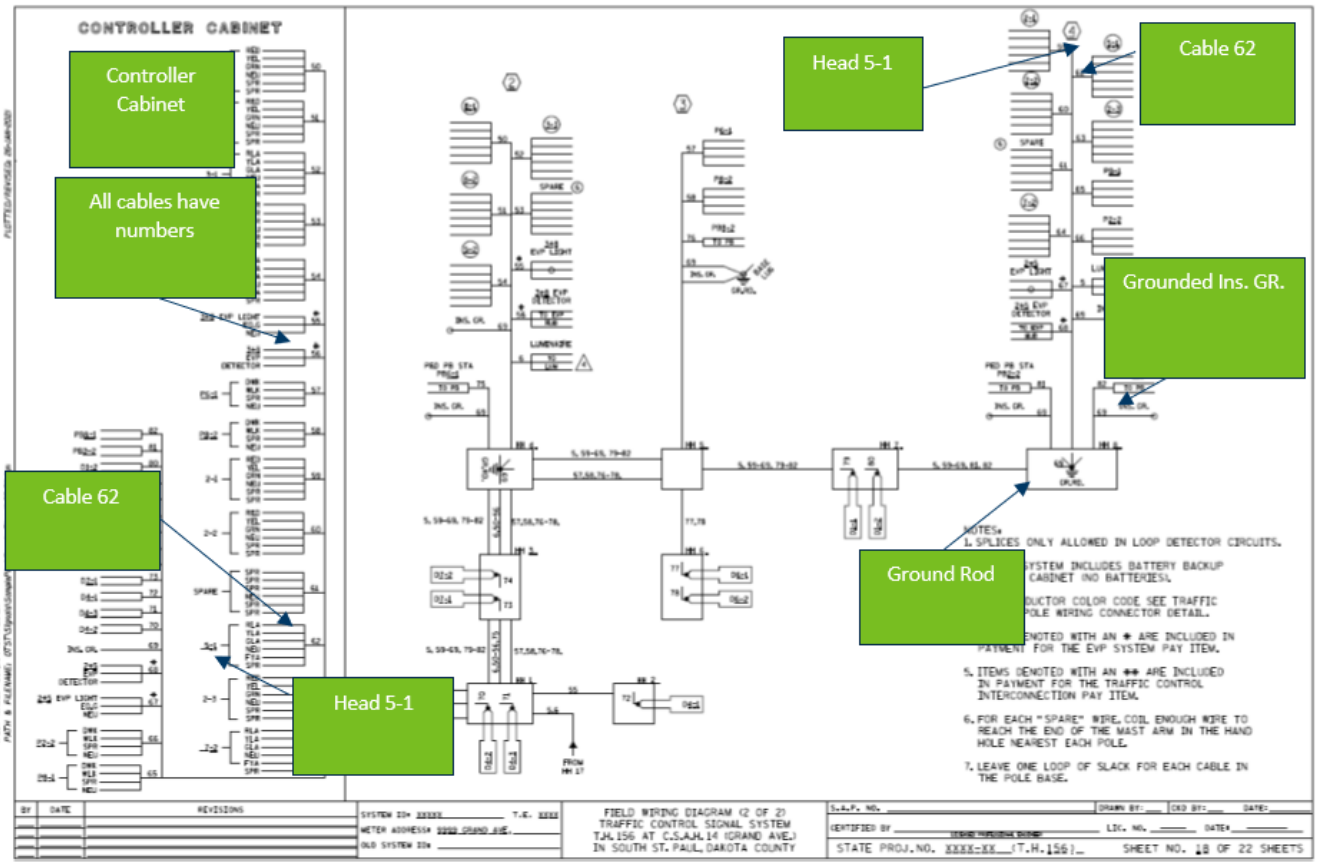
The handholes are shown as the solid black square on the plan sheet. \



4.18 Field Wire Diagram – Page 17 and 18

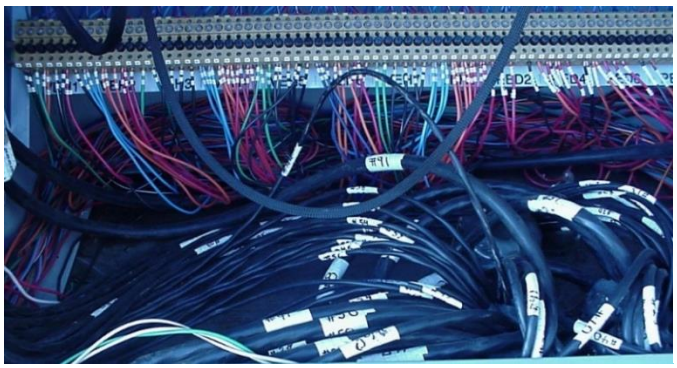
Below is the Field Wiring Diagram.

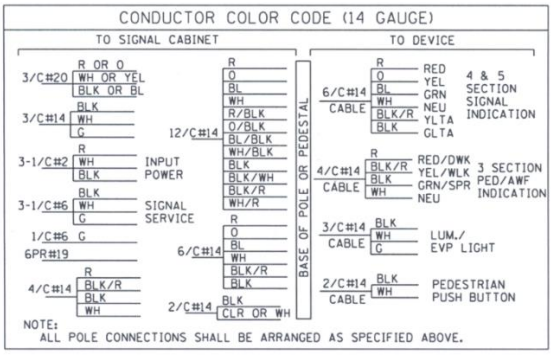




4.18.1 Field Wiring

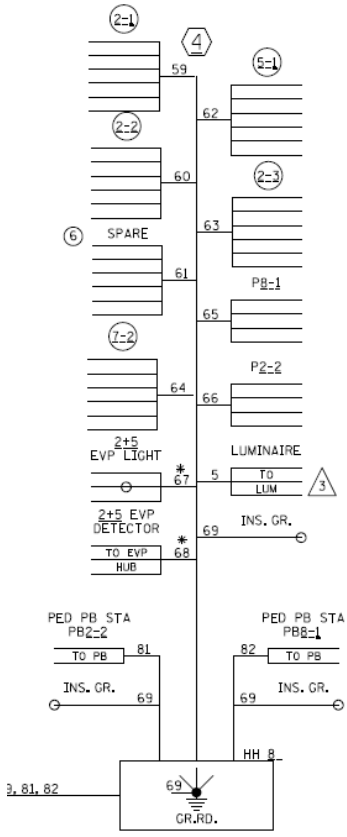
The photo below shows the cables terminated into the cabinet, and the image below show the conductor color code chart.

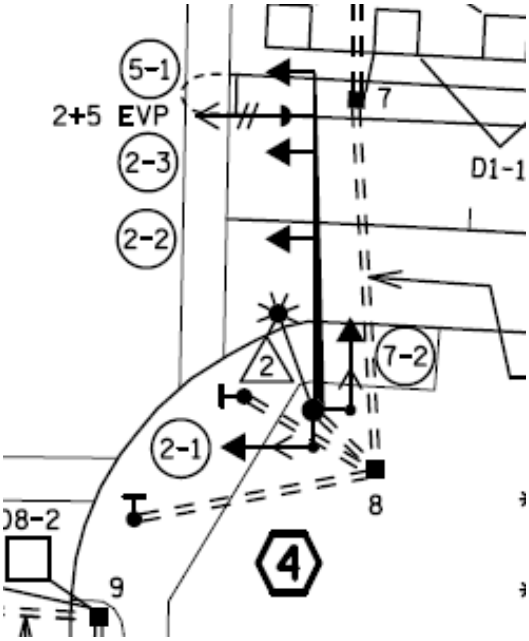


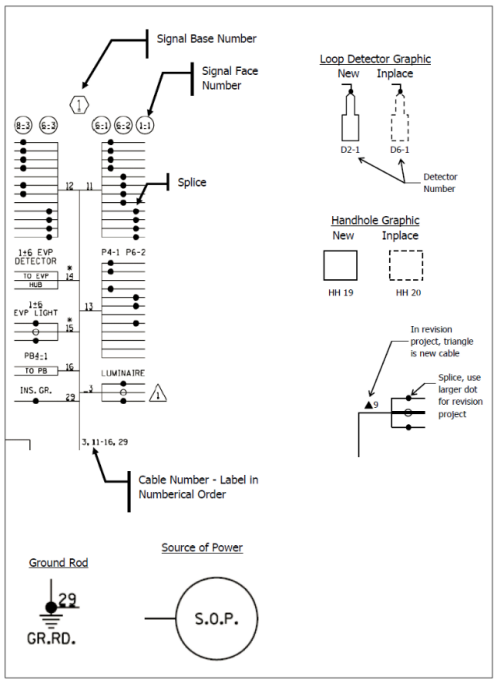


4.18.2 Wire Diagram to Layout Cross Reference

Pole #4 wire diagram to layout sheet. On the left is Page 18, and on the right is Page 15. The field wiring diagram is used to describe how the actual field wiring shall be placed.

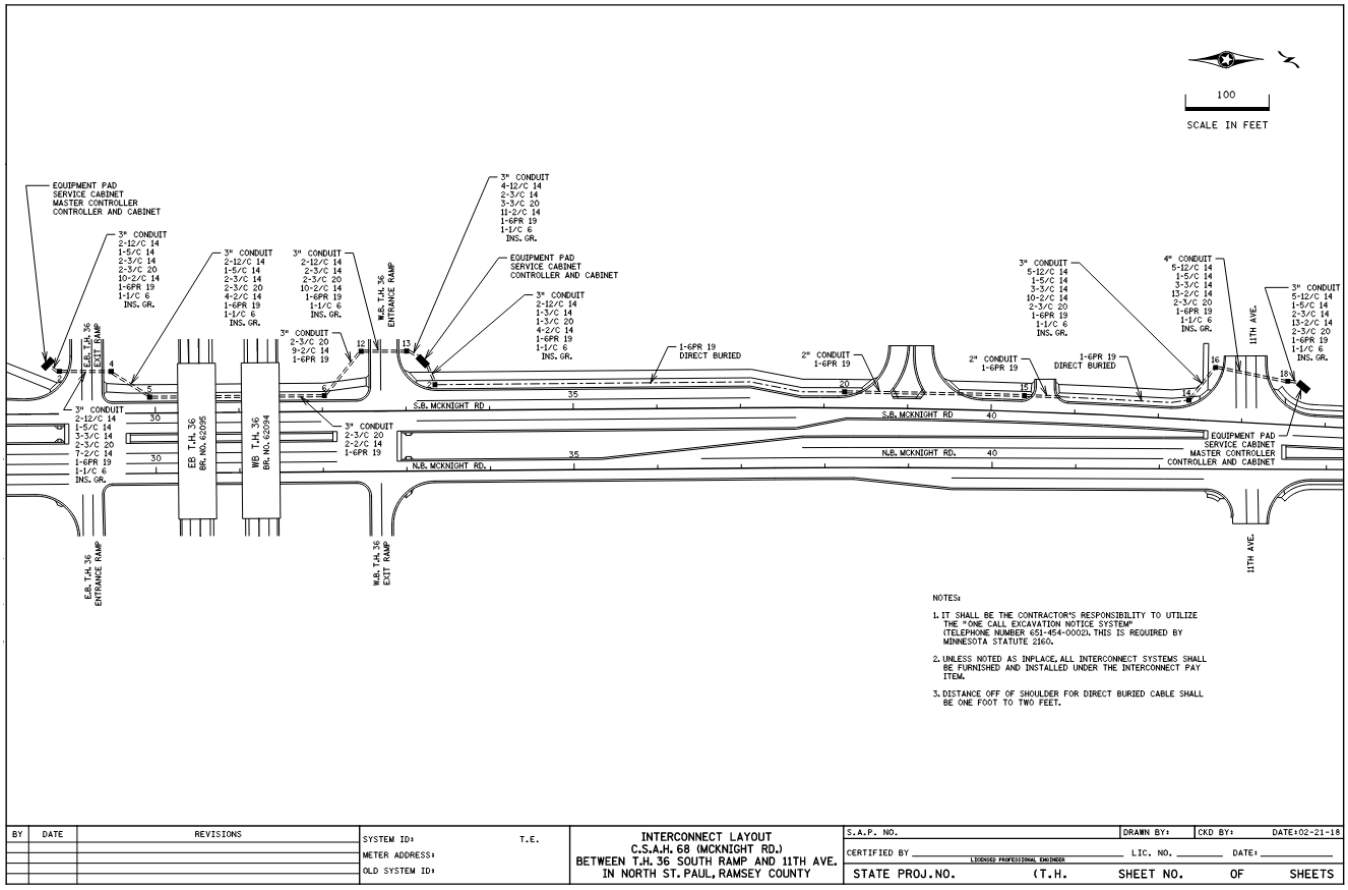






4.19 Interconnect Layout – Not Part of Example Plan

The image below depicts a sample interconnect layout. Interconnect is a means of remotely controlling some or all of the functions of a traffic signal and is also used for timing and coordination of series of traffic signals. A group of intersection controllers is typically interconnected by fiber optic cable (current standard) or may be interconnected by twisted pair copper wire (old standard). In rare cases, time-based coordination or wireless interconnect may need to be used. The current sample interconnect layout sheet is available at the following link: http://www.dot.state.mn.us/trafficeng/signals/signalplansheets.html.



4.20 Other Material Reference

Refer to these other MnDOT manuals for more information:

- Traffic Control Signal Design Manual
- Roadway Lighting Design Manual
- Traffic Signal Timing and Coordination Manual
- Traffic Engineering Manual
- MN MUTCD

MnDOT publishes a MicroStation signal cell library file for signal design in CAD, which is available at the following link: http://www.dot.state.mn.us/caes/cadd/

5. CABINETS

5.1 Traffic Signal Cabinet and Signal Service Cabinet

On the right is an image showing a typical installation of a Traffic Signal Cabinet and Signal Service Cabinet on a concrete pad. They are located adjacent to a signalized intersection and house the controller which detects all vehicle and pedestrian activity and activates signals accordingly. Both cabinets meet Underwriters Laboratories (UL) standards.

Inside, there are numerous circuit breakers, switches, cables, and more. It furnishes power, and control to virtually all devices in, or adjacent to the intersection, including:

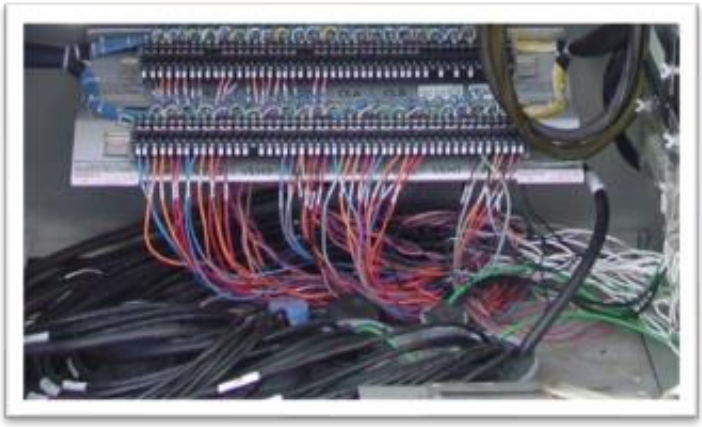
- Vehicle and pedestrian indications
- Control equipment
- Convenience light and GFCI receptacle
- Roadway lighting

Right: Interior of signal service cabinet

Left: Interior of traffic signal cabinet

5.2 Field Wiring in Traffic Signal Cabinet

All vehicle, pedestrian, and miscellaneous indications are connected to fuses and returned to neutral and ground busses. All detector loops, and any other detection devices, are connected to loop/pedestrian push-button (PPB's) hook-up panel.



Top Left: Indication Hook-Ups

Top Right: Indication returns and grounds

Bottom Left: Indication Hook-Ups

5.3 Typical Traffic Signal Cabinets

5.3.1 Current Standard

Both sizes sit on the same bolt pattern, which is the same as the last generation cabinets. The 350 ATC cabinet is the MnDOT standard and is double-wide. The 352 ATC cabinet is available as an option for local agencies and is single-wide. Below to the left is an image of a 350 ATC cabinet, and below to the right is an image of a 352 ATC cabinet.

5.3.2 Old Standard

Both sizes sit on the same bolt pattern. Both last generation cabinets have identical panels and are wired identically. The "P" size cabinet (60") has enough room only for basic control equipment and is well-sized for business/downtown areas. The "R" size cabinet (77") has room enough to add equipment for special equipment and operations, including:

- Autoscope
- Sonic Emergency Vehicle Preemption

5.4 Power Panel

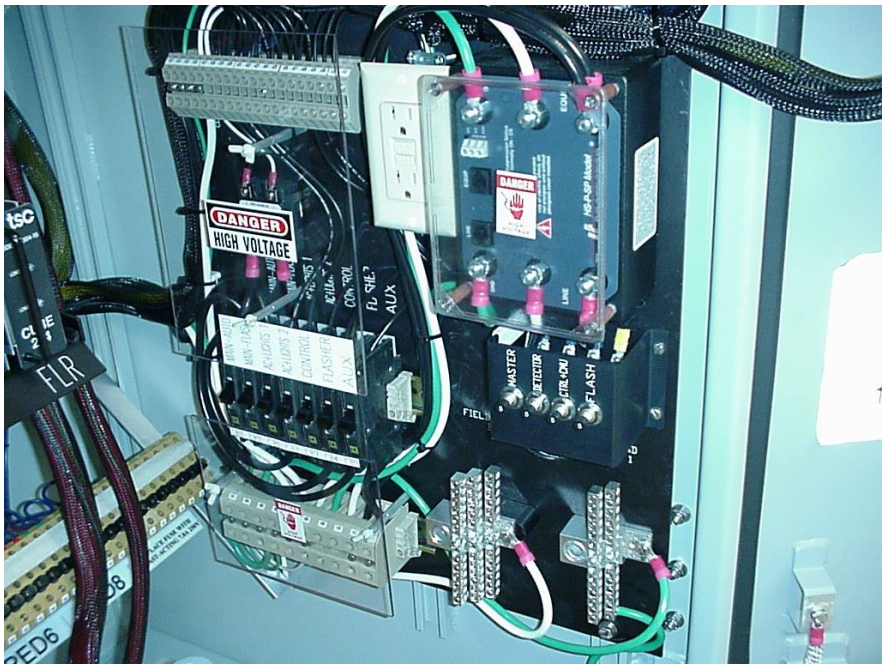
Electrical service from "Signal Service Cabinet" is connected here (120VAC, single-phase, 60Hz). Power Line protection is provided to help prevent damage from electrical overloading.

- Lightning
- Surges
- Nearby powerlines

Many neutral and ground wires are connected here. Provision for connecting test/maintenance equipment by furnishing a GFCI outlet for items such as:

- Drills
- Meters
- Power Line Monitors

Some areas are covered by plexiglass to help prevent electrical shock.



5.5 Cabinet Fans/Convenience Light Panel

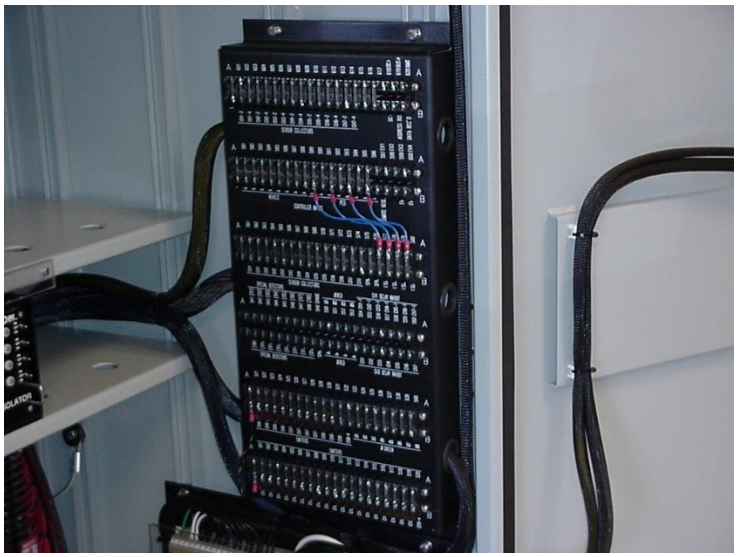
The convenience light is for cabinet maintenance. There is also 1 or 2 ventilation fans and a thermostat for control of the ventilation fans.

5.6 Detector Interface Panel

Includes wiring for all outputs of detection devices with 32 detector outputs in current cabinet configuration.
Wiring for inputs to the controller include 24 inputs in basic configuration for the latest model.
Wiring for inputs to, and outputs of controller to permit special functions:

- Detector reset
- Controller reds and greens
- EVP functions

Most special functions are currently accomplished via controller programming. In earlier controllers, these functions were accomplished with additional wiring.



5.7 Detector Amplifier Rack

The detector amplifier rack provides a physical housing for "plug-in type, rack-mountable" detector amplifier units. It distributes AC and DC power to all detector units as needed. All outputs are wired to the Detector Interface Panel. All detector inputs are wired from the loop/pedestrian push button hook-up panel. Various other inputs/outputs to accomplish proper, or enhanced detector operation. Detector power supply (shown furthest left in picture) supplies DC power to the detector rack.

5.8 Controller Interface/Load-Switch/Flash Transfer Relay Panel

5.8.1 Controller Interface Panel

All of the wires of the 3 NEMA controller connectors are terminated on the Controller Interface Panel (177 connections). Many of the Conflict Monitor Unit (CMU) wires (approx. 49 of 81) are also terminated here. This is where signals input and output from the controller. Most other assemblies and equipment are directly, or indirectly connected here.

5.8.2 Load-Switch Panel

Load-switches are devices that convert the low-voltage DC outputs of the controller to high-voltage AC that power the indications in the intersection.

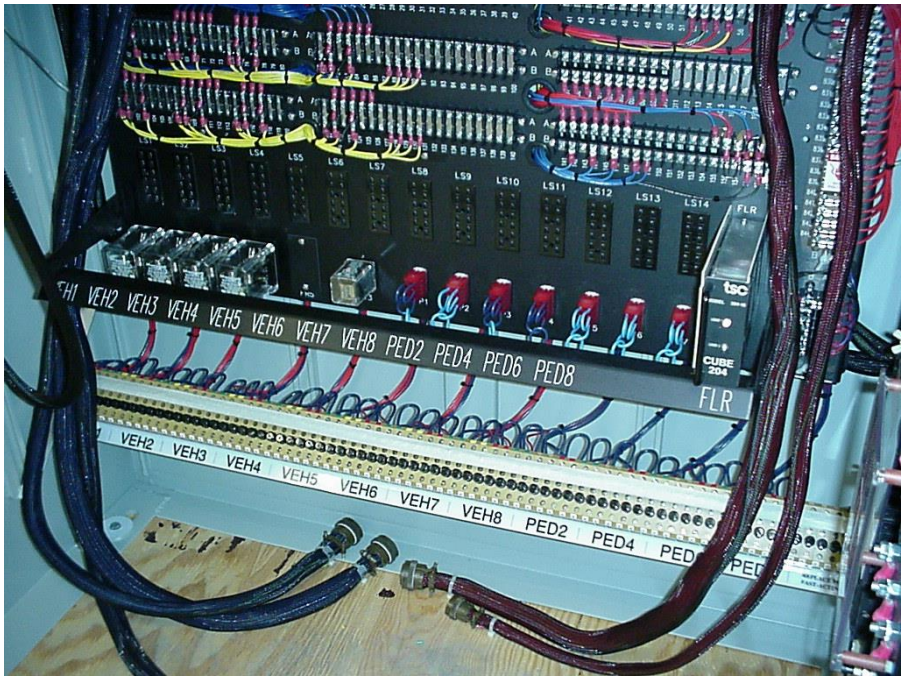
Opto-isolators in each load-switch help to protect the controller from high currents entering the controller from:

- Lightning
- Over-voltage
- Powerlines

A Flasher is also located on the Load-Switch Panel. The flasher supplies power to the indications when the intersection is in the "Flash" mode. This is similar in basic operation to the load-switch and has 2 alternating outputs, each 1 Hz, 50% duty cycle.

Flash Transfer Relays (FTR's) are also located on the Load-Switch Panel. These FTR's transfer indications between the load-switches and flasher. FTR's usually control only the RED indications; the flash color (amber or red) is determined by "Flash Plugs."

All field indications are connected to 80 indicating fuses in the Weidmueller Fuse Panel. These provide a relatively easy way of connecting field indications. Usually, there is one wire for each individual indication. The neon lamp on each fuse location indicates if fuse is "blown."



5.9 Auxiliary Interface Panel

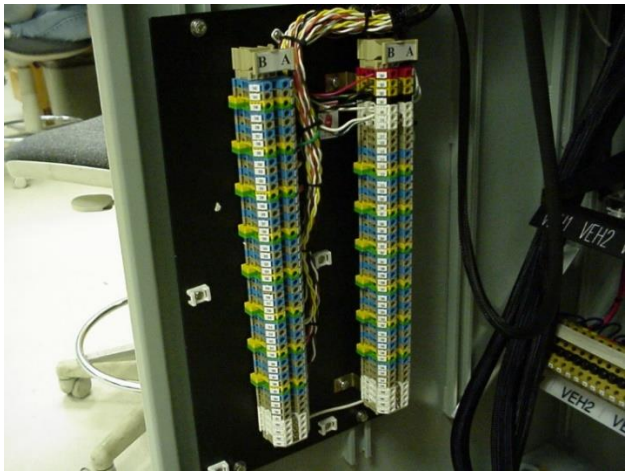
This panel provides terminations for making additional electrical connections such as:

- EVP
- Auxiliary detection
- Interlock functions

5.10 Loop/Pedestrian Push Button Hook-Up Panel

This panel provides terminations for virtually all detection field wires.

- Vehicle detection types
  - Loop
  - Microwave
  - Ultrasonic
  - Magnetometer
  - Video
- Railroad Preemption
- Pedestrian detection devices
  - Push buttons
  - Optical sensors
- EVP
  - Optical
  - Sonic



5.11 Auxiliary Panel

On the auxiliary panel, there are multiple control and test switches, including Control Equipment Power, Detector Power, Master Controller Power, Cabinet Lamp Power, "Stop-Timing Override", and Vehicle Test switches.

5.12 Police Panel

There are three settings on the Police Panel:

- AUTOMATIC: Normal "Stop-and-Go" and "Walk/Don't Walk" operation
- SIGNALS OFF: All traffic signal indications go dark
- FLASH: Normally flashes Red/Red, pedestrian heads are off

If intersection has gone to flash due to automatic fault detection, it cannot be "reset" using this switch. If it's necessary to put the signal to "SIGNALS OFF" or "FLASH", it can be returned to "AUTOMATIC" operation. The operation will resume at the point at which the switch was moved from AUTOMATIC operation.

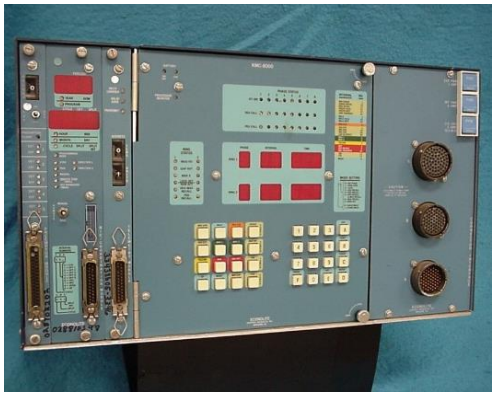
6. CONTROLLER OPERATIONS

In this Chapter you will be introduced to the traffic signal controller operations.

6.1 Econolite Controllers

6.1.1 KMC8000

1. Oldest of the controllers displayed on this page
2. The most rugged of the three
3. The most difficult to install
4. Least capable without extensive external wiring/equipment
    - More external connections
    - More complicated wiring



KMC8000

6.1.2 ASC8000

1. Newer and less rugged than the KMC8000
2. Less wiring with less difficulty
3. Capabilities increased greatly

ASC8000

6.1.3 ASC2

1. Great capability with the least external connections

6.1.4 ASC2S

1. Same as ASC2 except for surface mount technology
2. Surface mount technology results in small-size, lightweight (~7x9x15 inches/~8½lbs)

ASC2

ASC2S

There is also the KMC10,000 (left) and ASC2M (middle) controllers, as well as Intelight controllers (XN-1, right).

6.1.5 ASC3 controller

1. Great capability
2. Fully compliant with NEMA TS2

6.1.6 Cobalt Controller

1. Newest, with great flexibility
2. Touch screen

6.2 NEMA (National Electrical Manufacturers Association) Controllers

NEMA's involvement in controller design helped greatly to simplify installations. Their controllers include standardization of A, B, C (1, 2, 3) connectors, operating limits, and timed intervals. The standardization of timed intervals include: passage time, maximum green time, gap reduction, walk and ped clearance, and many more intervals with proper operation dictated by NEMA.

Some key points on NEMA controllers include:

- Standardized connectors
- Standard "pin-outs"
- Standard Input/Output (I/O) names
- Connectors physical identical/interchangeable

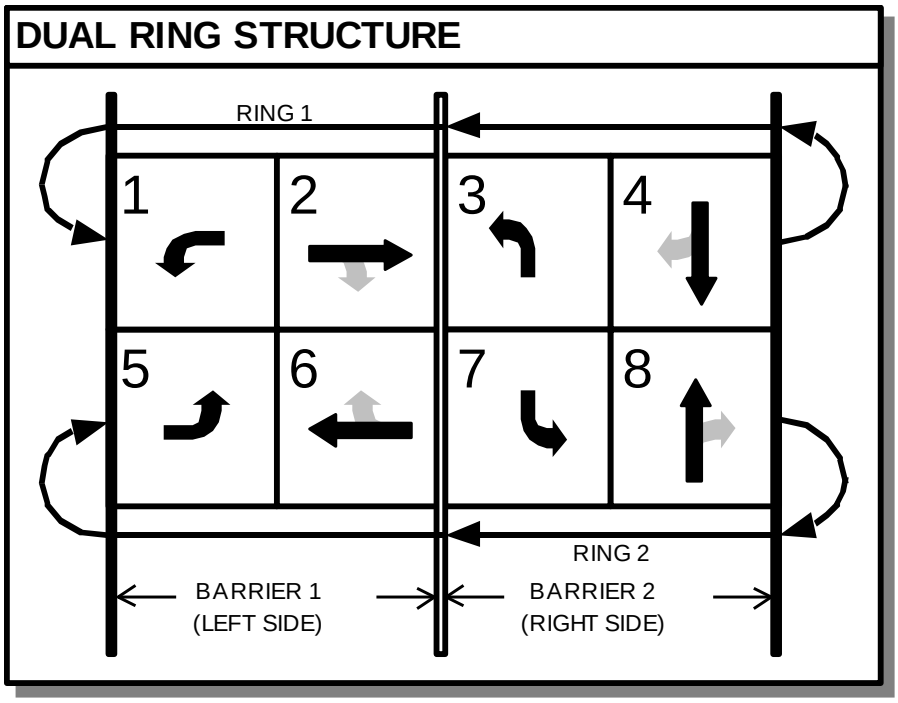
Below are three specifications of NEMA controller operating limits. There are many other parameters that have contributed to a better product:

- Operating temperature range: -30°F to 165°F
- Humidity range: >95% @ 40°F to 110°F
- Operating voltage: 89 to 135 VAC

6.3 Dual-ring and Concurrent Group Controllers

A dual-ring controller operates similar to two separate controllers.

- Ring 1 contains phases ∅1, ∅2, ∅3, ∅4
- Ring 2 contains phases ∅5, ∅6, ∅7, ∅8
- No more than one phase from either ring can time at any given time



An 8∅ (eight-phase) usually has two concurrent groups.

- Concurrent Group 1 contains phases ∅1, ∅2, ∅5, ∅6
- Concurrent Group 2 contains phases ∅3, ∅4, ∅7, ∅8
- Phases from one group cannot time with phases of the other group

Combining two rings with two concurrent groups gives the following:

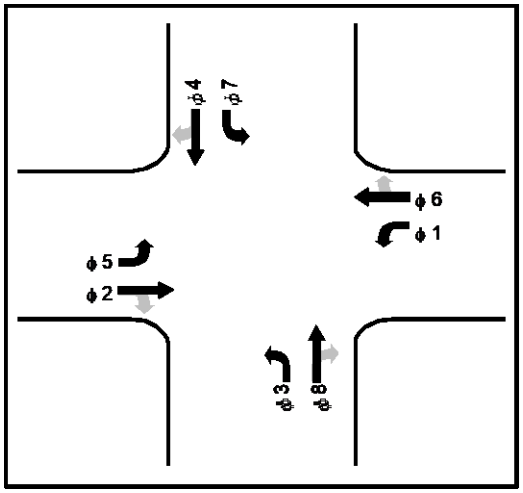
- ∅1 or ∅2 allowed to time with ∅5 or ∅6 and vice-versa
- ∅3 or ∅4 allowed to time with ∅7 or ∅8 and vice-versa

Barriers

- Phase(s) must terminate their timing and cross the "barriers" together

Exceptions

- The model of the current discussion has been about a "dual-ring, two concurrent group, eight-phase controller configuration"
- It can all be changed, within limits, to perform special operations



6.4 Malfunction Monitor Unit

The malfunction monitor unit (MMU) is a device that monitors cabinet output and internal cabinet voltages. If the MMU senses an improper signal output or internal voltage, it will put the intersection into the all red flashing mode of operation.

7. FIELD OPERATIONS

In this chapter, you will be introduced to the operation of signals in the field. This includes controller elements such as cycle length and phases, pedestrian timing requirements, pre-timed and actuated signal control, and system control. For more in-depth information on field operations, refer to the Traffic Signal Timing and Coordination manual at the following link: http://www.dot.state.mn.us/trafficeng/signals/manual.html

7.1 Controller Timing

The objective of traffic signal timing is to assign the right-of-way to alternating traffic movements in such a manner to minimize the average delay to any group of vehicles or pedestrians and reduce the probability of accident producing conflicts.

A traffic signal controls traffic by assigning right-of-way to one traffic movement or several non-conflicting movements at a time. Right-of-way is assigned by turning on a green signal for a certain length of time or an interval, ended by a yellow change interval during which a yellow signal is displayed, followed by the red signal.

7.2 Cycle Length

The cycle length is the total time to complete one sequence of signalization around an intersection. In an actuated controller, a complete cycle is dependent on the presence of calls on all phases. In a pre-timed controller, it is a complete sequence of signal indications. In a fully actuated signal, the cycle length varies. The cycle length is fixed in a coordinated or pre-timed signal.

Short cycle lengths typically yield the best performance in terms of providing the lowest overall average delay if the capacity of the cycle to pass vehicles is not exceeded. The cycle length, however, must allow adequate time for vehicular and pedestrian movements. Longer cycles are used during peak periods to provide more green time for the major street, to permit larger platoons in the peak direction, and/or to reduce the number of starting delays.

7.3 Phase Change Interval

The phase change interval timing (yellow) advises drivers that their phase has ended, and they should either:

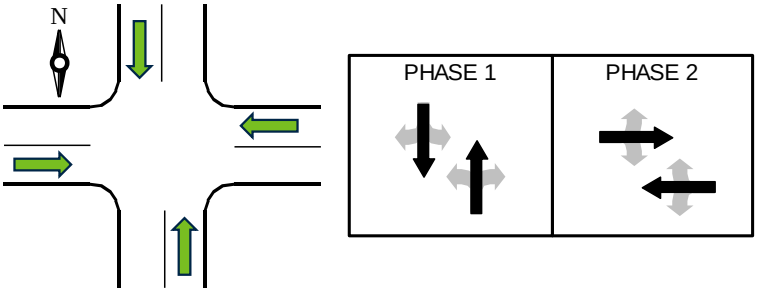
- Come to a safe stop prior to the stop line
- Proceed through the intersection if they are too close to the intersection to stop

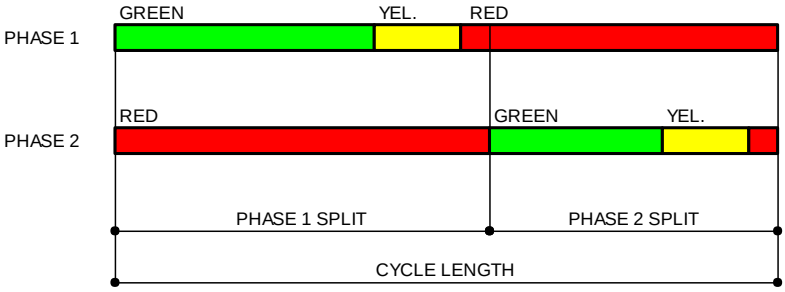
The Intersection Clearance Interval (All-Red) provides a vehicle enough time at the end of yellow to clear the intersection before the next green is displayed.

The MN MUTCD states that the exclusive function of the steady yellow interval shall be to warn traffic of an impending change of right-of-way assignment. The yellow vehicle change interval should have a range of approximately 3 to 6 seconds. Generally, the longer intervals are appropriate for higher approach speeds. The yellow vehicle change interval should be followed by a short all-way red clearance interval, of sufficient duration to permit the intersection to clear before cross traffic is released.

Minnesota Traffic Laws state that vehicular traffic facing a yellow indication are warned that the related green movement is being terminated or that the red indication will be exhibited immediately thereafter when vehicular traffic shall not enter the intersection.

The figures below show the timing operation for a basic two-phase or two-traffic movement pre-timed controller. Note that at the end of phase 1 and phase 2 yellow, there is a short all-red clearance interval.





7.4 Pedestrian Timing

7.4.1 Walk

The MN MUTCD states "the WALK interval should be at least 4 to 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb before the clearance interval is shown." If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.

7.4.2 Flashing Don't Walk

The flashing DON'T WALK interval is determined by the following formula: flashing DON'T WALK = D/R

- D = Distance from the near curb or shoulder to at least the center of the farthest traveled lane
- R = Walking rate of 3.5 ft/sec is the assumed walking rate unless special conditions (school kids, elderly, or handicapped) require a slower walking rate

See Chapter 9 on pedestrians for further details.

7.5 Pre-Timed Signal Control

Under these conditions, the signal assigns right-of-way at an intersection according to a predetermined schedule. The sequence of right-of-way (phases) and the length of the time interval for each signal indication in the cycle is fixed. Timing is based on historic traffic patterns.

No recognition is given to the current traffic demand on the intersection approaches unless detectors are used. The major elements of pre-timed control are (1) fixed cycle length, (2) fixed phase length, and (3) number and sequence of phases.

Advantages to pre-timed control include:

- Simplicity of equipment provides relatively easy servicing and maintenance
- Can be coordinated to provide continuous flow of traffic at a given speed along a particular route, thus providing positive speed control
- Timing is easily adjusted in the field
- Under certain conditions can be programmed to handle peak conditions

Disadvantages to pre-timed control include:

- Do not recognize or accommodate short-term fluctuations in traffic
- Can cause excessive delay to vehicles and pedestrians during off-peak periods

7.6 Traffic-Actuated Signal Control

Traffic-actuated control of isolated intersections attempts to adjust green time continuously, and in some cases, the sequence of phasing. These adjustments occur in accordance with real-time measures of traffic demand obtained from vehicle detectors placed on one or more of the approaches to the intersection. The full range of actuated control capabilities depends on the type of equipment employed and the operational requirements.

Advantages to actuated signals include:

- Usually reduce delay (if properly timed)
- Adaptable to short-term fluctuations in traffic flow
- Usually increase capacity (by continually reapportioning green time)
- Provide continuous operation under low volume conditions as an added safety feature, when pre-timed signals may be put on flashing operation to prevent excessive delay
- Especially effective at multiple phase intersections

Disadvantages to actuated control include:

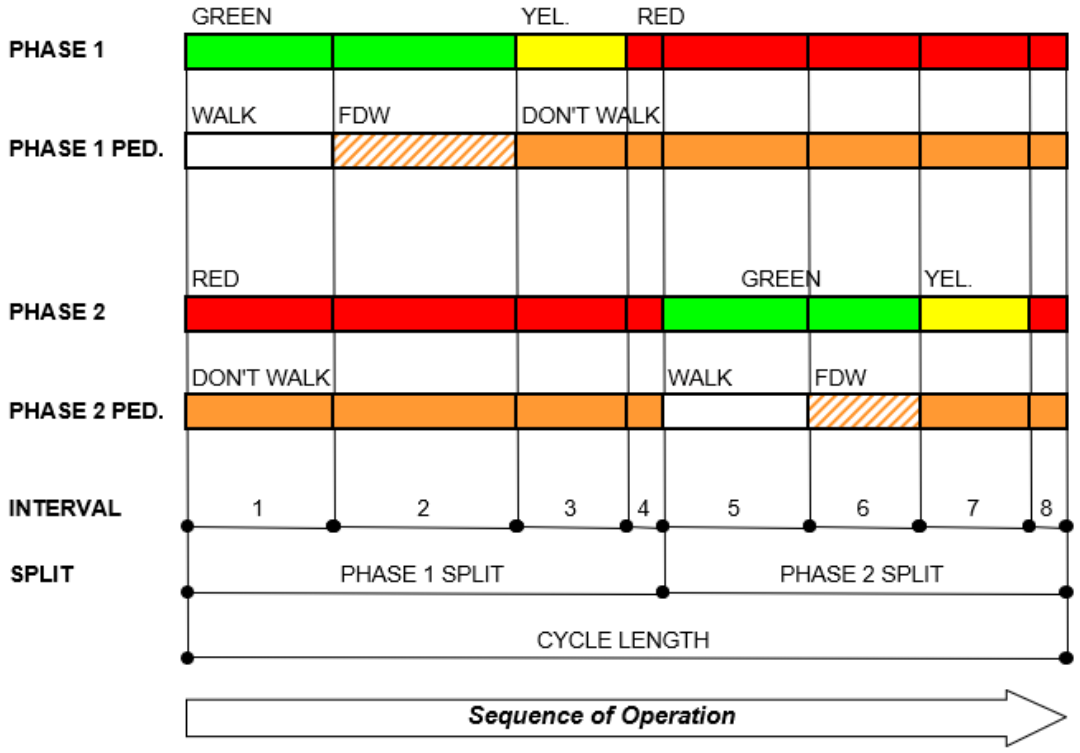
- The cost of an actuated installation is substantially higher than the cost of a pre-timed installation
- Actuated controllers and detectors are much more complicated than pre-timed signal controllers, increasing maintenance and inspection skill requirements and costs
- Detectors are costly to install and require careful inspection and maintenance to ensure proper operations

Traffic actuated signal control can be further broken into the following categories: Semi-Actuated and Full Actuated Control. In full actuated control, all signal phases are actuated, and all signalized movements require detection. Many MnDOT applications require full-actuated density operation (refer to the Traffic Signal Timing and Coordination Manual).

7.7 Traffic Signal Phasing

A traffic signal phase, or split, is the part of the cycle given to an individual movement, or combination of non-conflicting movements during one or more intervals. An interval is a portion of the cycle during which the signal indications do not change. The predetermined order of phases is the sequence of operation. This order is fixed in a pre-timed controller, and under certain circumstances, may be variable with an actuated controller.

For the figure below, there are eight intervals where the signal indications do not change. Notice that intervals 4 and 8 are all red periods (interval 4 is the phase 1 all red and interval 8 is the phase 2 all red). The phase 1 split is made up of intervals 1 through 4 and the phase 2 split is made up of intervals 5 through 8. The sum of split 1 and 2 is the cycle length.



7.8 Actuated Controller Phase Operations

Minimum Green Interval is the shortest green time for a phase. There must be a minimum green time so that stopped vehicles have enough time to get started and partially cross the intersection before the clearance interval appears. A minimum green time setting will accommodate the lowest expected number of vehicles that arrive per cycle. It also allows approaching vehicles a chance to reach detectors.

Passage time (vehicle extension or gap time) is typically set as the time it takes to travel from the vehicle detector to the stop line at the travel speed of the roadway for pulse loops or the average acceptable headway between vehicles for presence loops located close to the stop line.

Maximum Green establishes the maximum limit to which the green interval can be extended on a phase in the presence of a serviceable demand on a conflicting phase. Most controllers used by MnDOT can have two or more maximum green times programmed. The second maximum time can put into effect by time clock.

7.9 Recall

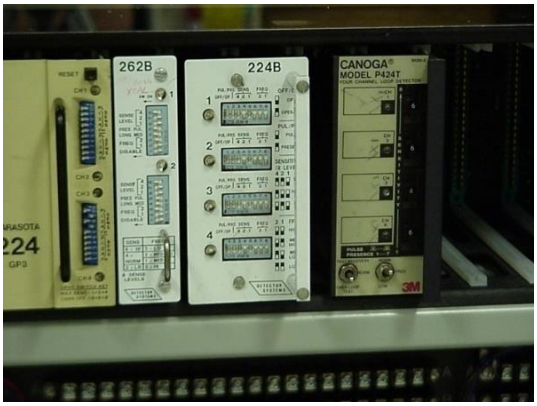
In the absence of an actuation, a controller unit will normally rest on the current phase being serviced. A recall will force the controller to return to a particular phase's green interval, even with no demand. An actuation is the operative response of any type of detector call.

- **Recall to Minimum:** When active and in the absence of a vehicle call on the phase, a temporary call to service the minimum initial time will be placed on the phase
- **Recall to Maximum:** With the maximum vehicle recall active a constant vehicle call will be placed on the phase and maximum green time will be placed on the phase
- **Recall to Pedestrian:** This feature provides vehicle green and pedestrian walk and clearance intervals

7.10 Vehicle Detection

One of the advantages to actuated control is the ability to adjust timing parameters based on actual vehicle or pedestrian demand. Since this vehicle or pedestrian demand varies at different times of the day, a detector is placed in the path of approaching vehicles or at a convenient location for the use of pedestrians. The actual operation of the signal is highly dependent on the operation of these detectors.

The images below show typical detector units in the controller cabinet. The detectors used in the field will be discussed in the following sections.



7.10.1 Presence Detection

A presence detector has the ability to sense that a vehicle, whether moving or stopped, has appeared in its zone of detection. A call is a registration of a demand for the right-of-way by traffic at a controller unit. An extension detector is one that is arranged to register an actuation at the controller unit only during the green interval for that approach so as to extend the green time of the actuating vehicles.

- **Call & Extend:** Vehicles put a call into the controller at any time
- **Call-Only:** Vehicles put a call into the controller only during red
- **Delay Call:** Vehicles put a call into the controller only after a programmed delay-time
- **Delay Call-Immediate Extend:** Vehicles place a call to the controller only after a programmed delay-time except when the phase that calls the detector is Green, then the call goes in immediately

7.10.2 Emergency Vehicle Preemption (EVP) Detection

An EVP detector is a device that preempts a traffic signal controller; it has priority over normal traffic operations. See Chapter 11 for further details. There are two types of EVP detection.

- Optical
    - Strobe light pulsing at very specific frequency
    - Can have digital information encoded on the pulsing light
- Sonic
    - Actually "hears" sirens approaching using directional microphones

7.10.3 Types of Detectors

A **loop detector** is the most common detector type. It is a loop of wire imbedded in the pavement carrying a small electrical current. When a large mass of metal passes over the loop, it senses a change in inductance of its inductive loop sensor due to the passage or presence of a vehicle near the sensor.

A **magnetometer** measures the difference in the level of the earth's magnetic forces caused by the passage or presence of a vehicle near its sensor. A **microwave radar detector** is a detector that is capable of sensing the passage of a vehicle through its field of emitted microwave energy. An **ultrasonic detector** is capable of sensing the passage or presence of a vehicle through its field of emitted ultrasonic energy. A **video detector** responds the video image or changes in the video image of a vehicle.

7.11 Coordinated Systems

A coordinated system is a series of signalized intersections that are designed to interact as a system. The system concept as related to traffic signal control includes the methods, equipment, and techniques required to coordinate traffic flow along an arterial or throughout an area. Reasons for coordinating include:

- Move traffic through a series of intersections more efficiently
- Reduce delay
- Move vehicles in a grid system
- Help reduce gridlock for closely spaced intersections

7.12 System Objective

The major objective of a traffic control system is to permit continuous movement and/or minimize delay along an arterial or throughout a network of major streets. In the system, a timing plan is defined by a combination of control parameters for one or more intersections based upon an analysis of demand.

The major objective of a traffic control system is to permit continuous movement and/or minimize delay along an arterial or throughout a network of major streets. This involves the selection, implementation, and monitoring of the most appropriate operational plan. Basically, a traffic signal system provides the appropriate and necessary timing plans for each intersection in terms of individual needs as well as the combined needs of a series of intersections.

Timing plans for a system consists of:

- **System Cycle:** A specific cycle length is imposed throughout the system covered by the timing plan
- **Split:** Each movement in the intersection has a defined split
- **Offset:** The offset is the relationship of the beginning of the main street green at this intersection to a master system base time
    - Offset should be expressed in seconds
    - The difference in offset between intersections along a street defines the speed at which traffic can travel without stopping

7.13 Types of Traffic Signal Control Systems

Time of Day (TOD) Time Based System:

- Non-Interconnected System. The offset relationship is maintained by relying on the clocks in the local controllers
- Interconnected System. Local intersections are physically interconnected to ensure coordinated operation

Traffic Responsive System: Volume levels determine which out of a number of available cycle lengths is selected, and volume differential determines offset (i.e., inbound, outbound, or average).

8. HEAD AND LOOP PLACEMENT

In this chapter you will be introduced to traffic signal head placement and vehicle loop detector placement. A series of head and loop placement charts are included in Chapters 3 and 4 of the Traffic Control Signal Design Manual, which is available at the following link: http://www.dot.state.mn.us/trafficeng/signals/manual.html.

The following definitions are adapted from the latest version of the MN MUTCD.

8.1 Signal Heads and Indications

8.1.1 Pedestrian Signal Head

A pedestrian signal head, which contains the symbols WALKING PERSON (symbolizing WALK), UPRAISED HAND (symbolizing DONT WALK), and countdown numbers is installed to direct pedestrian traffic at a traffic control signal. The head is comprised of two components; a pedestrian signal housing and a pedestrian signal indication that fits within the housing.

8.1.2 Pedestrian Signal Housing

This is a polycarbonate housing that protects the light source and other required components. The housing includes an indication mounting door and sun visor.

8.1.3 Pedestrian Signal Indication

This is a Light Emitting Diode (LED) hand and person countdown indication module that is installed within the pedestrian signal housing.

8.1.4 Vehicle Signal Head

This is an assembly of one or more signal sections that is provided for controlling vehicle traffic movements on one or more approaches. This assembly of signal sections also includes a background shield.

8.1.5 Signal Section

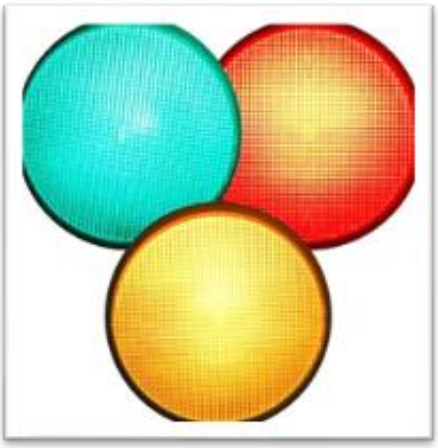
The signal section is the assembly of a signal housing, signal lens, if any, and light source with necessary components to be used for displaying one signal indication. The section is comprised of two components; a signal housing and a signal indication that fits within the housing.

8.1.6 Signal Housing

The signal housing is the part of a signal section that protects the light source and other required components. It includes a hinged opening (with visor) in which the signal indication is mounted. This is one of two components that make up a signal section.

8.1.7 Signal Indication

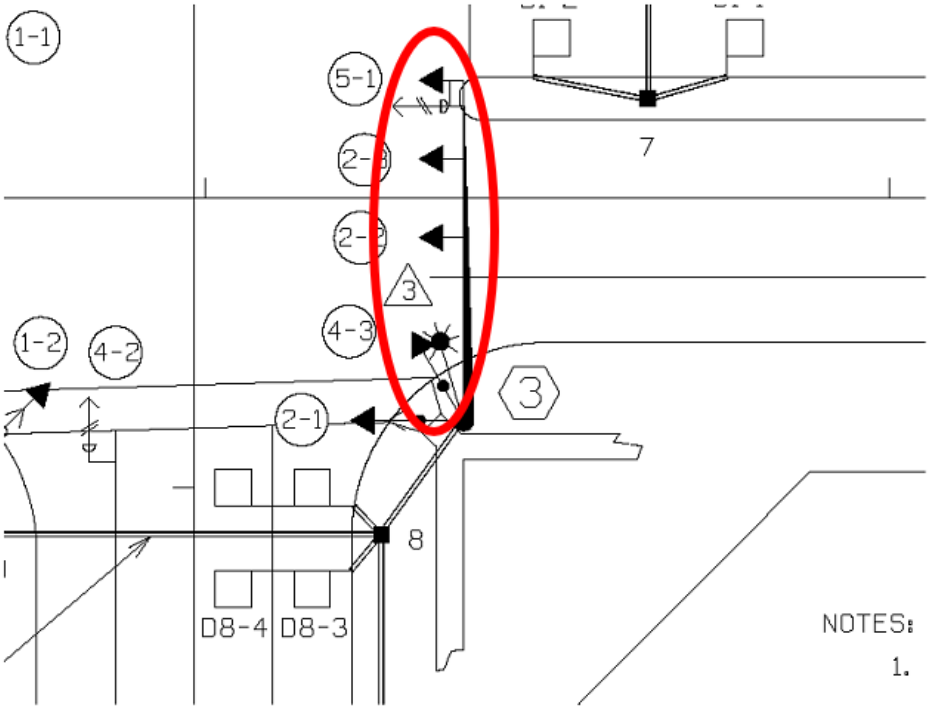
The signal indication is what illuminates the signal lens or equivalent device. Light Emitting Diode (LED) are the indications that are currently installed within the signal housing. This is one of two components that make up a signal section.



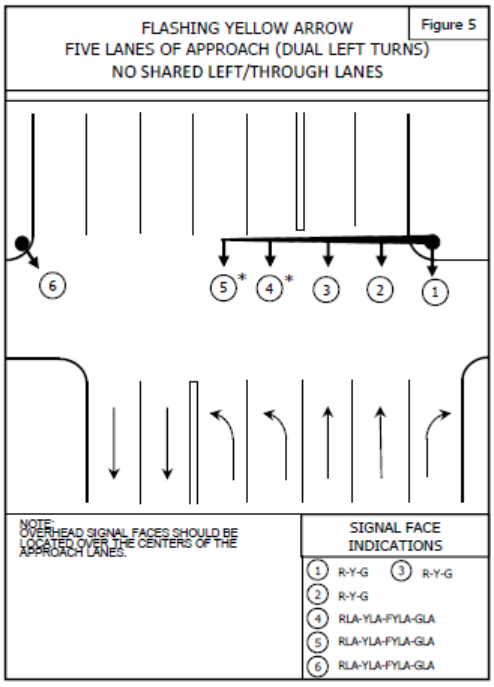
8.2 Head Placement

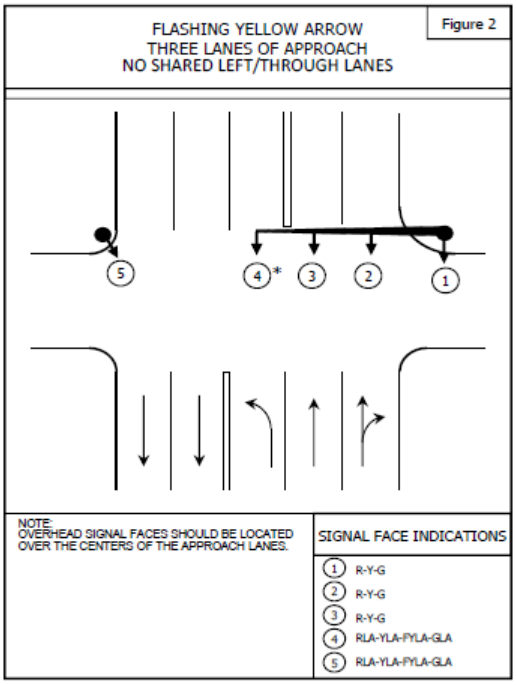
When placing signal heads, you should consider signal operations and review information from the field observations checklist (signal design). Then refer to the signal head placement charts in the Traffic Control Signal Design Manual, standard plates, technical manual for symbols, and uniform traffic signal plan labeling format (Traffic Control Signal Design Manual).

A filled in triangle indicates a new signal head, while an open triangle indicates an existing signal head.



Below are two examples of signal head placement charts, which are included in the Traffic Control Signal Design Manual, available at the following link: http://www.dot.state.mn.us/trafficeng/signals/manual.html. These charts show the minimum number of signal heads. There must be more than one signal head per traffic movement. These layouts are not definitive and should be considered the minimum arrangements. These figures do not cover every possible condition; they may need to be adapted to fit a particular situation.





8.3 Loop Placement

There are five considerations in loop detector placement design:

Guaranteed Green: All vehicles except right turn on red (RTOR) vehicles will be guaranteed service of a green light within a cycle.

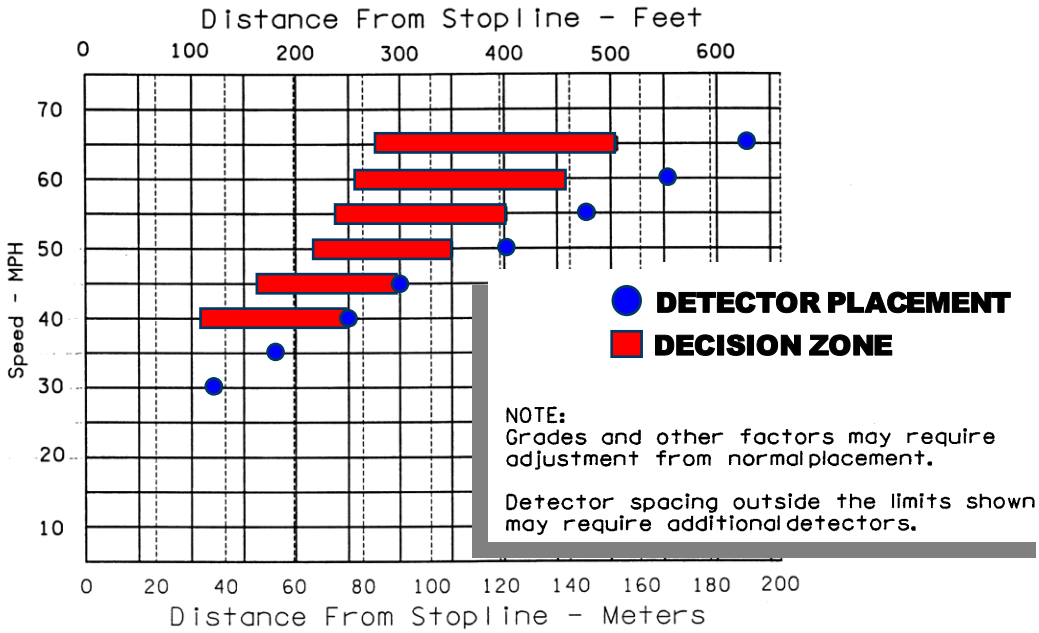
Safety: Consideration must be given to winter as well as summer conditions.

Failsafe: Alternatives must be provided for when a primary detector fails so that non-mainline phases don't have to be placed on recall.

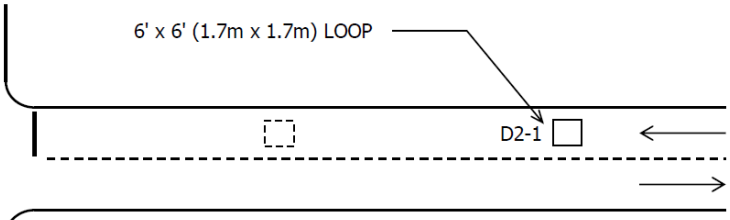
Maintenance: Detectors should be located in a good roadbed, if the surface is in a very poor condition it should be replaced.

Operation: Detectors should provide operation that is logical to the driving public.

The horizontal bar indicates a range of distance away from the intersection, within which some drivers will, and some will not, stop for a yellow light. Detector placement allows the signal to change to yellow when this area near the intersection does not have vehicles present. The decision zone is 2 to 4-1/2 seconds away from the stop bar.



The image below shows the typical detector placement for loop detectors on the major approach. There is no stop-line detector and the phase is placed on recall (i.e. the green is returned to this movement after servicing the conflicting movements).

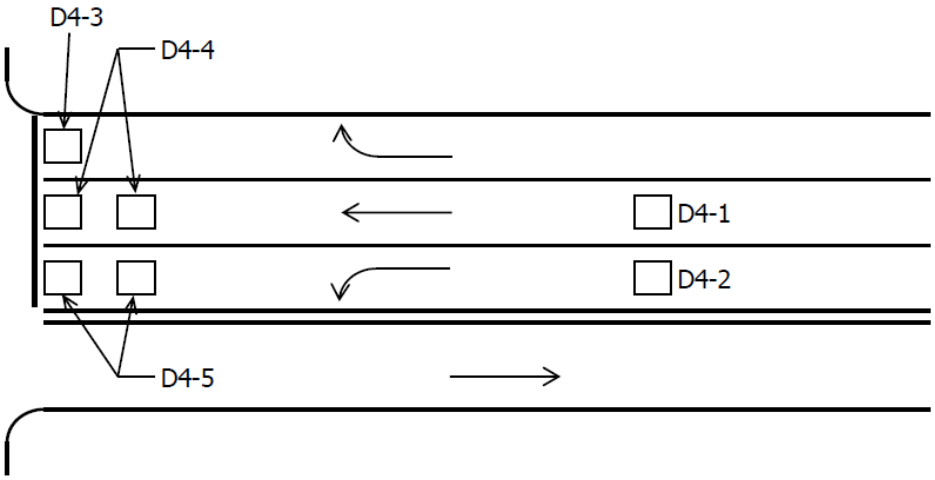


SPEED (MPH)	LOCATION	OPTIONAL 2 POINT LOOP	FUNCTION
30	120' (37 m)		1
35	180' (55 m)		1
40	250' (76 m)		1
45	300' (92 m)		1
50	400' (122 m)		1
55	475' (145 m)	240' (75 m)	1
60*	550' (168 m)	275' (84 m)	1
65*	625' (191 m)	315' (96 m)	1

LOCATION = DISTANCE FROM STOP BAR TO LOOP DETECTOR
* ONLY APPLY TO DIVIDED 4-LANE ROADWAY

LOOP DETECTOR FUNCTIONS
1 = CALL AND EXTEND

The image below shows the typical detector placement for loop detectors on a minor approach.



LOCATION = DISTANCE FROM STOP BAR TO LOOP DETECTOR

SPEED (MPH)	LOCATION
30	120' (37 m)
35	180' (55 m)
40	250' (76 m)

LOOP DETECTOR FUNCTIONS
1 = CALL AND EXTEND
7 = DELAY CALL - IMMEDIATE EXTEND

NUMBER	FUNCTION	SIZE
D4-1	1	6' x 6' (1.7 x 1.7 m)
D4-2	1	6' x 6' (1.7 x 1.7 m)
D4-3	7	6' x 6' (1.7 x 1.7 m)
D4-4	1	2-6' x 6' (1.7 x 1.7 m)
D4-5	1	2-6' x 6' (1.7 x 1.7 m)

Where the minor approach is low volume and low speed, the back detectors (D4-1 and D4-2) are sometimes omitted.

9. PEDESTRIAN

In this chapter you will be introduced to the movement of pedestrians at signalized intersections. More information on pedestrian control features can be found in Chapter 4E of the MN MUTCD, available at the following link: www.dot.state.mn.us/trafficeng/publ/index.html.

9.1 Need for Pedestrian Control

9.1.1 Safety

The primary need for pedestrian control is to reduce the number and severity of traffic accidents involving pedestrians. Pedestrians are slow and fragile as compared to motor vehicles; a collision between a vehicle and a pedestrian almost always results in at least an injury, often a fatality. The pedestrian population includes many people who are not familiar with traffic laws (one does not need to pass an examination to become a pedestrian).

9.1.2 Traffic Flow

Where pedestrian flow is heavy, special controls may be necessary to prevent reduction in capacity. At unsignalized intersections a steady stream of pedestrians preempting crosswalks may reduce vehicular capacity considerably. At signalized intersections lacking special pedestrian signals, conflicts between vehicular movements and pedestrians may cause congestion.

9.2 Pedestrian Timing Requirements

The pedestrian timing requirements include the Walk Interval and Flashing Don't Walk Interval (Pedestrian Clearance).

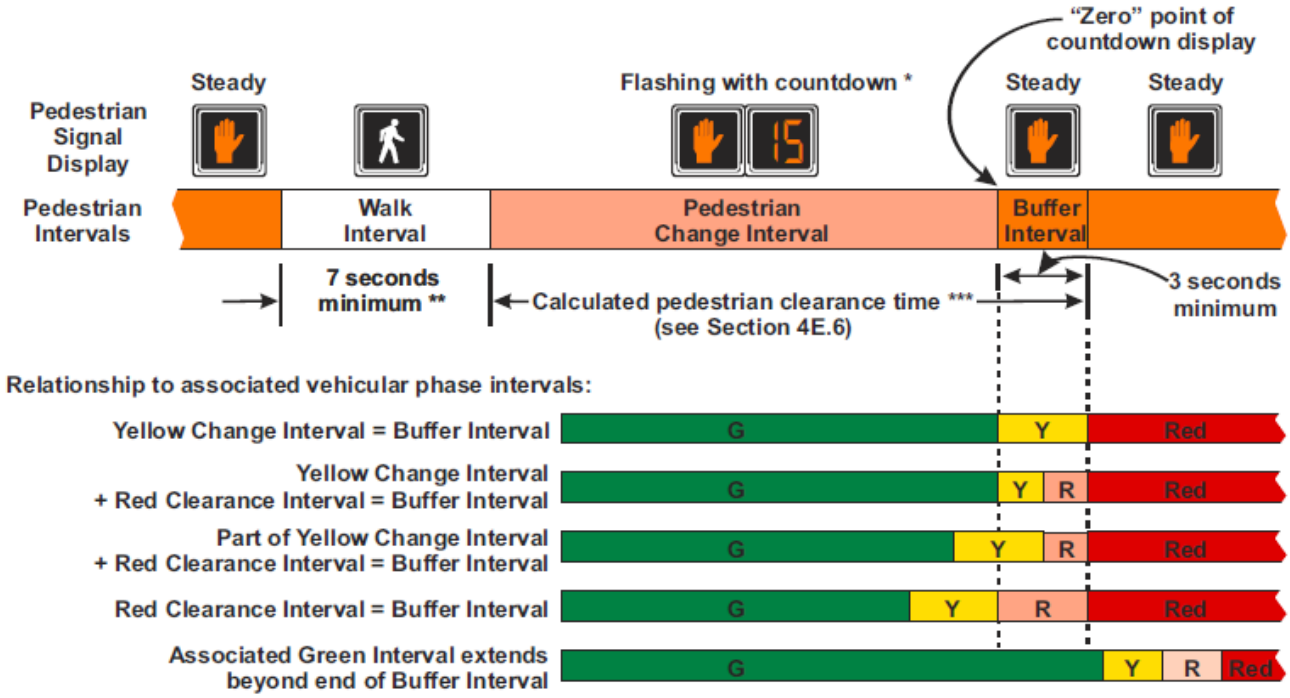
The **Walk Interval** is the time given to allow the pedestrian to leave the curb and begin crossing the street. The walk interval is typically 4 to 7 seconds. This allows pedestrians adequate time to leave the curb and begin crossing. MnDOT typically uses 7 seconds, based on MN MUTCD Chapter 4E guidance. The MN MUTCD indicates this option as well: "If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used." Under special circumstances, such as at a school crossing with numerous pedestrians, walk times may need to exceed 7 seconds.

The **Flashing Don't Walk** (FDW) or pedestrian clearance is the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median. It is based on the distance to cross (D) and the rate at which a pedestrian walks (R).

The calculation of the flashing don't walk is: FDW = D/R

The MN MUTCD specifies a walking rate of 3.5 feet per second. There is an option to use a walking rate of 4.0 feet per second if there is an extended push button feature or passive pedestrian detection.

The figure below illustrates the pedestrian intervals and their possible relationships with associated vehicular signal phase intervals.



9.3 Pedestrian Timing Recommended Practice

For a undivided roadway or divided roadway with a median island less than 6 feet wide, the pedestrian is provided time to cross the entire intersection, without stopping in the middle. The walk interval should be 7 seconds but may be reduced to 4 if it is necessary to minimize pedestrian timing considering other factors.

The Flashing Don't Walk (FDW) time should not be less than Walk time and the time may be reduced by the yellow interval if it is necessary to minimize pedestrian timing considering other factors. FDW time is calculated using:

FDW = D/R

Where D is the distance across in feet, from the curb to the far side of the farthest travel lane and R is the walking rate in feet per second. Guidance is to use 3.5 feet/second, but where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time.

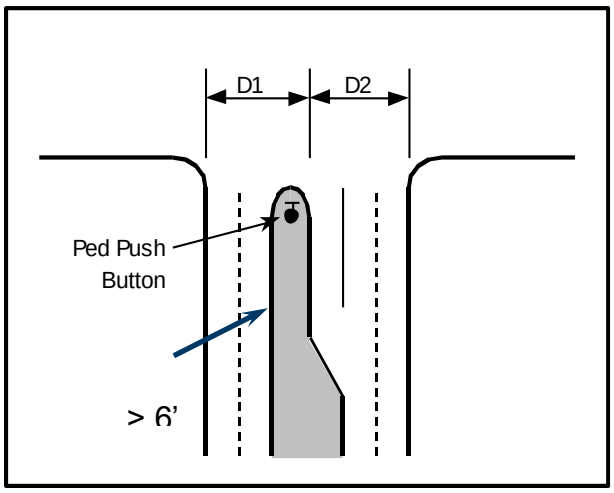
In divided roadways with medians, there are two options:

Option 1 (cross completed – preferred method): The timing is sufficient to allow a pedestrian who starts to cross on the beginning of Walk interval to cross the entire roadway. A pedestrian, who begins to cross later, may have to stop in the median, press the ped button, and wait for the next Walk interval.

- Walk = D1/R
- Flashing DON'T Walk = (D2/R)

Option 2 (cross to medians only)**:** The crossing distance should be determined by using the longest distance from one side to the median.

The below graphic shows the measurements of D1 and D2.



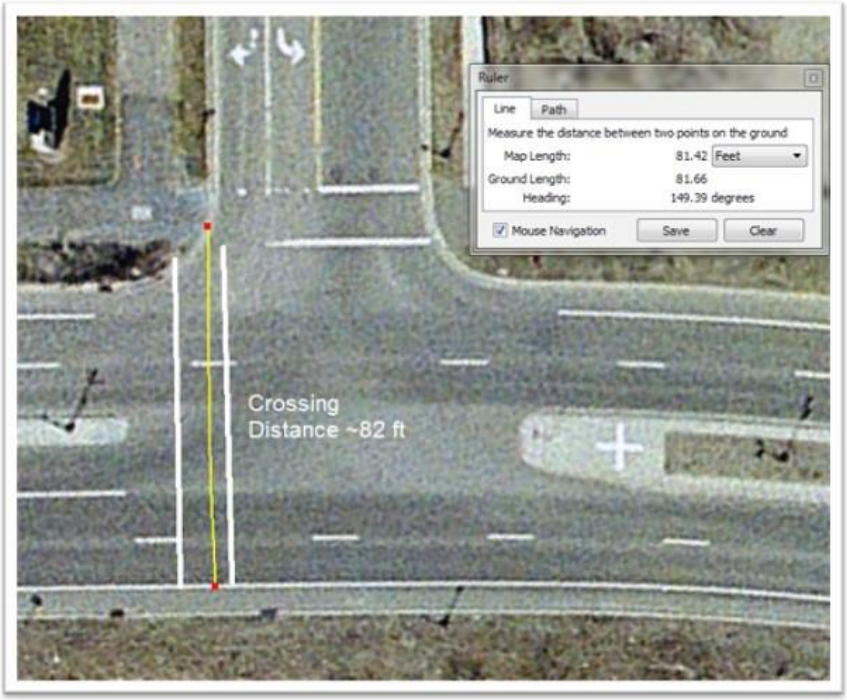
More details on MnDOT's recommended timing practice can be found in the Traffic Signal Timing and Coordination Manual.

9.4 Pedestrian Timing Requirements Example

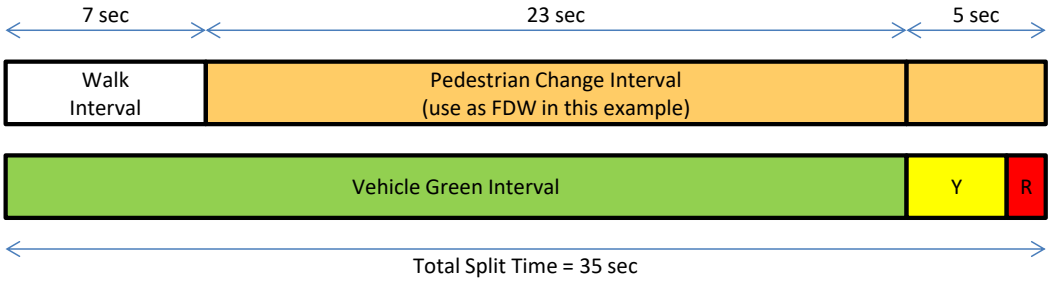
For this example, a pedestrian is required to cross in the north-south direction (82 feet). Thus, D = 82 feet. For normal conditions, 3.5 feet per seconds is used as the crossing speed. This speed may need to be reduced under special circumstances. We will use the typically 7-second Walk interval proceeding the Don't Walk interval. Additionally, the pedestrian clearance time will be set to equal the controller FDW. The "buffer" or solid don't walk is equal to the Yellow and All-Red for the vehicle phase.

The flashing don't walk would then be:

FDW = 82 feet / 3.5 feet per second = 23 seconds

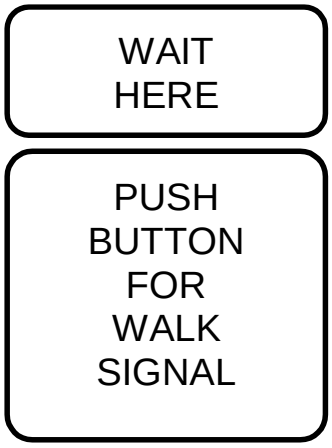


Total Split Time (given vehicle yellow = 4 seconds and all-red = 1 second) is 35 seconds.

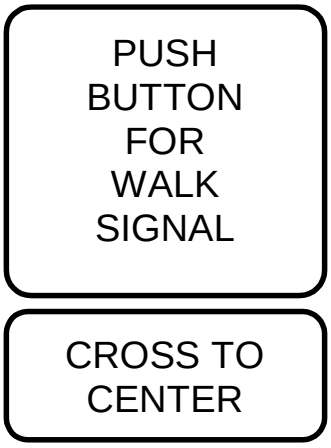


9.5 Pedestrian Information Sign

The Pedestrian Information Sign provides pedestrians with more information at the traffic signal; additionally, MnDOT uses braille on these signs. The sign shall be used on all traffic signal installations that have pedestrian indications.



in medians



at corners

10. ADVANCED WARNING FLASHER

In this chapter you will be introduced to Advanced Warning Flashers (AWF). The information presented in this section is from Chapter 4 of the Traffic Signal Timing and Coordination Manual and Chapter 4O of the MN MUTCD, both of which are available at the links below.

http://www.dot.state.mn.us/trafficeng/signals/manual.html

http://www.dot.state.mn.us/trafficeng/publ/mutcd/index.html

10.1 Advanced Warning Flasher

The AWF is a device which, at certain high-speed locations, has been found to provide additional information to the motorist describing the operation of the traffic signal. It can assist the driver in making safer and more efficient driving decisions. The additional information includes a sign/flasher combination to get the driver's attention and warn that the driver must prepare to stop.

The Minnesota AWF system consists of a flasher and sign located on the main street approaches to a high-speed signalized intersection. It is connected to the traffic signal in such a way that when the main street green is about to change to yellow, the flasher is turned on to warn the approaching drivers of the impending change. Basically, the purpose of an optimally designed combination of traffic signal and AWF system is twofold: 1) to inform the driver in advance of a required driving decision (prepare to stop) and 2) to minimize the number of drivers that will be required to make that decision.

10.2 AWF Consideration

The guidelines in the Traffic Signal Timing and Coordination Manual indicate when the installation of advanced warning flashers (AWF) for signal change interval should be considered. Due to the complex nature of traffic flow characteristics, these guidelines should be applied along with engineering judgement. Guidelines should be reviewed for each prospective installation. The considerations include:

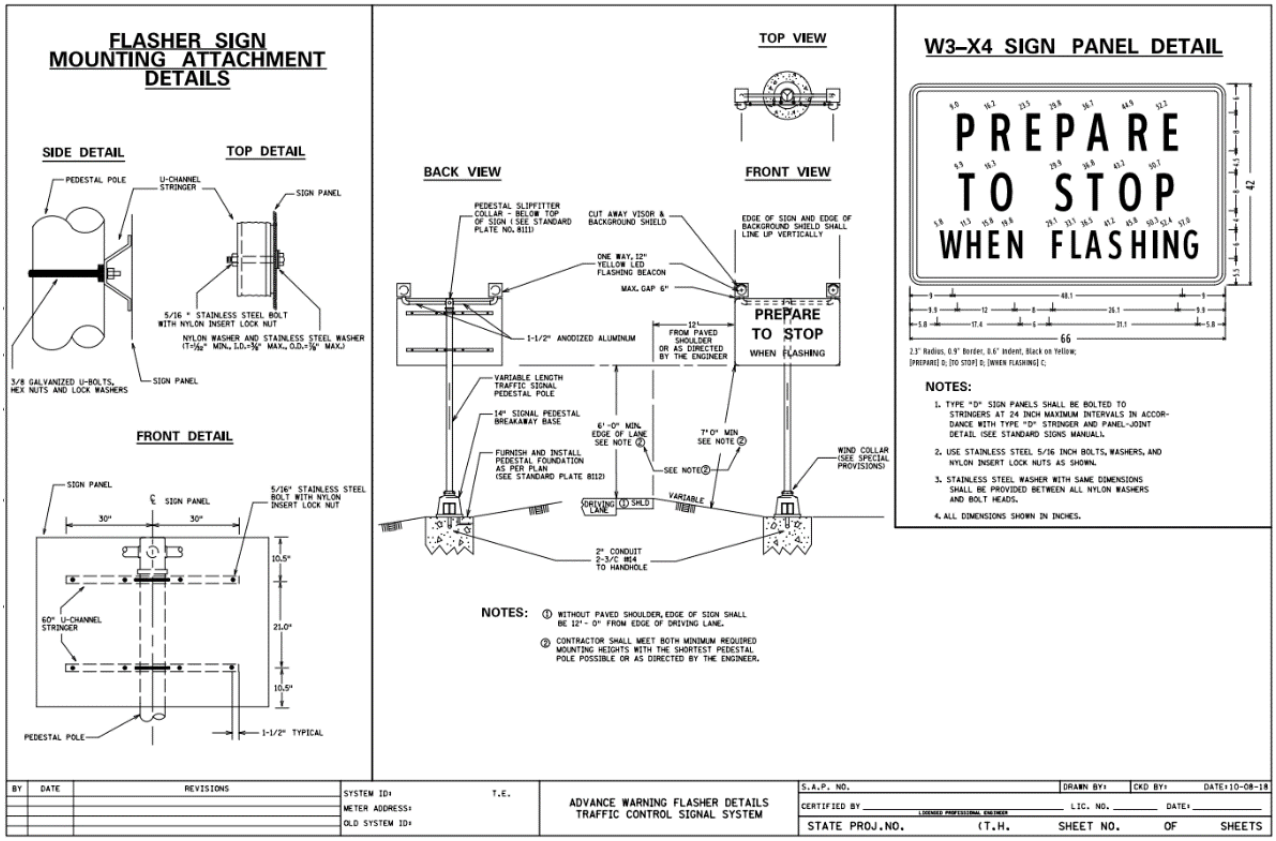
- Isolated or unexpected signalized intersection
- Limited sight distance
- Dilemma Zone
- Accidents
- Heavy truck volume
- Engineering judgment

10.3 Guidelines for Installation

Per the MN MUTCD Section 4O, there are guidelines for AWF installation that cover items including: AWF power supply, AWF sign placement, leading flash period, and detector placement. The AWF shall flash yellow in a wig-wag fashion prior to the termination of the green, and during yellow and red periods of the signal. The flasher shall be set back from the intersection as shown in the table on the next page from the MN MUTCD. The AWF set back location is based on the posted speed (mph). The leading flash is the amount of time, prior to the signal turning yellow, that the AWF flashes. The detection of the intersection shall be determined without regard to the AWF.

Posted Speeds (mph)	AWF Placement (feet)	Leading Flash (seconds)
40	560	8.0
45	560	7.0
50	700	8.0
55	700	7.0
60	850	8.0
65	850	7.5

The figure below is an Advanced Warning Flasher Detail. A copy of the most current version of this can be downloaded from the website.



11. EMERGENCY VEHICLE PREEMPTION (EVP) AND RAILROAD (RR) PREEMPTION

The transfer of signal control to a special signal operation is called preemption. There are three common types of preemption, based on different reasons: emergency vehicles, railroad, and transit vehicles. This chapter will cover emergency vehicle and railroad preemption. The information presented in this section is from Chapter 4 of the Traffic Signal Timing and Coordination Manual and Chapter 4D of the MN MUTCD, both of which are available at the links below.

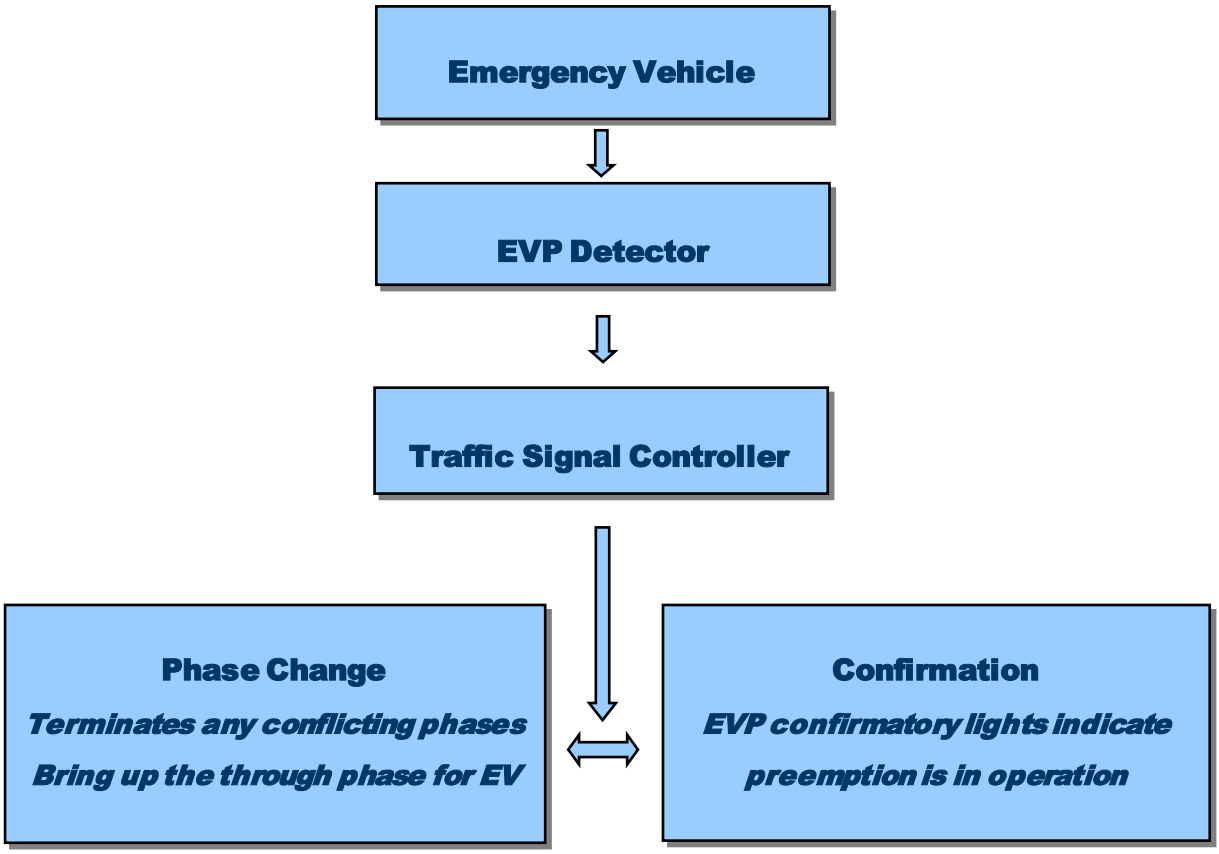
http://www.dot.state.mn.us/trafficeng/signals/manual.html

http://www.dot.state.mn.us/trafficeng/publ/mutcd/index.html

11.1 Emergency Vehicle Preemption

Emergency vehicle preemption (EVP) is a system installed on authorized emergency vehicles and at traffic signals which allows the authorized emergency vehicles to travel through signalized intersections in a safe and timely manner.

The system works as follows: An authorized emergency vehicle approaching a signalized intersection en-route to a call has an activated emitter (a strobe light oscillating at a specified frequency). The oscillations are detected by an EVP detector mounted on the signal mast arm. The detector may be located elsewhere to increase the range. The signal controller terminates any conflicting phases to bring up the through phase for the authorized emergency vehicle. Indicator lights mounted on the mast arm indicate that preemption is in operation.



11.1.1 Guidelines for Construction

Within the State of Minnesota, EVP detection systems shall respond to the following emitted frequencies:

- High Priority: 14.035 Hz ± 0.05 Hz
- Low Priority: 9.639 Hz ± 0.03 Hz

All newly constructed signals shall be wired for EVP. This includes running the necessary electrical conductors to the base of each pole or terminating in the mast arm as appropriate.

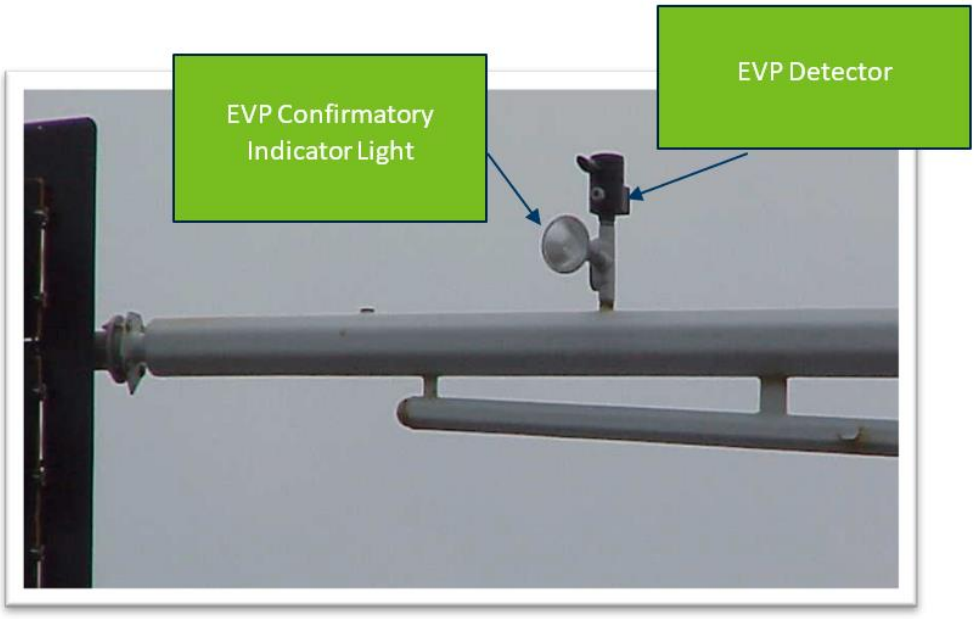
Traffic signals with EVP shall use confirmatory white indicator lights. The confirmatory light shall only be used during signal preemption. Railroad preemption shall have priority over all other types of preemption, including authorized emergency vehicles.

11.1.2 EVP Confirmatory Indicator Light

The white/clear confirmatory indicator light shall be mounted, in most cases, on the signal mast arm, one indication light facing each direction of approach. The EVP confirmatory light shall remain dark (off) when the EVP operation is not active. When the EVP is in operation, the indicator light shall flash or be steady under conditions defined below.

The purpose of the confirmatory indicator light is to verify to the authorized emergency vehicle driver that the signal controller has received the call and to verify to the authorized emergency vehicle drivers approaching from different directions which direction of approach will receive preemption.

A steady light facing an approach means that the authorized emergency vehicle preemption has been received by the signal controller for that approach. A flashing light facing an approach means that the signal controller has received a call for preemption from an authorized emergency vehicle on a conflicting approach and is responding to that call.



11.1.3 Operation of the Confirmatory Light

Under two-phase operations, the approach that is preempted will receive a steady confirmatory light along with the opposing approach. The controller will cycle through to bring up the circular green indications. The conflicting approaches will receive flashing confirmatory lights and circular red indications.

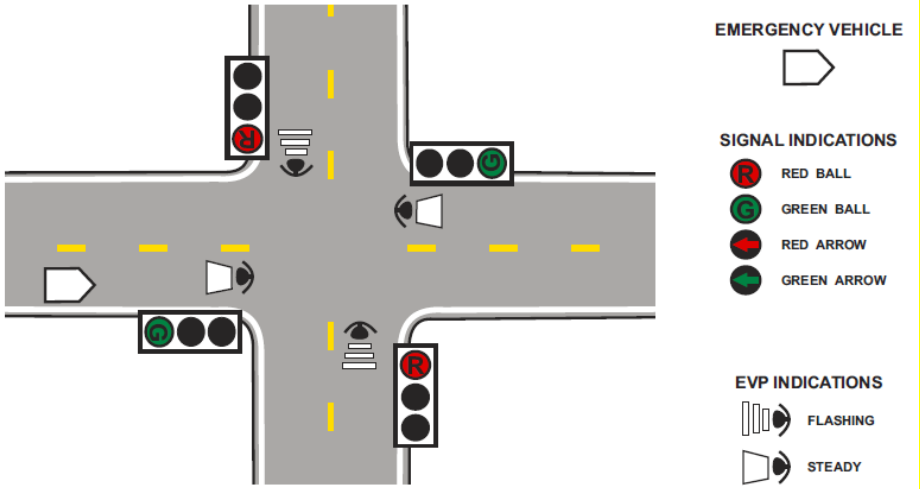


Figure 4D-21. Emergency Vehicle Preemption (EVP) - Two Phase Operation

Under protected/permissive operation, the authorized emergency vehicle's approach shall receive a steady confirmatory indication light along with the opposing approach. The controller shall cycle through to bring up the circular green signal indication. The left turn green arrow is not given on the preempted approach since a permissive green ball for the opposing flow would have to be terminated first. An opposing left turner, seeing the signal go to yellow, might mistakenly assume that the preempted approach was also yellow, and turn into the oncoming traffic proceeding on a green. This is referred to as a "left turn trap." To avoid this, the left turn green arrow is not given to any approach. The operation of this intersection, under preemption, is similar to that of a two-phase intersection. Conflicting approaches shall receive flashing confirmatory indication lights and circular red signal indications.

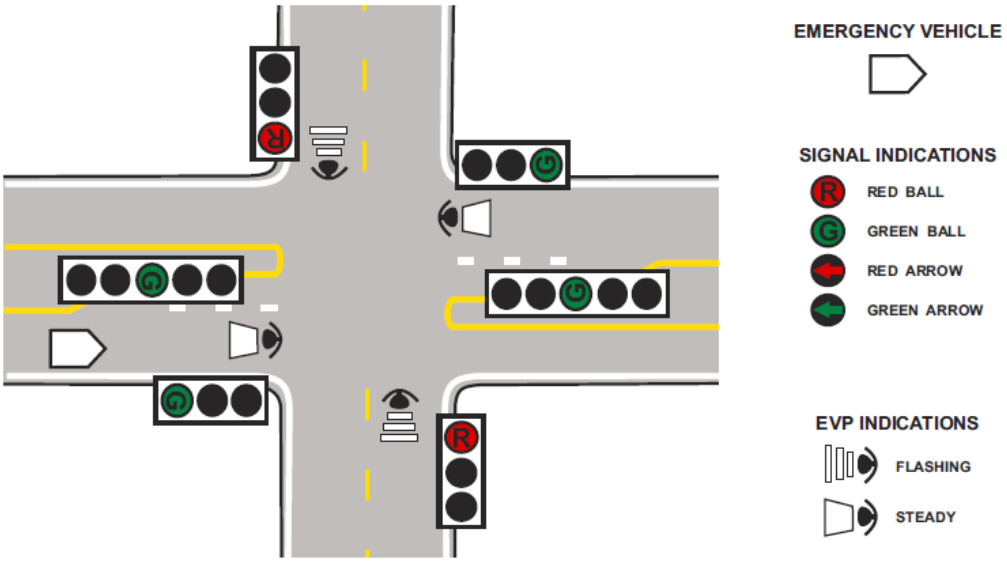


Figure 4D-22. Emergency Vehicle Preemption (EVP) - Protected/Permissive Operation

At a location like a freeway ramp, where there is only protected/permissive operation available to one approach (i.e. there are no opposing left turns), the controller shall cycle through to bring up the circular green and left turn green arrow. This is possible because the left-turn trap situation is not present.

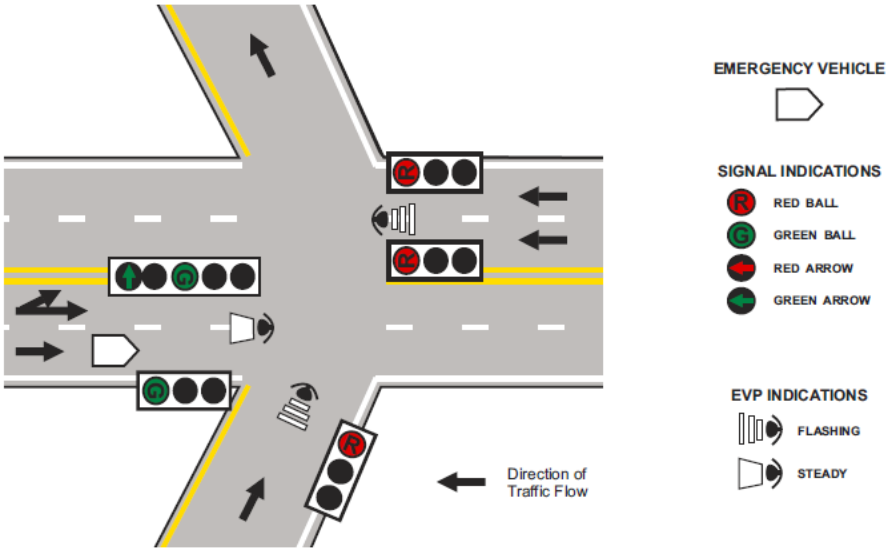


Figure 4D-23. Emergency Vehicle Preemption (EVP) - Ramp/One-Way/T-Intersection Protected/Permissive Operation

When a signal only has protected left turns, the authorized emergency vehicle's approach shall receive a steady confirmatory indicator light, a protected left turn green arrow, and a circular green. The opposing and conflicting approaches shall receive flashing confirmatory indicator lights and red indications. Refer to the MN MUTCD for additional details.

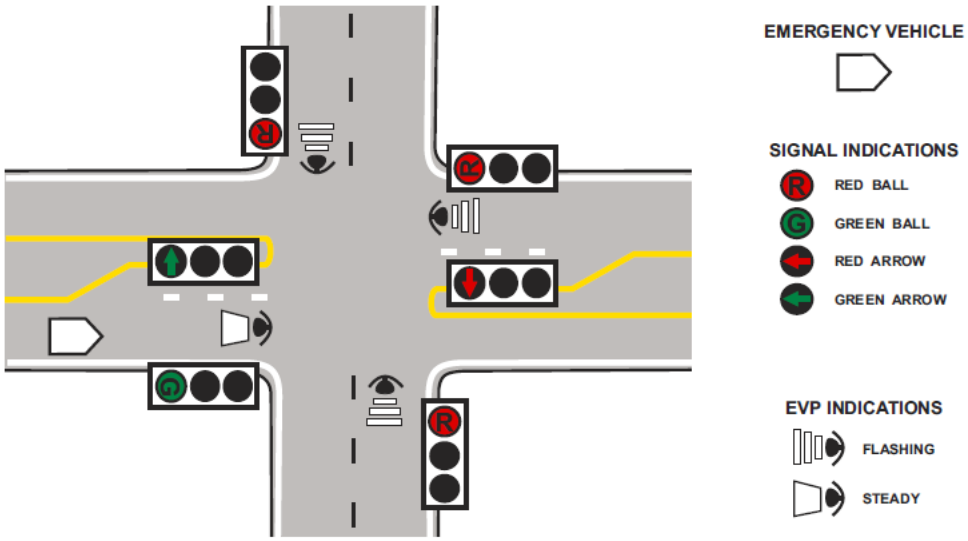


Figure 4D-24. Emergency Vehicle Preemption (EVP) - Protected Operation

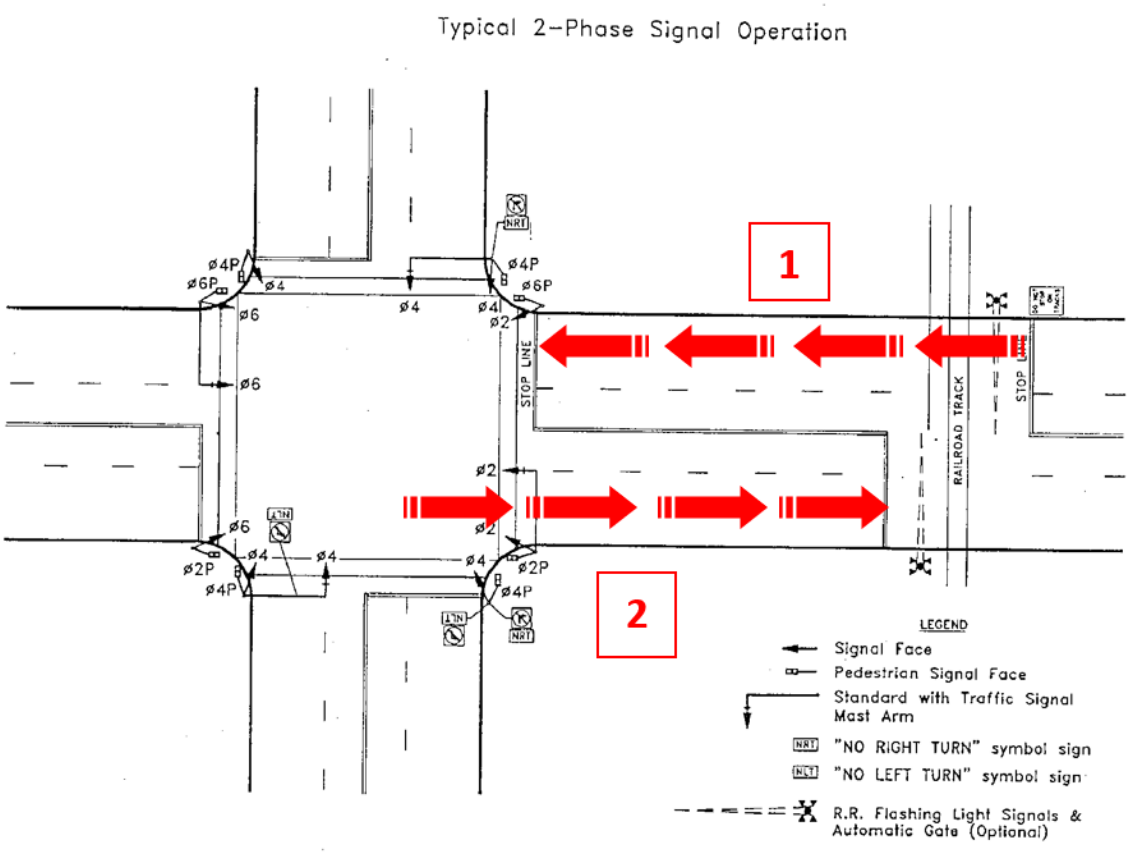
11.2 Railroad Preemption

Railroad preemption is a system installed on traffic signals which allows trains or Light Rail Transit (LRT) vehicles to preempt the signal and travel through the intersection in a safe and timely manner.

11.2.1 Guidelines for Preemption

If either of the following conditions are present, consideration should be given to interconnect the traffic signal and railroad grade crossing:

- Highway traffic queues that have the potential for extending across a nearby rail crossing
- Traffic queued from a downstream railroad grade crossing that have the potential to interfere with an upstream signalized intersection



Condition 1: Highway traffic queues behind the intersection stop line that has the potential to block the railroad tracks.

Condition 2: Highway traffic queues behind the railroad grade crossing stop line that has the potential to interfere with the signalized intersection.

When the determination has been made to preempt the traffic signal for a train, many items need to be considered that include:

- Distance between the traffic signal and the grade crossing
- Intersection geometry
- Track orientation
- Approach speed of the train

11.2.2 Guidelines for Operation

There are two goals related to railroad preemption.

- Goal 1: Permit traffic to clear the tracks before the train reaches the crossing
- Goal 2: Clear the traffic at the intersection

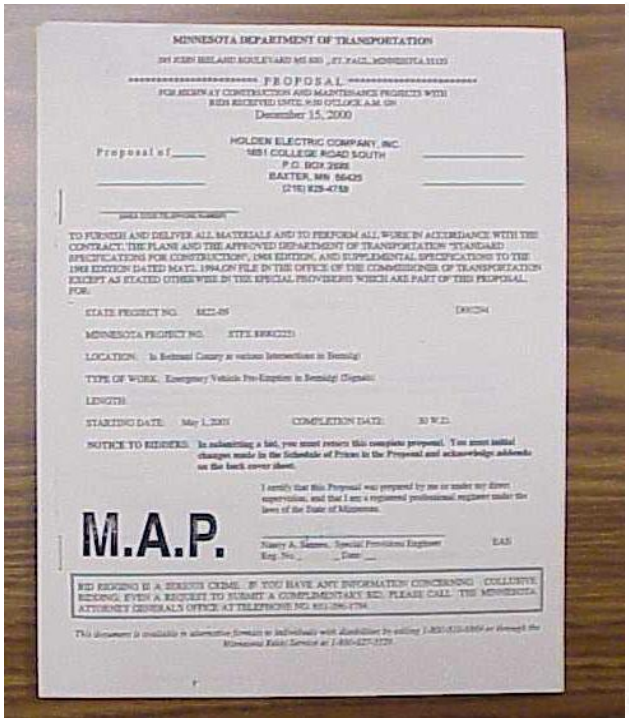
The image above is of a railroad cabinet and the image below is of a railroad crossing.

12. CONTRACT DOCUMENTS

This chapter will cover the Standard Specifications for Construction Book (Spec Book), the Contract Proposal, and Supplemental Agreements.

The Spec Book contains standard specifications to be used and referred to in the design of traffic signal plans and in the preparation of traffic signal Special Provisions. Plan designers need to be aware of the specifications contained in the Spec Book that may apply to their individual project.

Each individual project will have a Contract Proposal. The Contract Proposal contains many important documents, including the Special Provisions for the Project. The image below on the left is of a Contract Proposal, and the image on the right is of the Spec Book.

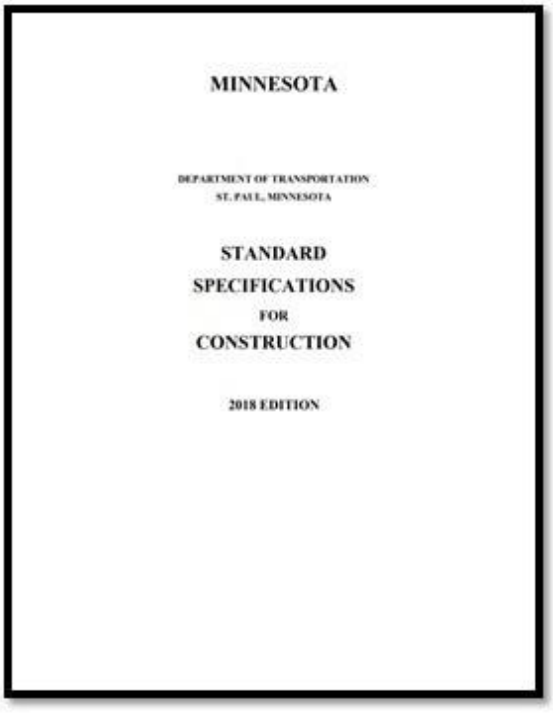

MINNESOTA DEPARTMENT OF TRANSPORTATION

PROPOSAL

December 15, 2000

HOLDEN ELECTRIC COMPANY, INC.
1851 COLLEGE ROAD SOUTH
P.O. BOX 2688
BAXTER, MN 56425
(218) 829-4758

M.A.P.


MINNESOTA

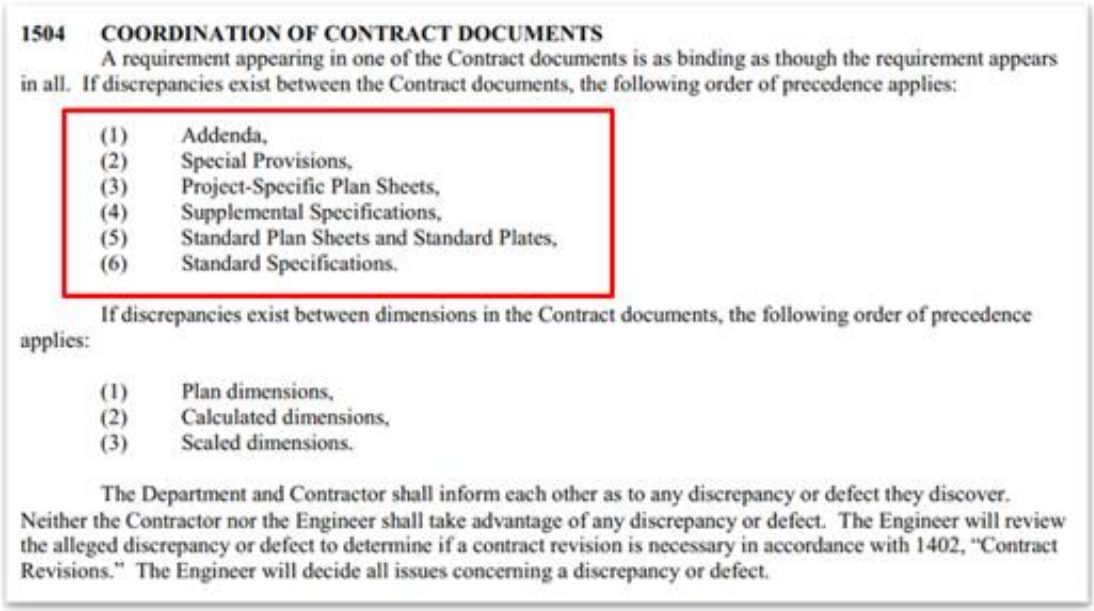
DEPARTMENT OF TRANSPORTATION
ST. PAUL, MINNESOTA

STANDARD
SPECIFICATIONS
FOR
CONSTRUCTION

2018 EDITION

12.1 Spec Book

The Spec Book has three divisions: Division I: General Requirements and Covenant, specifications labeled as 1000 series (1101 thru 1911); Division II: Construction Details, specifications labeled as 2000 series (2021 thru 2581); and Division III: Materials, specifications labeled as 3000 series (3101 thru 3985). The Spec Book is available at the following link: http://www.dot.state.mn.us/pre-letting/spec/.



1504 COORDINATION OF CONTRACT DOCUMENTS

A requirement appearing in one of the Contract documents is as binding as though the requirement appears in all. If discrepancies exist between the Contract documents, the following order of precedence applies:

(1) Addenda,
(2) Special Provisions,
(3) Project-Specific Plan Sheets,
(4) Supplemental Specifications,
(5) Standard Plan Sheets and Standard Plates,
(6) Standard Specifications.

If discrepancies exist between dimensions in the Contract documents, the following order of precedence applies:

(1) Plan dimensions,
(2) Calculated dimensions,
(3) Scaled dimensions.

The Department and Contractor shall inform each other as to any discrepancy or defect they discover. Neither the Contractor nor the Engineer shall take advantage of any discrepancy or defect. The Engineer will review the alleged discrepancy or defect to determine if a contract revision is necessary in accordance with 1402, "Contract Revisions." The Engineer will decide all issues concerning a discrepancy or defect.

12.1.1 1504 Coordination of Contract Documents

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12.1.2 Division II: Construction Details

Division II contains miscellaneous construction sections, as well as MnDOT 2565 (Traffic Control Signals). The format of MnDOT 2565 is as follows:

Description:

- Has a general information section
- Has a definitions section

Materials:

- Has a general information section
- Specifies various materials, including references to Division III of the Spec Book

Construction Requirements:

- Has a general information section
- Specifies the requirements for constructing a traffic control signal system

Method of Measurement:

- Traffic control signal systems are measured as an integral unit complete in place and operating with the complete installation at *one intersection* being considered one unit

Basis of Payment:

- There is a payment schedule listed in this section that shows the Item No., Item, and Unit. There is only one item used for traffic control signal systems in the Spec Book, however, signal system projects do use other "individual" pay items. These pay items are written as part of the Special Provisions.

12.1.3 Division III: Materials

Division III includes a section entitled "Electrical Materials" which contains various material specifications for traffic control signal systems. Many of these material specifications are referred to by MnDOT 2565. The format of these material specifications is divided into the following: scope, requirements, and inspection and testing.

Electrical Systems Materials Section

- Conduit (3801 thru 3803)
- Luminaires (3810)
- Lighting System Equipment (3812)
- EVP Equipment (3814)
- Cables and Conductors (3815)
- Handholes (3819)
- Mast Arm Pole Standards (3831)
- Traffic Signal Pedestals (3832)
- APS Push Buttons and Mounting Hardware (3833)
- Vehicle Signal Heads (3834)
- Pedestrian Signal Heads (3835)
- Service Equipment (3837)
- Junction Boxes (3838)

12.1.4 Other Standards and Supplemental Specifications

The Spec Book includes other national and local standards specified in the book, as listed below. Additionally, all electrical equipment to be furnished by a Contractor shall conform to other regulations, standards, and Codes as specified in the "Spec Book."

- **AASHTO**, American Association of State Highway and Transportation Officials
- **ASTM**, American Society of Testing and Materials
- **ITE**, Institute of Transportation Engineers
- **ICEA**, Insulated Cable Engineers Association
- **NEC**, National Electrical Code
- **NEMA**, National Electrical Manufacturers Association
- **RUS**, Rural Utilities Service
- **UL**, Underwriter Laboratories, Inc.

Supplemental specifications are additions and revisions to the standard specifications that are approved after the standard specification book has been printed and distributed. They are published separately (usually in paperback booklet form) until the next updated Spec Book is published and released. The plan and proposal for each specific project will state if there are supplemental specifications that apply.

12.2 Contract Proposal

Each MnDOT project has a proposal, which includes addendums, notice to bidder, special provisions by division (2565), attachments, and contract schedule (bid prices).

Each Proposal contains Special Provisions by Division, for example:

- Division S – General Requirements
- Division SL – Electric Street Lighting
- **Division SS – Traffic Control Signals**
- Division ST – Traffic Signs and Devices
- Division SZ – Freeway Traffic Management Systems

Division SS may be formatted into more than two SS sections.

12.2.1 Special Provisions

Special Provisions are "additions and revisions" to the Standard and Supplemental specifications. They cover conditions relevant to a specific project. If an item is adequately addressed or specified in the Spec Book, Standard Plates, Plan, or other Contract documents, then that item should not be duplicated within the Special Provisions.

Division SS (Traffic Control Signals) typically include the following sections for a new signal system, but more may be needed depending on the project conditions (e.g. for temporary signal systems, revise signal systems, etc.):

- SS-1 Removing Traffic Control Signal Systems
- SS-2 Traffic Control Signals
- SS-3 Emergency Vehicle Preemption (EVP) Systems
- SS-4 Traffic Control Interconnect

Division SS special provisions are available at the following link:
http://www.dot.state.mn.us/trafficeng/signals/manual.html

All signal system Special Provisions that are part of MnDOT projects or have State Aid funding involved will have a SS-1 "Qualification of Workers" specification. SS-3 EVP may be incidental to the traffic signal system and therefore be part of SS-2 "Traffic Control Signals".

12.2.2 Special Provisions Format

A typical set of Special Provisions for a signal system is formatted similar to the Spec Book; however, the actual format of the Special Provisions may vary somewhat when compared to the Spec Book format. Special Provisions may also include detail drawings that are pertinent to the specific project. The following is a closer look at a typical set of Special Provisions for a signal system:

Traffic Control Signals

Signal system Special Provisions will have a description paragraph of the work: what work is involved, location of project; and what documents the project shall be in accordance with.

Traffic Control Signals:

Description Section:

This section will usually include a list of Department furnished materials being supplied to the Contractor and language specifying where the Contractor is to pick-up the Department furnished materials. This section may also include any Plan changes, notes to bidders, specifying whether or not an agreement will apply to the project, etc.

Materials Section:

This section will cover any material items that are not covered in other Contract documents, or language in other documents that needs to be modified for this specific project.

Construction Requirements:

This section contains language dealing with the actual construction of the signal system. Like the materials section, it will include language that modifies items in the Spec Book, Plan, or other Contract documents.

Measurement and Payment:

This section will specify exactly how the signal system will be measured and paid for. The pay items in this section need to match the pay item(s) listed on the statement of estimated quantities sheet in the Plan.

The following is a "sample" pay item for a signal system set of Special Provisions:

> Removing and salvaging the existing traffic control signal system; furnishing and installing materials and electrical equipment; and installing Department furnished materials as specified herein, all to provide a complete operating new full-traffic-actuated traffic control signal system at the intersection of _____ and _____ in _____, _____County as contained in these Special Provisions and in the Plans will be measured as an integral unit and paid for as specified in MnDOT 2565.4 and MnDOT 2565.5 respectively for Item No. 2565.516 (TRAFFIC CONTROL SIGNAL SYSTEM).

The majority of signal system Special Provisions are written by the MnDOT Office of Traffic Engineering for State let projects. Consultants, however, usually prepare the Special Provisions for consultant designed MnDOT projects.

12.2.3 Addendums

At times it may become necessary to provide additional information, corrections, additions, or deletions to the Special Provisions, Plans, and/or Spec Book after the Project is put out for bid, but before the actual letting of the Project. This information is provided to bidders by creating an "Addendum". These addendums are then sent out to Contractors, suppliers, etc. that have purchased the Contract documents for the specific project. These addendums are sent out with enough lead time to allow bidders the opportunity to consider the addendum in preparing their bid. All addendums will be located in the front portion of the MnDOT final project proposal.

12.3 Supplemental Agreements

It is important that Plans and Special Provisions are clear, accurate, and adequately indicate the work that the Contractor is required to perform. However, when that does not happen, or if some item(s) is inadvertently omitted from the project documents, MnDOT will negotiate a supplemental agreement with the Contractor to rectify the situation. There are occasions when supplemental agreements are necessary due to field conditions that were not apparent at the time of the project design. It is in the best interest of everyone to keep supplemental agreements to a minimum.

Supplemental agreements are written after the Contract is underway and negotiated between Contractor and project Engineer.

13. MAINTENANCE

In this chapter you will be introduced to Maintenance Agreements and Traffic Signal Maintenance Categories.

In a maintenance agreement, the maintenance responsibilities are spelled out in the MnDOT Traffic Control Signal Agreement. Refer to Chapter 2 for more information. The agreement will have a number upon which other documents may refer to. The number will be in effect until another agreement is written, in which it will state that the new number supersedes and terminates the old agreement number.

Within the maintenance agreement, the power cost provider is specified, and maintenance responsibilities are outlined. Maintenance is divided into two categories of responsibilities: minor maintenance and major maintenance.

A quick and easy reference is the signal responsibility list, which is a report in the Transportation Asset Management System (TAMS). This list can be generated by the Office of Traffic Engineering or requested by the Electrical Services Section (ESS).

The list contains an index that shows the responsibility types, the system types with abbreviations, in a format that makes the responsibility easily recognizable.

Minor Maintenance includes:

- Vehicle indication lights
- Luminaire lamp replacement
- Paint signals

Major Maintenance includes:

- Knockdowns
- Loop replace/repair
- Head replace

13.1 Maintenance Responsibilities

Traffic Signal Maintenance is divided into four categories: Response Maintenance, Preventative Maintenance, Operations Maintenance, and Design Modification.

13.1.1 Response Maintenance

Response maintenance involves procedures that are undertaken when traffic signal and control equipment fail, either fully or partially. These include knockdowns, heads turned/indications out, loop failure, and an operations complaint.

13.1.2 Preventative Maintenance

Preventative maintenance practices involve inspecting, cleaning, and adjusting signals at regular intervals and replacing components as necessary. They are performed by MnDOT Electrical Services Section (ESS) every 12-24 months. These maintenance activities include testing the MMU; checking indications, loops, pedestrian push buttons, controller clock, and additional items.

13.1.3 Operations Maintenance

Operations maintenance is performed by MnDOT District Operations Staff every 6-12 months. These maintenance activities include checking operation, indications, loops, pedestrian push buttons, controller and clock, and cleaning the cabinet and replacing air filter (1/year).

13.1.4 Design Modification

Design modification involves changing the signal display, timing plans, or equipment to reflect changed traffic conditions. These modifications are performed on an as-needed basis or as funding allows. They include upgrading outdated equipment, replacing end of life hardware, ADA upgrades, and flashing yellow arrow retrofits.

13.2 New Signals

For new signals, the district operations responsibilities include:

- Ensuring the timing and operation needed is programmed into the controller
- All indications, loops, push buttons, EVP are checked to ensure the signal is operating at 100% at turn-on
- When a new signal is placed into operation, a logbook must be put into the cabinet, along with field intersection layouts and cabinet prints
- The color code chart must be part of the logbook or cabinet file

The image below is a screenshot of the maintenance responsibilities for a particular signal, from MnDOT's Transportation Asset Management System (TAMS).