DRAFT NOTICE / Foreword

The *Traffic Electrical Equipment Manual* for the Washington State Department of Transportation is currently under development and is still in DRAFT form. However, elements contained within are needed to support design, construction, and operation of traffic electrical equipment - highway lighting, traffic signals, and ITS equipment. Therefore, portions of this manual have been made available for use in DRAFT form.

The *Traffic Electrical Equipment Manual* is for use by the Washington State Department of Transportation engineering and operations personnel, and consultant workforces performing these functions for the Department. This manual provides detailed information for designing, inspecting, and operating traffic electrical systems, which includes highway lighting, traffic signal, and ITS equipment. It has been developed for state facilities and may not be appropriate for all county roads or city streets that are not state highways.

The requirements described in *Traffic Electrical Equipment Manual* have been developed based on a combination of regulatory requirements, the needs of the Department, and the unique environment presented by installing electrical equipment as part of a highway system. Most electrical laws and codes are oriented towards structures, requiring clarification and interpolation for roadway systems. Much of this information has previously been scattered among other resources such as other manuals, policy documents, white papers, training materials, and institutional knowledge. By assembling this information in one location, these resources are more readily available and can be applied with greater consistency throughout the Department.

Following the guidance of the *Traffic Electrical Equipment Manual* is mandatory for state owned highway electrical systems. It has been written to provide the maximum amount of flexibility possible for these types of systems, but many constraints have also been imposed.

As with other manuals, updating the *Traffic Electrical Equipment Manual* is an ongoing process and revisions are issued regularly. The addition of new or modified design criteria to the *Traffic Electrical Equipment Manual* through the revision process does not imply that existing features are deficient or inherently dangerous. Nor does it suggest or mandate immediate engineering review or initiation of new projects. Comments, questions, and improvement ideas are welcomed.

During this DRAFT availability period, please direct all questions and comments to:

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Chapter E1 Power System Design

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E1.1 General

This chapter describes the design of individual electrical power circuits for illumination, signal, and ITS equipment, powered from WSDOT electrical service cabinets, and the associated features required in the service cabinet to support these circuits. This chapter only addresses fixed (or nearly fixed) loads on single phase systems. For variable loads such as motors, or three phase systems, contact the WSDOT Headquarters Traffic Office. This chapter also does not address any marine terminal, vessel, or related electrical systems.

Only one electrical system may be run through any connected conduit, junction box, or piece of equipment, with the sole exception of a separate supply entering an electrical service or transformer cabinet. For WSDOT, each electrical service cabinet and transformer is considered a separate electrical system. For example, wiring from the load side of a transformer cabinet may not use any of the same conduit or junction boxes as wiring from the electrical service cabinet supplying the transformer. Exceptions may be allowed for special equipment requiring multiple input voltages with approval of the Region Signal Maintenance Manager.

E1.2 Standard Load Sizes

Electrical circuits shall be designed using the following standard electrical loads. For equipment other than cabinets, including transformer cabinets, and luminaires (lights), the actual rated load of the equipment shall be used. Due to variations in cabinet equipment and actual loads drawn by different luminaires in the same wattage class, WSDOT has established standard load tables for equipment. These tables are divided into three categories: LED Luminaires, HPS Luminaires, and Cabinets.

Table 2-1; WSDOT LED Luminaire Standard Load Table

Wattage Class	Operating Voltage					
	120V		240V		480V	
	Amps	Watts	Amps	Watts	Amps	Watts
200	0.93	106	0.46	106	0.23	106
250	1.34	161	0.66	161	0.29	161
310	1.74	207	0.89	207	0.46	207
400	2.23	268	1.12	268	0.56	268
750	4.10	500	2.40	500	1.00	500

Table 2-2; WSDOT HPS Luminaire Standard Load Table

Wattage Class	Operating Voltage 120V Amps	120V Watts	240V Amps	240V Watts	480V Amps	480V Watts
100	2.2	130	1.1	130	0.6	135
150	1.7	188	0.9	188	0.5	188
200	2.2	240	1.1	240	0.6	240
250	2.6	300	1.3	300	0.7	300
310	3.4	365	1.7	365	0.8	367
400	4.0	472	2.0	472	1.0	472
750	6.8	840	3.5	840	1.8	840
1000	9.5	1102	4.7	1102	2.4	1102

Table 2-3; WSDOT Cabinet Standard Load Table

Wattage Class	Operating Voltage 120V Amps	120V Watts	240V Amps	240V Watts	480V Amps	480V Watts
1800	15	1800	7.5	1800	3.8	1800
2000	16.7	2000	8.4	2000	4.2	2000
2500	20.9	2500	10.5	2500	5.3	2500
3000	25	3000	12.5	3000	6.3	3000
3500	29.2	3500	14.6	3500	7.3	3500
4000	33.4	4000	16.7	4000	8.4	4000
4500	37.5	4500	18.8	4500	9.4	4500
5000	41.7	5000	20.9	5000	10.5	5000
7500	62.5	7500	31.3	7500	15.7	7500
10000	83.4	10000	41.7	10000	20.9	10000
15000	125	15000	62.5	15000	31.3	15000
25000	208.4	25000	104.2	25000	52.1	25000
37500	312.5	37500	156.3	37500	78.2	37500

Individual luminaires and transformer cabinets shall use the appropriate load data from Tables 2-1, 2-2, or 2-3 as applicable. The minimum allowable size for standalone transformer cabinets is 3000W. For traffic signal and ITS cabinets, there is a minimum standard load which must be used for each type of cabinet. These minimum standard loads are listed in Table 2-4.

Transformers are sized based on the total load supplied multiplied by 1.33. The additional 33% allows for future additional load. Transformers are available in any of the wattage classes listed in table 2-3, from 3000W up. These are standard sizes, so the next higher size than the calculated load must be selected.

Table 2-4; WSDOT Minimum Standard Cabinet Loads

Cabinet Type		Minimum Wattage Class
Cabinet Series	**Cabinet Includes**	
Single-Width (33x series) [1]	Ramp Meter (RM)	2500
	Traffic Signal (SG)	3000
	Variable Message Sign (VM) [2]	3500
	Tolling	4500
	All Other 33x	2000
Double-Width (33xD series)	Ramp Meter (RM)	3000
	Traffic Signal (SG)	4000
	Tolling	4500
	All Other 33xD	2500
[1] Includes NEMA Cabinets (EX: P44) [2] VMS Systems may not be installed in double-width cabinets at this time		

Cabinet loads may be higher depending on the equipment installed. Selected cabinet load ratings must be approved by the Region Signal Maintenance Manager to ensure adequate circuit capacity. All cabinets, with the exception of transformer cabinets and some VMS cabinets, operate on 120V. All other loads shall initially be determined using 240V or lower. Additional criteria in Section E1.3 will determine if a 480V circuit may be used.

E1.3 Wire Size

Wire size for a circuit shall be determined using a combination of ampacity (total amps that can safely be carried) and line loss requirements. These values are determined for each segment in the circuit. Wire sizes may not decrease along a circuit when moving from any end load to the electrical service cabinet.

The length of a circuit segment (L_S) is the horizontal physical length of the conduit between the two opening points plus 10 feet, to account for sweeps and slack. Where wire is routed up a pole (such as to an aerial circuit connection), add the height of the pole to the ground segment length connected to that pole.

At light standards, there is a segment from the junction box to the pole base, and a second segment from the base to the actual luminaire. As with other conduit runs, the circuit segment length of the between the box and the pole is the horizontal physical conduit length plus 10 feet. For the wire in the pole itself, the length of the segment is the height of the pole (H1 height) plus the length of the luminaire arm (example: a 40 ft pole with a 12 ft arm would have a segment length of 52 ft). The segment in the pole is always #10 copper wire (Pole and Bracket Cable).

Ampacity and line loss depend on the type of wire selected. Aluminum wire may only be used under the following circumstances:

1. Aerial triplex wire installation. This is normally only temporary, though some long term installations do exist.
2. In locations with repetitive wire theft. Requires approval from the Region Signal Maintenance Manager.

Copper wire must be used for all other cases.

To check ampacity and determine line loss for a segment, the total load on that segment must be determined. The total load for a segment (A_S) is the sum of all loads, in amps, from equipment located at or beyond the end of the segment farthest from the electrical service cabinet.

All Signal and ITS Cabinet loads are evaluated at 120 volts. Signal and ITS cabinets that are located a significant distance from the electrical service cabinet normally require a transformer with the cabinet. The transformer is supplied by a higher voltage circuit to allow for smaller wire over the longer distance.

Lighting and transformer supply circuits shall initially be evaluated at 240 volts, unless there is a special case justifying 120 volts for a lighting circuit. If the wire size for any lighting circuit exceeds #2 AWG, or any transformer supply circuit exceeds #2/0 AWG, then 480 volt circuits may be used for all circuits supplied from that electrical service cabinet. Note that only 480 volt circuits are available from a 480 volt service (Type E or Type C), requiring a separate transformer cabinet for any lower voltage loads.

Wire shall not be smaller than #8 AWG (copper) for all circuits, and shall not be smaller than #6 AWG (copper) for any circuit powering a Traffic Signal or ITS cabinet, regardless of distance. #10 AWG (copper) wire may be considered for lighting circuits with approval from the Region Signal Maintenance Manager.

E1.3.1 Line Loss

Line loss shall be determined for all circuits and all branches of those circuits. Line loss is represented by a reduction in voltage V_d (voltage drop). Voltage drop is calculated for every segment of the circuit. Each run of conduit between openings, such as in a junction box or cabinet, is a segment. The voltage drop for the segment is calculated using the formula shown in Equation 3-1:

$$V_D = 2L_S A_S R_W \qquad \textit{Equation (3-1)}$$

Where:

- V_D = Voltage Drop for the segment, in volts.
- A_S = Total amp load on that segment, in amps.
- L_S = Length of the segment, in feet. Length of the conduit segment path between outlets plus 10 feet. For aerial circuits, add 10% of the distance between poles to account for sag.
- R_W = Wire Resistance, in ohms/ft.

Wire resistance is dependent on the type and size of wire. For WSDOT systems, the values for copper and aluminum wire are listed in Table 3-1.

Table 3-1; WSDOT Wire Resistance (R_W) Values [1]

Wire Size (AWG)	Resistance (ohms) / ft	
	Cu [2]	Al [2]
14	0.0032600	N/A
12	0.0020500	N/A
10	0.0012900	N/A
8	0.0008090	0.0012800
6	0.0005100	0.0008080
4	0.0003210	0.0005080
2	0.0002010	0.0003190
1	0.0001600	0.0002530
1/0	0.0001270	0.0002010
2/0	0.0001010	0.0001590
3/0	0.0000797	0.0001260
4/0	0.0000626	0.0001260
250 kcmil	0.0000535	0.0001000
300 kcmil	0.0000446	0.0000847

[1] Resistance values are derived from NEC Chapter 9, Table 8, Conductor Properties. WSDOT uses values for coated copper for calculations.
[2] Cu = Copper; Al = Aluminum

The maximum voltage drop for a circuit is limited to a certain percentage of the operating voltage, which varies depending on the type of circuit. The maximum percentage voltage drop allowed for various circuit types is listed in Table 3-2.

Table 3-2; WSDOT Maximum Voltage Drop by Circuit Type

Circuit Type	Maximum Voltage Drop (V_D)
Supply to Signal or ITS Cabinet	3%
Supply to Transformer Cabinet	5%
New Illumination Circuit	5%
Temporary Illumination Circuit	8%

E1.3.2 Ampacity

Although it is rarely an issue, the load for each segment must be verified against the ampacity of the wire for that segment. In the event that the load on a segment exceeds the ampacity of the wire for that segment, the wire size for that segment must be increased on that segment until it is greater than or equal to the segment load. Ampacity ratings for different wire types and sizes are shown in Table 3-3. Note that no more than four circuits (8 conductors) may be installed in a single conduit.

Table 3-3; WSDOT Wire Ampacity Values [1]

Wire Size (AWG)		14	12	10	8	6	4	2	1	1/0	2/0	3/0	4/0	250 kcmil	300 kcmil
Ampacity (A)	Cu [2]	14	17.5	24.5	35	45.5	59.5	80.5	91	105	122.5	140	161	178.5	199.5
	Al [2]	N/A	N/A	N/A	28	35	45.5	63	70	84	94.5	108.5	126	143.5	161

[1] Ampacities are derived from NEC Table 310.15(B)(16) for USE-2 conductors, and modified using Table 310.15(B)(3)(a) for up to 9 current carrying conductors.
[2] Cu = Copper; Al = Aluminum

E1.3.3 Grounding Conductor

All conduits require a grounding conductor, as described in Standard Specification 9-29.3(2)A3, regardless of the quantity or type of cables installed in the conduit (including empty conduits). The size of the grounding conductor is dependent on the circuit breaker protecting that circuit, when present. Due to the limited size of power circuits, WSDOT simplifies this by referencing the conductors in the conduit to determine the size of the ground conductor, as shown in Table 3-4.

Table 3-4; WSDOT Minimum Ground Conductor Sizes [1]

Largest cable in conduit	Minimum Ground Conductor Size (AWG)
Any Traffic Signal or ITS multi-conductor or fiber-optic cable; Power cables up to #1 AWG	#8
Power cables from #1/0 AWG to 300 kcmil	#6

[1] Ground conductor sizes based on NEC Table 250.122.

E1.4 Service and Transformer Cabinets

The type of service cabinet used depends on the required output voltages and the number of circuits. Table 4-1 shows the different WSDOT Electrical Service Cabinet Types and their available output circuits and voltages, as well as the circuit limitations for transformer cabinets.

Table 4-1; WSDOT Maximum Voltage Drop by Circuit Type

Service Cabinet Type	Available Voltage(s)	Circuits				Standard Plan
		Total Single Positions [1]	Available Single Positions [2]	Maximum Double (2 Pole) Circuits [3]	Maximum Lighting Circuits [4]	
Type A	120	2	2	N/A	1	J-10.16
Type B	120/240	10	8	4	4	J-10.17
Type B Modified	120/240	18	16	8	5	J-10.20
Type D	120/240	24	22	10	5	J-10.21
Type C	480	N/A	N/A	6	4	J-10.18
Type E	480	N/A	N/A	11	7	J-10.22
Transformer	120/240	6	6	4	N/A	J-10.25

[1] Single positions are single pole (1-Pole or 1P) breaker positions for 120V circuits. Type C and Type E service cabinets do not directly support external 120V loads – an external transformer is required.
[2] Single positions in some cabinets are pre-assigned for internal loads.
[3] Double positions are double pole (2-Pole or 2P) breaker positions for either 240V or 480V circuits, depending on the cabinet type. For the Type E service cabinet, one position is used for the internal transformer.
[4] The number of lighting circuits available is limited to the number of lighting contactors that will physically fit in the cabinet. Each lighting circuit requires its own contactor.

E1.4.1 Circuit Breakers and Contactors

Circuit breakers and contactors are determined from the total load, in amps, of the connected circuit. To simplify calculations, WSDOT requires that lighting circuit breakers be sized at 140% of the total circuit load, and all other breakers be sized at 125% of the total circuit load. Circuit breakers are only available in industry standard sizes, as shown in Table 4-2. The selected circuit breaker shall be rated equal to or greater than the calculated breaker size required.

Table 4-2; Standard Circuit Breaker Sizes (in Amps)

15	20	30	40
50	60	70	80
90	100	125	150
175	200	225	250

The following are standard circuits and breaker sizes found in electrical service cabinets (amperages are rounded up slightly):

- Photoelectric Control (Photocell and Contactor); 1W @ 120V => 0.01A; 1P-15A breaker.

- Ground Fault Circuit Interrupter (GFCI) Receptacle; 1800W @ 120V => 15A; 1P-20A breaker.
- Heat Strip; 100W @ 120V => 0.85A; 1P-15A breaker.
- Internal Transformer (Type C and E Services Only); 3kW @ 480V => 6.25A; 2P-15A breaker.

Contactors are only used in lighting circuits. As with circuit breakers, these have limited standard sizes and are only available in 30, 60 and 100 amp sizes. The contactor amp rating shall be equal to or greater than the total lighting circuit load. The selected circuit breaker should also be checked against the ampacity of the connected circuit wire, as it must be the smallest standard size to support the rated ampacity of the wire.

E1.4.2 Main Breakers and Utility Connections

Main circuit breaker and utility connection wiring (service conductors) are determined from the total cabinet load, in amps, required from the serving utility. The total cabinet load is the sum of all external and internal cabinet loads. The total internal cabinet load depends on the type of cabinet:

- Type A: 1W / 0.01A (Photocontrol)
- Type B, Type B Modified: 1801W / 15.01A (Photocontrol, GFCI)
- Type C, Type E: 3 kW / 6.25 A (Internal Transformer)
- Type D: 1901W / 15.86A (Photocontrol, GFCI, Heater)

After calculating the total cabinet load, the main circuit breaker is sized at 125% of the total cabinet load. This is to address all continuous and non-continuous loads, as well as allow for future capacity. The main breaker must also be a standard size, as listed in Table 4-2. Main breakers may not be smaller than 60 Amps, with the single exception of Type A services, which require a minimum 30 Amp main breaker.

The size of the service conductors is based on the selected rating of the main breaker. The service conductor is selected such that it can carry the full amperage rating of the main breaker. Table 4-3 shows the appropriate wire size for each main breaker size and serving voltage type. Aluminum is only used for aerial service connections (aluminum triplex). Unless allowed by the serving utility, the riser from the metering point to the aerial connection point at the top of the pole shall be copper.

Table 4-3; WSDOT Minimum Service Conductor Sizes [1]

Main Breaker Size (Amps)		30	40	50	60	70	80	90	100	125	150	175	200	225	250
Service Conductor Size (AWG)	Cu [2]	8 [3]	8 [3]	8 [3]	6	6	4	4	3	2	1/0	2/0	3/0	3/0	4/0
	Al [2]	6 [3]	6 [3]	6 [3]	4	4	3	2	2	1/0	2/0	3/0	4/0	250 kcmil	300 kcmil

[1] Sizes derived from the ampacities listed in NEC Table 310.15(B)(16) for USE-2 conductors.
[2] Cu = Copper; Al = Aluminum
[3] Smallest allowable service conductor size is #8 AWG for copper and #6 AWG for aluminum.

When specifying the size of service conductors and any conduit supporting them, the wire note must read similar to the following example: "Install 2 inch conduit, riser, weather-head, and three #2 conductors unless otherwise directed by the serving utility." Conduit size is determined as shown in Section E1.6. Include risers and weather-heads only for aerial service connections.

E1.4.2 Locating Service and Transformer Cabinets

If other cabinets are present, install the service cabinet on the same concrete pad if possible. Transformer cabinets shall always be installed on the same concrete pad as at least one of the cabinets that they supply. All cabinets require a minimum of 42 inches of clear, level space, comprised of either concrete pad or gravel (CSBC or similar) in front of all access doors. When a meter socket is required to be installed on the outside of the cabinet, 42 inches of clear, level space is required from the face of the installed meter. There must also be 42 inches of clear, level space along at least one side of the cabinet if there is access or a meter on multiple sides of the service cabinet.

For freeways and expressways, not including surface streets within limited access right of way or ramp terminals, a separate meter pedestal should be installed. The meter pedestal should be located such that it is accessible from a surface street outside of the highway right of way. This avoids the need for utility personnel to have to stop on the side of a freeway or expressway to access a meter or their service connection. If right of way fence is present, try to locate the meter pedestal just outside the right of way fence. Otherwise, install a pocket or gate in the fence such that the meter pedestal is on the WSDOT side of the right of way line.

When a remote meter pedestal is used, size the conductors between the meter pedestal and the actual service cabinet based on the total load on the service cabinet and a maximum voltage drop of 1%. Calculate the voltage drop using the method shown in Section 1.3.1. The meter pedestal shall include a disconnect breaker in the customer (lower) portion of the pedestal that is the same size as the service cabinet main breaker.

E1.5 Conduit

E1.5.1 Wire and Conduit Routing

WSDOT systems allow for a certain amount of overlap for wiring within a conduit and junction box system. However, there are certain restrictions on how conduits may be shared:

- Conduit may not be shared between wire, of any type, powered from one electrical service or transformer cabinet and wire powered from a different electrical service or transformer cabinet. This includes wiring powered by a transformer cabinet and wiring powered by the electrical service cabinet powering that transformer cabinet. WSDOT considers each electrical service cabinet and transformer cabinet an independent power source.
- Power conductors may not be installed in the same conduit as Traffic Signal or ITS cables, unless approved by the Region Signal Maintenance Manager
- For new installations, no more than four power circuits may be installed in one conduit.

- For new installations, it is recommended that lighting circuits be installed in conduits separate from cabinet and transformer power circuits.

Conduits should be placed close to the roadway shoulder where trenching can be used to install the conduit. Conduit should generally parallel the edge of the roadway or similar geographic features, as installation is typically easier than trying to install straight runs between points – particularly when the space between junction boxes is anything other than flat, open ground (grass, dirt, or similar bare ground).

E1.5.2 Conduit Sizing

Conduit sizes are determined from the amount of cross-sectional area will be occupied in the conduit by wiring. For WSDOT systems, the conduit capacities shown in Table 5-1 and the wire areas in Table 6-2 are used to accommodate all allowable conduit types. Table 5-2 only shows single, current carrying conductors; for other wire types, see Traffic Signal and ITS specific guidance.

Table 5-1; WSDOT Conduit Capacities [1]

Conduit Size (in)	26% fill (in^2)	40% fill (in^2)	Total Area (100% fill) (in^2)	Metric Size [2]
1/2 [3]	*0.056*	*0.087*	*0.217*	*16*
1	0.179	0.275	0.688	27
1 1/4 [3]	*0.322*	*0.495*	*1.237*	*35*
1 1/2 [3]	*0.445*	*0.684*	*1.711*	*41*
2	0.747	1.150	2.874	53
3	0.1675	2.577	6.442	78
4	2.927	4.503	11.258	103
5	4.642	7.142	17.855	129
6	6.655	10.239	25.598	155

[1] Capacities based on Schedule 80 PVC conduit, as shown in NEC Chapter 9, Table 4.
[2] Metric Size shown for reference only for metric as-built plans.
[3] Special case sizes. May only be used to modify an existing conduit run or with special permission.

Table 5-2; Single Conductor Wire (USE-2) Cross-Sectional Areas [1]

Wire Size (AWG)	14	12	10	8	6	4	2	1	1/0	2/0	3/0	4/0	250 kcmil	300 kcmil
Area (in^2)	0.023	0.029	0.035	0.062	0.081	0.108	0.146	0.197	0.229	0.274	0.322	0.385	0.478	0.555

[1] Areas based on manufacturer specification sheets for USE-2 wire.

The maximum conduit fill percentage is dependent on the type of installation:

- Existing conduit, with or without existing wire: 40%. Based on NEC Chapter 9, Table 1, for more than two cables.
- New conduit: 26%. Allows for additional future cables.

WSDOT assumes that all conduits will have more than two conductors at some point. The sum of the cross-sectional areas of all installed cables must be less than or equal to the area allowed by the applicable fill percentage. Equation 6-1 demonstrates this comparison. Do not forget to include the ground conductor.

$$Q_1A_1 + Q_2A_2 + \cdots + Q_nA_n \leq A_{CF}$$ *Equation (6-1)*

Where:

- Q_n = Quantity of conductor type "n".
- A_n = Cross-sectional area of conductor type "n", per Table 6-2, in square inches.
- A_{CF} = Allowable conduit fill area, per Table 6-1, in square inches.

All new conduits shall be either 2-inch, 3-inch, or 4-inch diameter conduit, with the following exceptions:

- 1-inch conduit shall be used between a light standard foundation and its serving junction box.
- 1-inch conduit shall be used between a surface mounted luminaire (wall or ceiling, including suspended) and its serving junction box or hand hole.
- 1/2-inch, 1 1/4-inch, and 1 1/2-inch conduit may only be used to extend or modify an existing conduit run of that size.
- 5-inch and 6-inch conduit may be used under special circumstances with approval from the Region Signal Maintenance Manager.
- See Traffic Signal and ITS specific guidance for special cases for those types of systems.

Standard conduit types are Schedule 80 PVC, Schedule 80 HDPE, or Rigid Metal (RMC), and do not need to be specified in the Contract, as their use is dictated by Standard Specification 8-20.3(5)B. Liquid-Tight Flexible Metal Conduit (LFMC) is allowed in special cases, such as the last conduit segment connecting to a surface mounted luminaire or as a special type of expansion/deflection fitting. Specifying LFMC requires the approval of the Region Signal Maintenance Manager.

Empty spare conduits, or the equivalent empty space in occupied conduits, are required to be installed under the following circumstances:

- Any new conduit road crossing: minimum 2" spare conduit, connected to junction boxes on either side of the roadway. This does not include driveways.
- Any new service cabinet: minimum 2" spare conduit into service cabinet, connected to a junction box outside the cabinet pad.
- Any new transformer cabinet: minimum 2" spare conduit into load side of cabinet, connected to a junction box outside of the cabinet pad.

- See Traffic Signal and ITS specific guidance for additional spare conduit requirements for those types of systems.

Equivalent empty space means empty space equivalent to the 40% fill area of an empty conduit of the required size.

E1.5.2 Conduits In or On Structures

Installing conduits in or on structures requires coordination with the structure designer. All conduits installed on or in structures are 2-inch diameter conduits, with the exception of 1-inch conduits connecting to luminaires (or their supports) and ITS outerduct (see ITS specific guidance for more details).

On new construction, all cast in place barrier for bridge rails or walls shall include two, 2-inch conduits installed in the barrier, regardless of their use – both may be empty. Each conduit run shall be fully isolated from any other, including its own junction boxes both on and off the structure. A third conduit may be installed within a barrier, but a note must be added requiring that the conduits be tied such that they are stacked vertically in the barrier. No more than three conduits may be installed in a barrier, not including 1-inch branches to luminaires or other equipment. Ensure that the structure designer knows how many conduits are being installed in each barrier.

Conduits may only be installed on the outside of existing structures with the approval of the WSDOT Bridge and Structures office. Example of locations where conduit is surface mounted include the outside of a bridge face, across a bridge pier crossbeam, or up a bridge pier column. These should be limited to the maximum extent necessary for the system to work. Transitions from columns to crossbeams or from crossbeams to the bridge itself are required to be LFMC. Conduit bodies may be necessary to provide pull points on either side of the LFMC segment. Sharp conduit corners on structures are the only other location where conduit bodies may be considered for conduit runs.

E1.6 Junction Boxes

Junction boxes provide access to and accommodate changes in direction of conduits and wiring. Junction boxes shall be spaced no more than 180 feet apart, as measured along the ground from box to box, or between boxes mounted on a structure. Junction boxes are also required if a conduit run will exceed 360° of bends between outlets. For conduit installed in the ground, 180° of bends are normally taken up by the 90° bends up into the box or cabinet at each end, limiting horizontal bends to 180°.

Larger power circuits for cabinets may be installed in conduit runs routed through pull boxes, spaced at up to 1000 feet apart, with approval from the Region Signal Maintenance Manager.

E1.6.1 Ground Installed Boxes

Junction boxes installed in the ground should be located off of the shoulder of the roadway, outside of any paved surface. In locations with sidewalk, junction boxes should be located outside of the sidewalk if at all possible. Junction boxes may not be placed in the bottom of a ditch, and must be located between the edge of the paved road surface and the ditch flow line, as close to the paved road surface as possible. Do not install a box in an active traffic lane if at all possible.

Table 6-1 shows the six standard types of junction boxes for ground installations, and includes pull boxes.

Table 6-1; WSDOT Ground Junction Boxes

Box Type	Standard Plan Reference	Maximum conduit allowance (inches)
Type 1	J-40.10	6
Type 2	J-40.10	12
Type 4	J-40.20	6
Type 5	J-40.20	12
Type 6	J-40.20	24
Type 8	J-40.30	24
Pull Box	J-90.10	40

The maximum allowed conduit is the limit of the sum of the diameters of all conduits entering the junction box. If the sum of the diameters of all conduits entering the box exceeds the maximum allowed conduit rating, then a larger box or multiple boxes must be used. Use the smallest junction box necessary for total diameter of conduits entering the box.

Type 4, Type 5, and Type 6 junction boxes are heavy-duty (HD) versions of the Type 1, Type 2, and Type 8 boxes, respectively. HD boxes are required where the box will be within a paved surface, such as a roadway lane or shoulder, or a commercial driveway. HD boxes should be considered for other locations where it is likely that larger trucks will be driving over the box, such as a driveway to a gravel pit or similar construction or material site.

Pull boxes are available in both standard and heavy-duty, and may be used for long power runs or where multiple boxes may not be an option to support many conduits. Consult with the Region Signal Maintenance Manager before using pull boxes.

Where a box will be installed in a sidewalk, including sidewalk crossing a driveway or similar vehicle access, boxes with slip-resistant surfacing are required and should be called out in the Contract to increase awareness. Slip-resistant lids and frames are mandatory per Standard Specification 8-20.3(6), but this is sometimes overlooked on projects where there are only a few boxes requiring slip-resistance. Adding a note in the Contract is a simple way to avert any potential issues.

E1.6.2 Structure Mounted Boxes

Structure mounted junction boxes are stainless steel junction boxes, rated NEMA 3R (weather-resistant) or 4X (watertight), and commonly referred to as just “NEMA boxes”. WSDOT has three basic types of NEMA boxes: in-barrier mounted, surface mounted, and in-deck mounted. When viewing a structure mounted junction box, as viewed from the opening (lid), the distance from the lid to the back of the box is the depth (D), the horizontal dimension is the width (W), and the vertical dimension is the height (H).

E1.6.2A In-Barrier Boxes

In-barrier boxes are fixed at an effective size (usable space) of 18” W x 8” H x 8” D. Conduits may only enter the left and right sides (ends) of the box – they may not enter the top, bottom, or back of the box. Each end can only support up to 4 inches of total conduit diameter, typically as either two 2-inch conduits or one 2-inch conduit with up to two 1-inch conduits. Although there are two types of in-barrier boxes – NEMA 3R Adjustable (Standard Plan J-40.37) and NEMA 4X Fixed (Standard Plan J-40.36) – they have the same capacity. Contractors determine which type based on the construction method used for the barrier. Plans should just reference “NEMA barrier box”.

E1.6.2B Surface Mounted and In-Deck Boxes

Surface mounted boxes are mounted to the surface of a structure, rather than being set into the structure. In-deck mounted boxes are similar to in-barrier boxes, except that they are embedded in the ground surface of the structure – typically sidewalk or other non-driving surface. These boxes are required to be sized based on the sizes of the conduit entering the box, and which faces of the box they are entering (NEC 314.28). Conduit may enter any face of these boxes except for the lid. To simplify things, and to reduce the need for custom ordered boxes, WSDOT requires all surface mounted and in-deck box dimensions to be multiples of 2 inches (6”, 8”, 12”, 18”, etc.). No dimension may be smaller than 6 inches.

Boxes are sized to accommodate both the amount of conduit entering and the manipulation of the wiring passing through them. Each wall with conduit entering must be used to evaluate minimum dimensions. For a given wall, dimensions relative to that wall are determined as follows:

1. The distance to the wall opposite the wall being evaluated depends on where other conduits enter the box. If a conduit enters the opposite wall of the box, the minimum distance to the opposite wall is 8 times the diameter of the largest conduit entering the wall being evaluated. For all other cases, the minimum distance to the opposite wall is 6 times the diameter of the largest conduit entering the wall being evaluated, plus the sum of the diameters of all other conduits entering the wall being evaluated. WSDOT ignores splices and same conductor through-pulls when sizing boxes.

2. The dimensions of the wall being evaluated depend on the sizes and number of conduits entering that wall. WSDOT only allows a single row or column for standard installations, so there should only be one line of conduits in any wall. The axis of the row or column (axis with one or more conduits) is the long dimension, and the perpendicular axis (axis is always only one conduit) is the short dimension. The minimum size of that wall dimension is the sum of the conduit diameters along that axis, plus 1.5 times the number of conduits in that axis, and is shown in Equation 7-1.

$$L_{min} = (D_{C1} + D_{C2} + \cdots + D_{Cn}) + 1.5"Q_C \qquad \text{Equation (6-1)}$$

Where:

- L_{min} = The minimum box wall length, for that dimension.
- D_{Cn} = Diameter of conduit “n”, in inches, in that row or column.
- Q_C = The total quantity of conduits in that row or column of conduits.

Example:

A box wall has two 1-inch conduits and one 2-inch conduit in a single row, and no other factors control the dimensions of the wall where those conduits enter. The wall dimensions would be:

$$L_{min-long} = (1" + 1" + 2") + 1.5"(3) = 4" + 4.5" = 8.5"$$

$$L_{min-short} = 2" + 1.5"(1) = 2" + 1.5" = 3.5"$$

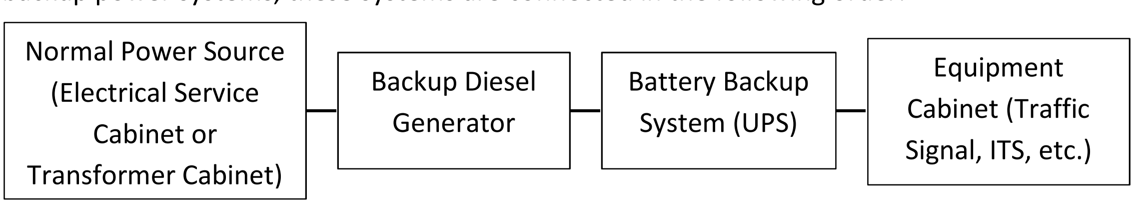
Rounding up to the nearest 2-inch increment, greater than or equal to 6, this particular wall’s dimensions would be 10” by 6”.

Repeat these calculations for each wall with conduit entering. The largest value calculated for each box dimension (height, width, and depth) are used for the overall box dimensions.

E1.7 Backup Power Supplies

Backup power supplies include diesel generators and battery backup systems (BBS or UPS – Uninterruptible Power Supplies). This section only discusses providing permanently installed backup power to a single cabinet requiring 120V power. For backup power to multiple cabinets or to loads requiring 240V or 480V, contact the Headquarters Traffic Office for assistance.

The Region Signal Maintenance Manager will determine if battery backup power, generator backup power, or both are required. Generally, a battery backup system will provide 8 hours of backup power, and a generator will provide up to 72 hours of backup power. When including backup power systems, these systems are connected in the following order:



If battery or generator backup power are not required, that block is omitted from the functional block diagram.

UPS systems are designed to support the basic loads of a traffic signal cabinet. Backup generators must be sized such that they can provide the total load of the protected cabinet, as determined in Section E1.2. Specify the minimum total load that must be supported by the generator in kilowatts (kW). Generator sizes vary between manufacturers, and this allows for selection of a standard generator from a particular manufacturer.

E1.8 References

The following references are used in the development of this chapter.

E1.8.1 Laws and Regulations

National Electrical Code (NEC), NFPA, Quincy, MA

Revised Code of Washington (RCW) 19.28, Electricians and Electrical Installations

Washington Administrative Code (WAC) 296-46B, Electrical Safety Standards, Administration, and Installation

E1.8.2 Design Guidance

Design Manual, M 22-01, WSDOT

Standard Plans for Road, Bridge, and Municipal Construction, M 21-01, WSDOT

Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10, WSDOT