DEVELOPING A CONDUIT LAYOUT FOR THE CONTROL CENTER

- It is helpful to print the entire lighting system on a large-scale plot to develop the conduit layout.
- Locate the lighting control center on the large-scale plot.
- Connect the lighting loads with an effort to create splice points as close as possible to the control center. This technique will result in a reduced voltage drop as shown previously in Figure 4-3.

ASSIGNING THE PHASE AND CIRCUIT OF EACH LOAD

- The phase assigned to each light should be staggered; e.g., A, B, C, A, B, C, etc. In this configuration, if the B phase is tripped, those lights on phases A and C will help fill the gap caused by the loss of the lighting standards powered by the B phase.
- Two different phases should be assigned to twin-arm lighting standards.
- Circuit sets should be assigned to a general geographic location.

  For Example:

  In a 3-phase electrical system, circuits 2, 4, and 6 are assigned to the loops and ramps of the interchange; circuits 3, 5, and 7 are assigned to the northbound mainline; etc. This technique will assist in maintenance of the lighting system.
- In a 120/240 VAC, single-phase system, circuits 2 and 4 create a circuit set including legs L1 and L2.
- The photocell circuit assignment for the 277/480Y, 3-phase, SE-9 electrical service and CCW-1 control center is A-1. Thus, the next circuit set assignment is B-3, C-5, A-7.
- The photocell circuit assignment for a 120/240 VAC, or a 120/208 VAC electrical service and CCW-1 control center is L1-1 (or A-1)

DEVELOPING THE ELECTRICAL SCHEMATIC

- A schematic of the lighting control center electrical distribution should be created based on the geographic distribution of the lights and the location of the splice points. The Example Electrical Schematic, shown at the end of this appendix, provides an illustration of this task.
- The schematic provides a reference during voltage drop calculations to the various loads (wattage), phasing, circuit numbers, and distance from the control center. It does not need to be to scale and it is not included in the final plan set.

- A reference number is assigned to each luminaire and junction box. This number may be related to the actual pole number used on the plans or may be of some other convention as illustrated previously in TEDM Section V – Roadway Lighting, Chapter 4, 4.8.2.

BALANCING THE LOADS, VOLTAGE DROP CALCULATIONS, AND SIZING THE CONDUCTOR CABLES

- Each luminaire and splice point is listed in a spreadsheet noting distances, wattage, and amperage as shown in Table 2.

- The design engineer should attempt to balance the power load on each circuit set such that the amperage variation between each phase is as close to 0.0 as possible. The phase imbalance on any circuit set should not exceed 5%. Also, the total phase imbalance at the control center should not exceed 5%. However, it may be impossible to achieve these requirements without removing or adding a light.

- NEC requirements specify that the voltage drop in the feeder circuits (the conductors running from the transformer to the lighting control center) not exceed 3%. Voltage drops in the branch circuits (conductors running from the control center to the lights) should not exceed 5%.

- VDOT standards require the total voltage drop not to exceed 3% in any branch circuit. This procedure provides for future expansion of the system and flexibility to make field modifications during construction.

- Voltage drop calculations are made for each circuit set. VDOT's wire size program recognizes the load distribution and calculates a single wire size to be used by the circuit set throughout the entire length of the circuit. That is, the wire size is not reduced as the load is decreased.

- Other voltage drop programs are available that provide the lighting designer with the ability to step-down the wire size with decreasing load. The lighting designer should verify that use of such a program is acceptable to the VDOT Traffic Engineering Design Section and that the installation of a variety of wire sizes is acceptable to the District Maintenance Section. The lighting designer must closely control the amount of voltage drop in a system designed under this step-down wiring technique.

EXAMPLE VOLTAGE DROP CALCULATION

The following discussion relates to the example circuit show in Table 3 and the Example Electrical Schematic included with this Appendix. The voltage drop is based on the calculations delivered by the VDOT wire-sizing program.

- Two circuit sets are used in the attached example; Circuits 2, 4, 6 are used to power the lights along I-66 WB, circuits 3, 5, 7 are used to power I-66 EB.

- The VDOT wire size program should be used to evaluate each circuit. In the attached example, circuit B-4 requires only a #8 conductor. However, the entire circuit set is run with a #6 to simplify pulling the wire.

- Table 1 provides a listing of HPS luminaires and their associated current draw.

Table 1: HPS Luminaire Power/Amperage Values								
Line Voltage:		277 VAC			Line Voltage:		120 VAC	
Luminaire wattage		Luminaire current draw			Luminaire wattage		Luminaire current draw	
1000 WATTS		4.5 AMPS			1000 WATTS		10.4 AMPS	
400 WATTS		1.8 AMPS			400 WATTS		4.2 AMPS	
250 WATTS		1.2 AMPS			250 WATTS		2.8 AMPS	
150 WATTS		0.8 AMPS			150 WATTS		1.9 AMPS	
100 WATTS		0.5 AMPS			100 WATTS		1.2 AMPS	
70 WATTS		0.3 AMPS			70 WATTS		0.7 AMPS	

Table 2	PAGE	x	OF	y		
VDOT Project Name	MADE BY:	JH	DATE		08/10/00	
LUMINAIRE LAYOUT AND AMP BALANCING	CHKD. BY	TG	DATE		01/17/00	

CONTROL CENTER 18

Circuits 2,4,6

LUM	WATT	AMP BY PHASE			DIST
#		A-2	B-4	C-6	feet
18-6.1	400	1.8			320
18-5.1	400			1.8	290
18-4.1	400		1.8		310
18-3.1	400	1.8			305
18-2.1	400			1.8	300
18-1.1	400		1.8		40
18-13.1	400		1.8		250
18-12.1	400			1.8	310
18-11.1	400	1.8			310
18-10.1	400		1.8		300
18-9.1	400			1.8	300
18-8.1	400	1.8			265
JB 18-B					200
JB 18-A					20
CC-18					20

CIRCUITS 2,4,6	A-2	B-4	C-6	
TOTAL AMPS	7.2	7.2	7.2	
OVERALL TOTAL	21.6			
AVE CURRENT IN THREE PHASES	7.20			
DEVIATION FROM AVE.	0.00	0.00	0.00	
MAX DEVIATION FROM AVERAGE	0.00			
PHASE IMBALANCE	0.000			
% IMBALANCE	0.00			

Circuits 3,5,7

LUM	WATT	AMP BY PHASE			DIST
#		A-7	B-3	C-5	feet
18-19.1	400			1.8	345
18-18.1	400		1.8		350
18-17.1	400	1.8			310
18-16.1	400			1.8	300
18-15.1	400		1.8		300
18-14.1	400	1.8			200
18-HM1.1(1)	400	1.8			100
18-HM1.1(2)	400		1.8		100
18-HM1.1(3)	400			1.8	100
18-HM1.1					20
JB 18-D					310
18-25.1	400	1.8			305
18-24.1	400		1.8		300
18-23.1	400			1.8	310
18-22.1	400	1.8			300
18-21.1	400		1.8		300
18-20.1	400			1.8	100
JB 18-A					20
CC-18					20

CIRCUITS 3,5,7	A-7	B-3	C-5	
TOTAL AMPS	9	9	9	
OVERALL TOTAL	27			
AVE CURRENT IN THREE PHASES	9.00			
DEVIATION FROM AVE.	0.00	0.00	0.00	
MAX DEVIATION FROM AVERAGE	0.00			
PHASE IMBALANCE	0.000			
% IMBALANCE	0.00			

CONTROL CENTER 18 SUMMARY

CONTROL CENTER ONE	**A**	**B**	**C**	
TOTAL *	16.90	16.20	16.20	
AVERAGE CURRENT	16.43			
DEVIATION FROM AVE.	0.47	0.23	0.23	
% IMBALANCE	2.84			

* PHASE A HAS .7 AMPS ADDED TO ACCOUNT FOR THE PHOTOCELL

Table 3: Wire Size Program

Number of Branches				3					
Line voltage				277 VAC					
Maximum allowable voltage drop				3%					
Circuit A-2		Branch #1	Load (Amps)	Distance	**Circuit A-7**		Branch #1	Load (Amps)	Distance
	1	18-6.1	1.8	920		1	18-17.1	1.8	910
	2	18-3.1	1.8	645		2	18-14.1	1.8	200
		Branch #2	Load (Amps)				Branch #2	Load (Amps)	
	1	18-11.1	1.8	910		1	18-HM1.1(1)	1.8	410
	2	18-8.1	1.8	265		2	18-25.1	1.8	915
						3	18-22.1	1.8	700
		Branch #3	Load (Amps)						
	1		7.2	220			Branch #3	Load (Amps)	
	Required wire size:		**#4 AWG**			1		9	20
						Required wire size:		**#6 AWG**	
Circuit B-4		Branch #1	Load (Amps)	Distance	**Circuit B-3**		Branch #1	Load (Amps)	Distance
	1	18-4.1	1.8	915		1	18-18.1	1.8	960
	2	18-1.1	1.8	40		2	18-15.1	1.8	500
		Branch #2	Load (Amps)				Branch #2	Load (Amps)	
	1	18-13.1	1.8	870		1	18-HM1.1(2)	1.8	715
	2	18-10.1	1.8	865		2	18-24.1	1.8	910
						3	18-21.1	1.8	400
		Branch #3	Load (Amps)						
	1		7.2	220			Branch #3	Load (Amps)	
	Required wire size:		**#4 AWG**			1		9	20
						Required wire size:		**#8 AWG**	
Circuit C-6		Branch #1	Load (Amps)	Distance	**Circuit C-5**		Branch #1	Load (Amps)	Distance
	1	18-5.1	1.8	905		1	18-19.1	1.8	1005
	2	18-2.1	1.8	340		2	18-16.1	1.8	800
							Branch #2	Load (Amps)	
		Branch #2	Load (Amps)			1	18-HM1.1(3)	1.8	1015
	1	18-12.1	1.8	920		2	18-23.1	1.8	910
	2	18-9.1	1.8	565		3	18-20.1	1.8	100
		Branch #3	Load (Amps)				Branch #3	Load (Amps)	
	1		7.2	220		1		9	20
	Required wire size:		**#4 AWG**			**Required wire size:**		**#6 AWG**	

SIZING THE CONDUIT

Conduit size is based on the NEC 40% fill rule. That is, the conduit fill should not exceed 40% of the conduit cross-sectional area. The design engineer must include the electrical grounding conductor (EGC) in sizing the conduit. The electrical grounding conductor should be the same size as the largest phase/power conductor in the conduit run.

For example:

A wire run consisting of three, #00 AWG phase wires and a #00 neutral wire, plus three, #2 phase wires and a #2 neutral wire, plus a #00 ground wire. The cross-sectional area of all these wires is 1.5748 in^2. The cross-sectional area of 2" PVC schedule-40 conduit is 3.291 in^2. The maximum cable fill in this conduit is $3.291 in^2 \times 40\% = 1.3164 in^2$. In order to carry these cables, the design engineer should specify at least a 3" conduit (40% fill: 2.9072 in^2).

SIZING THE JUNCTION BOXES

NEC Section 314, 2002, provides guidelines for determining the size of a junction box**.** The following notes are helpful to the lighting designer:

The size requirement for a junction box is based on one of two methods depending on the size of wire entering the box:

1. **Volume requirements**: For junction boxes servicing wire sizes #6 or smaller, the size is based on the volume requirements of the conductors. The following example is typical of a roadway lighting junction box calculation:

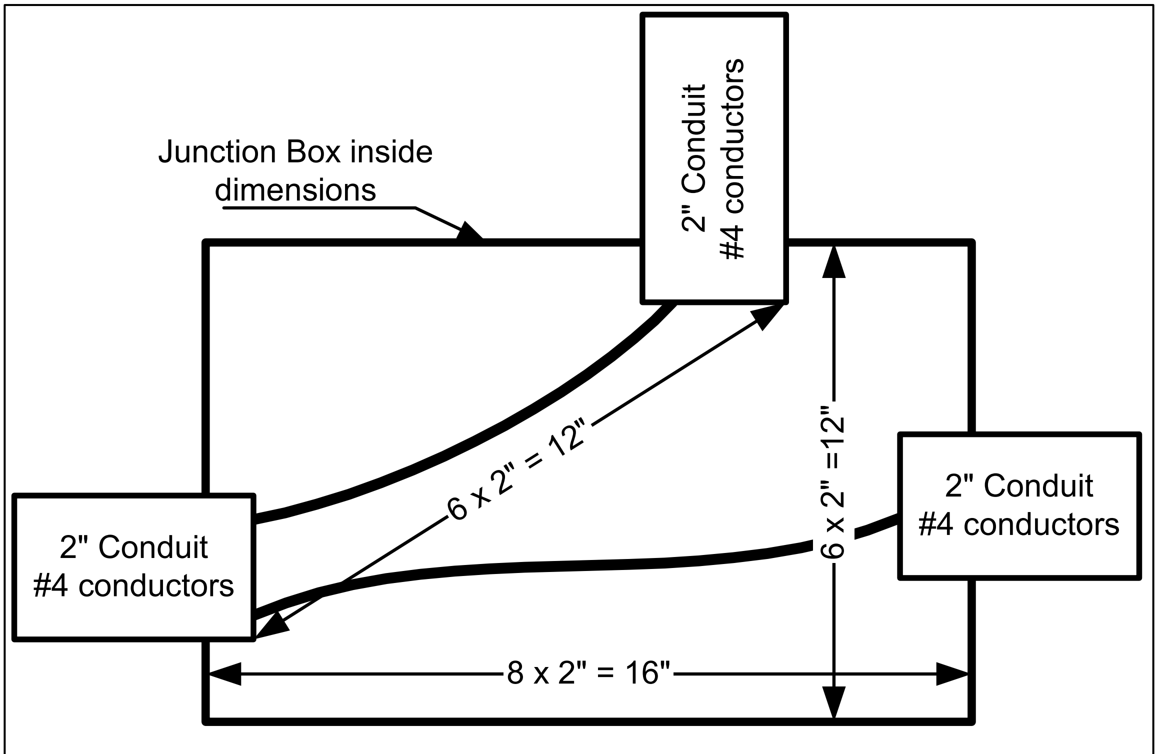
   A junction box serves as a conduit splice point in a "T" configuration: A single, 2" conduit containing 9#8 conductors enters the junction box (4#8 [Ckt 3,5,7 & N], 4#8 [Ckt 2,4,6 & N], 1#8 Ground). Exiting the junction box are two, 2" conduits, each containing 5#8 conductors. Assume that all conductors entering and exiting the box are spliced in the box; that is, there are no straight pulls. The total number of #8 conductors entering and leaving the box is 19. The required free space within the box is 3-in^3 per #8 conductor, 19 x 3-in^3 = 56-in^3. The internal volume of a VDOT Standard JB-1C is 2,600-in^3, more than sufficient for this example.

2. **Conduit entrance size**: For junction boxes servicing wire sizes #4 or larger, the junction box size is based on the size of the conduits entering and leaving the box, and if the box serves as a straight pull, "T", or "U"-Turnaround.

   Straight-pull junction boxes require a minimum **length** of 8 times the size of the conduits. However, for a junction box forming a "T" junction, this situation also requires a junction box **length and width** of 6 times the size of the conduit and the distance between the conduit entrance holes of 6 times the conduit size.

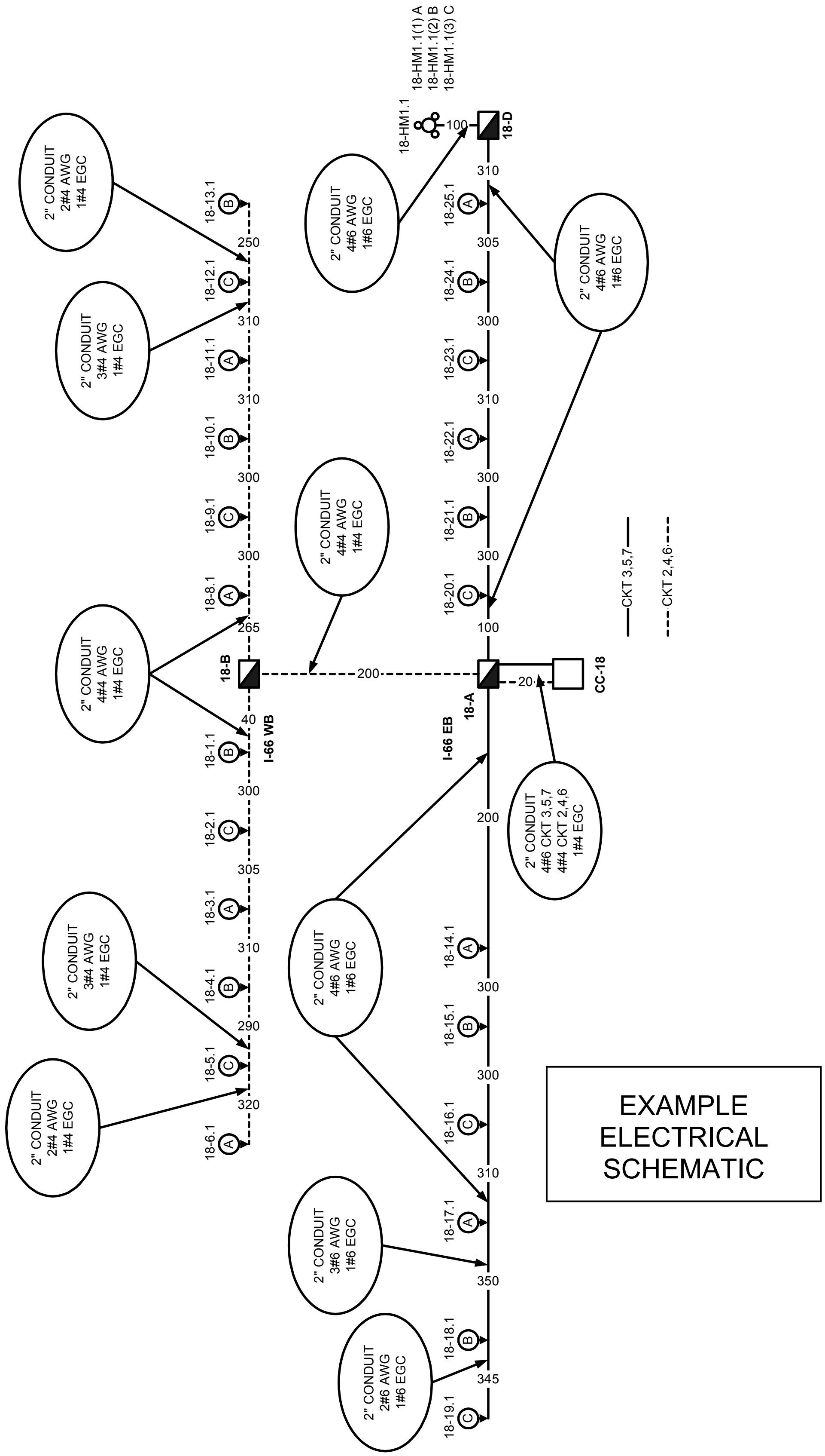
For example (see example Junction Box below):
Three, 2” conduits with #4 AWG conductor cables enter from three different sides of the box. The minimum junction box dimensions require the straight pull **length** to be 8 x the size of the conduit. The minimum **width** is based on the size of the conduits forming the “T” or “U” and must be 6 times the size of the conduit. The box must also be sized to allow for the direct line distance between conduits forming the “T” or “U” to be 6 times the size of the conduits. The figure below shows that a VDOT standard JB-2C (12” x 18”) will work for this example with room to spare.

The lighting designer should recognize that the NEC requirements are minimum standards. Situations may arise where larger boxes may be necessary to allow the contractor and VDOT maintenance personnel sufficient room to make splices.



Junction Box Example

Minimum Dimensions


EXAMPLE ELECTRICAL SCHEMATIC
I-66 WB
I-66 EB
18-A
18-B
18-D
CC-18
18-HM1.1
18-HM1.1(1) A
18-HM1.1(2) B
18-HM1.1(3) C
CKT 3,5,7
CKT 2,4,6
2" CONDUIT 2#4 AWG 1#4 EGC
2" CONDUIT 3#4 AWG 1#4 EGC
2" CONDUIT 4#4 AWG 1#4 EGC
2" CONDUIT 4#6 AWG 1#6 EGC
2" CONDUIT 3#6 AWG 1#6 EGC
2" CONDUIT 2#6 AWG 1#6 EGC
2" CONDUIT 4#6 CKT 3,5,7 4#4 CKT 2,4,6 1#4 EGC