Electrical Depth

Introduction

As a result of the proposed lighting system as illustrated in my Lighting Depth, the existing electrical system had to be adjusted to cater for the change in electrical load. The following is an outline of my electrical depth work that illustrates how this process was achieved. If necessary, circuit breakers and feeders were resized to cater for the change in demand.

In addition to this process, a study was done to see the cost benefit of replacing existing transformers for ones that are energy efficient. Also, a second study was done to see how feasible it would be to implement a photo voltaic array (PV) system on the roof of this building.

In all scenarios, electrical redesign was done such that it satisfies with the NEC (2005).

Existing System Overview

The current electrical system for this building utilizes a 12.47 KV incoming service that is distributed to the different loads in the building via a series of 480/277V and 208/120V transformers. The main 480/277V transformer directs power to the main switchboard which houses 14 switches, 3 of which distribute power to separate 208Y/120V distribution boards. An additional switch also provides power to the emergency distribution board and the remaining providing power directly to a proportion of the panelboards in the building. Also located on-site is a 250KW 408/277V diesel emergency generator which provides power to the emergency distribution board in the event that the main transformer experiences technical difficulties.

An emergency power system has also been put in place. In the event of failure, a 4-pole 150A automatic transfer switch changes location allowing an on-site 250KW 480Y/277V standby diesel generator to provide power. It will supply power to an emergency distribution board (EDB) which will maintain emergency life safety systems such as emergency lighting and mechanical equipment. The EDB has five 3-pole molded case circuit breakers all sized at 100A, one of which is a spare.

Note: *Please refer to Appendix E for a riser diagram of the existing system.*

Lighting Control Intent

The flexibility of the Lutron Grafik Eye 4000 makes it suitable for use in this type of building application, especially since there are interior spaces where multiple lighting scenes are desired. For example, the Multipurpose room is a space where multiple scenes are desired to cater for different types of events that may happen there.

Each Grafik Eye control unit is capable of controlling up to 24 different lighting zones as well as 16 different scene presets hence providing a very flexible system that will cater for the different lighting loads in this building. The system is also capable of connecting 8 control units together to control up 64 different lighting zones. As such, the Graphik Eye system has the potential to control the lighting in this entire building.

As LEDs and low-voltage lighting fixtures have been implemented in the redesign, low-voltage transformers shall be installed as well to distribute the needed power to them.

The following schedule shows the lighting control devices that have been implemented as well as the dimming panel schedule along with the associated lighting zones for the new system:

Note: *Please consult Appendix B for all product cutsheets.*

Lighting Controls Schedule
Location: UCSB Student Resource Building

Label	Manf. + Catalog No.	Description	Mounting	Remarks
S-A	"Lutron EcoSystem" C-SR-M1-WH	Closed loop daylight sensor	Ceiling	-
S-B	"Lutron EcoSystem" LOS-CDT-2000R-WH	360° Dual technology occupancy sensor. 24V DC	Ceiling	-
S-C	"Lutron" Grafik Eye 4000: GRX 45XX-T-WH	"XX" zone multiple scene series control unit (XX = 2-24)	Wall	"XX" - # of zones per space usage. (Consult lighting circuit and power plans) Assoc. w/ S-1
S-D	"Lutron" Nova T: NTFV	LED low voltage dimming control	Forum Counter	IO lighting recommended control interface. (use with F9)
S-1	"Lutron" GP Dimming Panel: GP24-2774M125-20	277 V Dimming Panel	Wall	Assoc. w/ S-C

LOCATION: ELEC. 1214 DIMMING PANEL "DPL1B" LOAD SCHEDULE
MOUNTING: SURFACE 20A MAIN C/B 277/480V, 3PH, 4W FED FROM "H1B"

CIRCUIT	ZONE	DESCRIPTION	VOLT	AMP	LOAD TYPE	LOAD VA
1	–	SPARES	277	20	–	–
2	–	KITCHEN, STORAGE [3]	277	20	FLUOR.	400
3	3	MULTIPURPOSE – CENTER	277	20	FLUOR.	1060
4	4	MULTIPURPOSE – ENTRY [3]	277	20	FLUOR.	100

(FEEDER: 1"C, 4 #8 AND 1 #10 GND.)

Original Dimming Panel Schedule

Dimming Panel "S-1" Load Schedule
Location: Elec. 1214
Mounting: Surface **50A M C/B** **277/480V, 3P, 4W** **Fed from "H1B"**

Circuit	Zone	Description	Volt	Amp	Load Type	Load VA
1	-	Spare	277	20	-	-
2	-	Kitchen, Storage	277	20	Fluor.	400
3	A	Mutilipurpose Rm. Linear Fixtures.	277	20	Fluor.	1112
4	B	Mutilipurpose Rm. LED Panels.	277	20	LED	133
5	C	Mutilipurpose Rm. Adjustable Accents.	277	20	Incand.	426
6	D	Mutilipurpose Rm. Adjustable Accents.	277	20	Incand.	284
7	E	SRC. 1219 Linear Fixtures.	277	20	Fluor.	417
8	F	SRC. 1219 Adjustable Accents.	277	20	Incand.	105
9	G	Forum: Counter Task Lighting	277	20	LED	135
10	H	Forum Linear Poles.	277	20	MH.	1923
11	I	Forum Counter: LED Panels	277	20	LED	84
12	J	Forum Linear Fluorescents.	277	20	Fluor.	264
13	K	Forum LED Railing Lights.	277	20	LED	1416
14	L	Forum Wall LED Panels.	277	20	LED	60
15	M	Forum LED Ceiling Lights.	277	20	LED	1100
16	N	North East Plaza Linear Poles.	277	20	MH.	692
17	O	North East Plaza In-grade uplights.	277	20	LED	75
18	P	North East Plaza Decorative Wall Scones	277	20	Fluor.	221
19	-	Spare	277	20	-	-
20	-	Spare	277	20	-	-
21	-	Spare	277	20	-	-
22	-	Spare	277	20	-	-
23	-	Spare	277	20	-	-
24	-	Spare	277	20	-	-

Total VA: 8847

New Dimming Panel Schedule

New Feeder Size: 4 - #8 THW – ¾” C and 1 #10 G

Notes

1. Calculations per NEC 2005: Tables 310-16, C8.

2. Only copper wires specified

3. Overcurrent protection devices oversized to allow for future growth.

S-1 Feeder Voltage Drop Calculation

8.847 KVA **/** √3 x 0.480 = 10.6 A

Steel Conduit (magnetic), #8 THW

p.f.	= 0.90
Length (L)	= 107 ft
*V_{drop}	= 0.699
Feeder Current (I_L)	= 10.6 A

Amp-feet	= I_L x L = 10.6 x 107 = 1138.48 = 1.138 x 1000 amp-ft
V_{drop} (l-n)	= 1.138 x 1.749 = 1.99 V
V_{drop} (l-l)	= √3 x 1.99 = 3.45 V

% Voltage Drop = 3.45 V / 480 V x 100% = **0.72% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*

North East Plaza

In an exterior environment, Title 24 requires that an astronomical time switch be implemented into the lighting system to allow for appropriate moderation of artificial light during the day. Fixtures located here shall be grouped by type and be controlled directly from the dimmer panel.

Branch Lighting Circuit Capacity Calculations

The following is a summary of the different loads in each zone. Please refer to the proceeding circuit and power plan for reference.

Zone	Fixtures	Loads
N	(4) E1	4 x 173 W/fixture = 692 W 692 W/1.00 = 692.0 VA (PF = 0.90) 692 VA / 277 V = 2.50 A
		Wire Size: 2-#12 THW · **Breaker Size:** 20A/ 1P · **Conduit Size:** ¾” C
O	(15) E2	15 x 5 W/fixture = 75 W 75 W/ 1.00 = 75.0 VA (PF = 1.00) 75.0 VA / 277 V = 0.27 A
		Wire Size: 2-#12 THW · **Breaker Size:** 20A/ 1P · **Conduit Size:** ¾” C
P	(4) E3	4 x 54 W/fixture = 216 W 216 W/ 0.98 = 220.4 VA (PF = 0.98) 220.4 VA / 277 V = 0.80 A
		Wire Size: 2-#12 THW · **Breaker Size:** 20A/ 1P · **Conduit Size:** ¾” C

20 A x 277 V x 0.8 (code limit) x 0.8 (contingency) = 3545.6 VA max per circuit

Therefore, **all designated zones satisfy this requirement**.

Branch Circuit Voltage Drop Calculation

Steel Conduit (magnetic), #12 THW,

p.f.	= 0.90
Length (L)	= 253 ft
*V_{drop}	= 1.749
Branch Current (I_L)	= 2.50 A
Single-Phase Circuit	= x2.0 factor

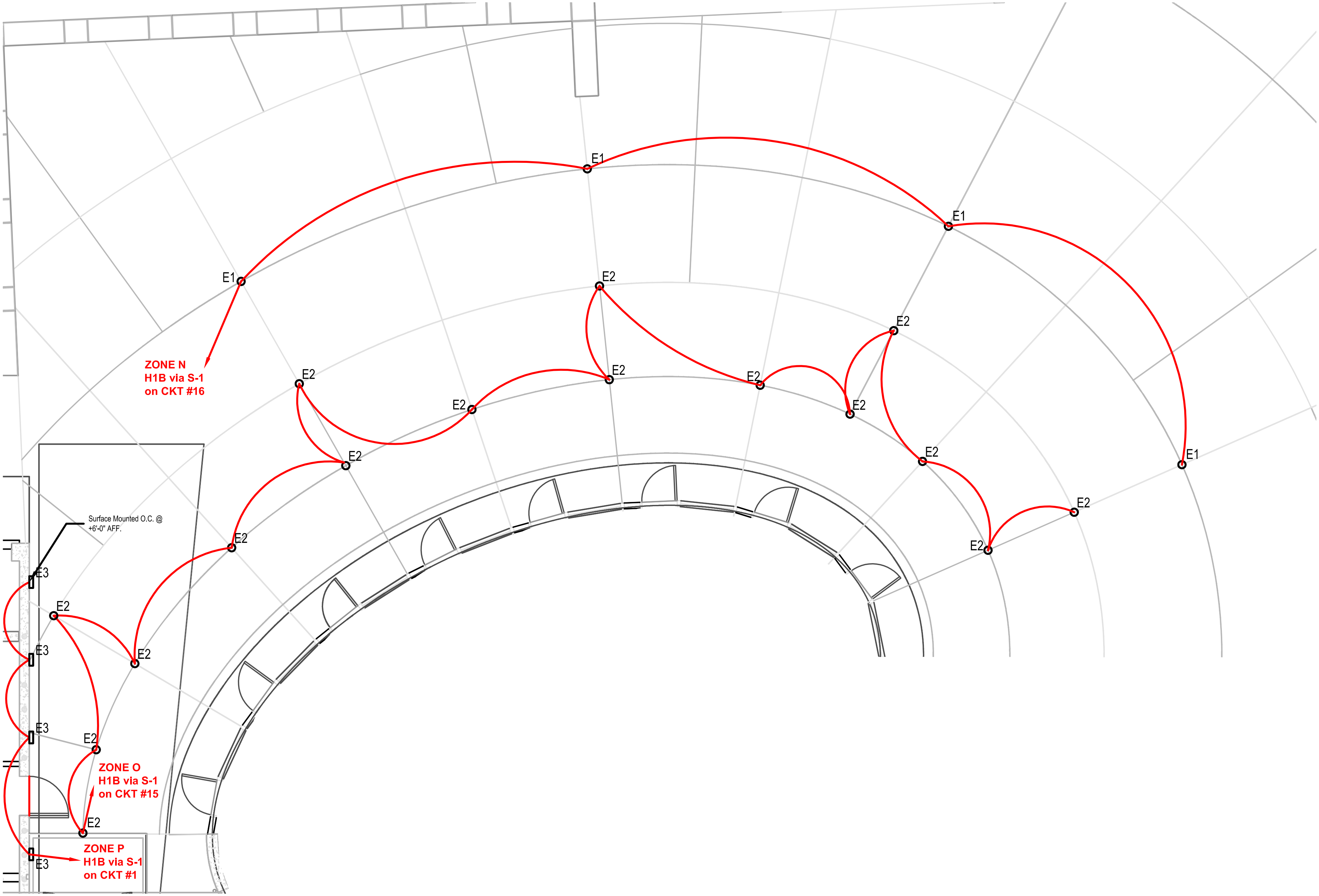
Amp-feet = I_L x L = 2.50 x 253 = 632.50 = 0.6325 x 1000 amp-ft

V_{drop} (l-n) = 0.6325 x 1.749 = 1.11 V
= 1.11 x 2 = 2.22 V

V_{drop} (l-l) = √3 x 1.11 = 1.92 V
= 1.92 x 2 = 3.83 V

% Voltage Drop = 3.83 V / 480 V x 100% = **0.80% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*



UCSB Student Resource Building

NE Plaza - Power and Circuit Plan

Scale: $\frac{3}{32}$" - 1'-0"

Panelboard Schedules Comparison

The following compares the original panelboard schedules with the new that has been changed to accommodate the new lighting installation in the North East Plaza. It is important to note at this point that most of the original lighting installation that has been connected via dimming panel "DPL1B" which was a small version of the Graphik Eye dimming panel. To accommodate for the increased in lighting load along with the new lighting in the four spaces that will be discussed, a bigger Graphik Eye dimming panel was specified as a replacement.

Besides a recalculation of the loads on the associated panel board, H1B, parts of the original lighting installation were connected via an inverter, and as such the change in load on this device had to be recalculated as well to reflect the system change. These are shown below.

PANEL H1B 277/480 VOLT, 3PH, 4W 225 AMP COPPER BUS

LOCATION: Elect. Rm. 1110 MAIN C.B: 150 AMPS

MOUNTING: Surface LOAD: 37 AMP 30 KVA

CK	LOAD (VA)			LOAD DESCRIPTION	OUTLETS			C.B.		BUS	C.B.		OUTLETS			LOAD DESCRIPTION	LOAD (VA)			CK
#	LINE A	LINE B	LINE C			RC	LT	P	TRP	ABC	TRP	P	LT	RC			LINE A	LINE B	LINE C	#
1	2316			SRC 1108,1109 +			14	1	20	A	20	1	2			North Site Lights +	200			2
3		2722		SRC 1106,1107 +			14	1	20	B	20	1	5			South Site Lights +		585		4
5			3108	SRC 1104,1105 +			18	1	20	C	20	1	5			North Site Lights (Alt. #5) +			490	6
7	336			Student Conf. 1103 +			4	1	20	A	20	1	2			East Site Lights (Alt. #6) +	235			8
9		0		Spare				1	20	B	20	1				Spare		0		10
11			0	Spare				1	20	C	20	1				Spare			0	12
13	0			Spare				1	20	A	20	1				Spare	0			14
15		0		Spare				1	20	B	20	1				Spare		0		16
17			0	Spare				1	20	C	20	1				Spare			0	18
19	0			Spare				1	20	A	20	1				Spare	0			20
21		0		Spare				1	20	B	20	1				Spare		0		22
23			0	Spare				1	20	C	20	1				Spare			0	24
25	0			Spare				1	20	A	20	1				Spare	0			26
27		0		Spare				1	20	B	20	1				Spare		0		28
29			0	Spare				1	20	C	20	1				Spare			0	30
31	0			Spare				1	20	A	20	1				Spare	0			32
33		0		Spare				1	20	B	20	1				Spare		0		34
35			0	Spare				1	20	C	20	1				Spare			0	36
37	790			Dimming Panel "DPL1B"	1			–	20	A	100	–			1	Panel H2B	5696			38
39		790		w/ Ckt. 37	–			–	–	B	–	–			–	w/ Ckt. 38		5446		40
41			790	w/ Ckt. 37	–			3	–	C	–	3			–	w/ Ckt. 38			4446	42
	3442	3512	3898	SUBTOTALS												SUBTOTALS:	6131	6031	4936	
																LINE TOTALS:	9573	9543	8834	
																LCL ADDER:	771.8	826.8	899.5	
																TOTAL VA/PHASE:	10345	10370	9734	
																LINE AMPS:	37	37	35	

NOTES:
\+ Via Lighting Control Panel/System

Original Panelboard "H1B" Schedule

PANELBOARD SCHEDULE												
VOLTAGE: 480Y/277V,3PH,4W SIZE/TYPE BUS: 100A SIZE/TYPE MAIN: 100A/3P C/B				PANEL TAG: H1B PANEL LOCATION: Elec. Rm 1110 PANEL MOUNTING: SURFACE						MIN. C/B AIC: 14K OPTIONS:		
DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	SRC	2316	20A/1P	1	*			2	-	0	0	0
Lighting	SRC	2722	20A/1P	3		*		4	20A/1P	585	S. Site	Lighting
Lighting	SRC	3108	20A/1P	5			*	6	-	0	0	0
Lighting	Stu. Conf.	336	20A/1P	7	*			8	20A/1P	235	E. Site	Lighting
0	0	0	-	9		*		10	-	0	0	0
0	0	0	-	11			*	12	-	0	0	0
0	0	0	-	13	*			14	-	0	0	0
0	0	0	-	15		*		16	-	0	0	0
0	0	0	-	17			*	18	-	0	0	0
0	0	0	-	19	*			20	-	0	0	0
0	0	0	-	21		*		22	-	0	0	0
0	0	0	-	23			*	24	-	0	0	0
0	0	0	-	25	*			26	-	0	0	0
0	0	0	-	27		*		28	-	0	0	0
0	0	0	-	29			*	30	-	0	0	0
0	0	0	-	31	*			32	-	0	0	0
0	0	0	-	33		*		34	-	0	0	0
0	0	0	-	35			*	36	-	0	0	0
Dim. Panel S-1	Elec. Rm.	2949	50A/3P	37	*			38	100A/ 3P	5696	Elec. Rm.	Panel H2B
w/ ckt 37	-	2949	-	39		*		40	-	5446	-	w/ ckt 38
w/ ckt 37	-	2949	-	41			*	42	-	4446	-	w/ ckt 38
CONNECTED LOAD (KW) - A		11.53								TOTAL DESIGN LOAD (KW)		45.93
CONNECTED LOAD (KW) - B		11.70								POWER FACTOR		1.00
CONNECTED LOAD (KW) - C		10.50								TOTAL DESIGN LOAD (AMPS)		55

New Panelboard "H1B" Schedule

New Feeder Size: 4 - #3 THW – 1¼" C and 1 #8 G

Notes:

1. Calculations per NEC 2005: Tables 310-16, C8.

2. Only copper wires specified.

3. NEC 80% current-carrying capacity included.

H1B : **Eaton Cutler-Hammer, PRL2a, Pow-R-Line C Panelboards**

480Y/277 V AC

Price: 1,344 USD

LIGHTING AND APPLIANCE PANELBOARD SIZING WORKSHEET

Panel Tag------------------------->					H1B	Panel Location:			Elec. Rm 1110		
Nominal Phase to Neutral Voltage------->					277	Phase:			3		
Nominal Phase to Phase Voltage-------->					480	Wires:			4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	Lighting	1	SRC	2316	VA	1.00	2316	2316		
2	A					VA	1.00	0	0		
3	B	Lighting	1	SRC	2722	VA	1.00	2722	2722		
4	B	Lighting	1	S. Site	585	VA	1.00	585	585		
5	C	Lighting	1	SRC	3108	VA	1.00	3108	3108		
6	C					VA	1.00	0	0		
7	A	Lighting	1	Stu. Conf.	336	VA	1.00	336	336		
8	A	Lighting	1	E. Site	235	VA	1.00	235	235		
9	B					VA	1.00	0	0		
10	B					VA	1.00	0	0		
11	C					VA	1.00	0	0		
12	C					VA	1.00	0	0		
13	A					W	0.95	0	0		
14	A					W	1.00	0	0		
15	B					W	1.00	0	0		
16	B					W	1.00	0	0		
17	C					VA	1.00	0	0		
18	C					VA	1.00	0	0		
19	A					VA	1.00	0	0		
20	A					VA	1.00	0	0		
21	B					VA	1.00	0	0		
22	B					VA	1.00	0	0		
23	C					VA	1.00	0	0		
24	C					VA	1.00	0	0		
25	A					VA	1.00	0	0		
26	A					VA	1.00	0	0		
27	B					VA	1.00	0	0		
28	B					VA	1.00	0	0		
29	C					VA	1.00	0	0		
30	C					VA	1.00	0	0		
31	A					VA	1.00	0	0		
32	A					VA	1.00	0	0		
33	B					VA	1.00	0	0		
34	B					VA	1.00	0	0		
35	C					VA	1.00	0	0		
36	C					VA	1.00	0	0		
37	A	Dim. Panel S-1	3	Elec. Rm.	2949	VA	1.00	2949	2949		
38	A	Panel H2B	2	Elec. Rm.	5696	VA	1.00	5696	5696		
39	B	w/ ckt 37	3	-	2949	VA	1.00	2949	2949		
40	B	w/ ckt 38	2	-	5446	VA	1.00	5446	5446		
41	C	w/ ckt 37	3	-	2949	VA	1.00	2949	2949		
42	C	w/ ckt 38	2	-	4446	VA	1.00	4446	4446		
PANEL TOTAL								33.7	33.7	Amps=	40.6
PHASE LOADING								kW	kVA	%	Amps
PHASE TOTAL			A					11.5	11.5	34%	41.6
PHASE TOTAL			B					11.7	11.7	35%	42.2
PHASE TOTAL			C					10.5	10.5	31%	37.9
LOAD CATAGORIES				Connected			Demand				Ver. 1.01
				kW	kVA	DF	kW	kVA	PF		
1		Lighting		9.3	9.3	1.25	11.6	11.6	1.00		
2		Panel H2B		15.6	15.6	1.00	15.6	15.6	1.00		
3		Dim. Panel S-1		8.8	8.8	1.25	11.1	11.1	1.00		
4				0.0	0.0	1.00	0.0	0.0			
5				0.0	0.0	1.00	0.0	0.0			
6				0.0	0.0	1.00	0.0	0.0			
7				0.0	0.0	1.00	0.0	0.0			
8				0.0	0.0	1.00	0.0	0.0			
Total Demand Loads							38.3	38.3			
Spare Capacity				20%			7.7	7.7			
Total Design Loads							45.9	45.9	1.00	Amps=	55.3

H1B - Feeder Voltage Drop Calculation

45.9 KVA **/** √3 x 0.480 = 55.2 A

Steel Conduit (magnetic), #3 THW

p.f.	= 0.90
Length (L)	= 116 ft
*V_{drop}	= 0.196
Feeder Current (I_L)	= 55.2 A

Amp-feet	= I_L x L = 55.2 x 116 = 6404.25 = 6.404 x 1000 amp-ft
V_{drop} (l-n)	= 6.404 x 0.196 = 1.26 V
V_{drop} (l-l)	= √3 x 1.26 = 2.17 V

% Voltage Drop = 2.17 V / 480 V x 100% = **0.45% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*

INVERTER INV/H1B
LOCATION: Elec 1110 (277V, 1PH, 3W)
MOUNTING: Surface LOAD: 17 AMP 5 KVA

CK #	LOAD(VA) LINE	LOAD DESCRIPTION		OUTLETS RC	LT	C.B. P	TRP
1	370	West Entry Emerg. (Lvl 3) +			1	1	20
2					5	1	20
3	370	Main Forum (Lvl 3) +			1	1	20
4	170	Main Forum (Lvl 3) +			2	1	20
5	595	Student Resource Centers (Lvl 1) +			7	1	20
6	80	South Entry (Lvl 1) +			1	1	20
7	255	East Roof Terrace (Lvl 3) +			3	1	20
8	400	North Site Lights +			4	1	20
9	700	South Site Lights +			6	1	20
10	375	North Site Lights (Alt. #5) +			4	1	20
11	350	East Site Lights (Alt. #6) +			3	1	20
12	0	Spare				1	20
13	0	Spare				1	20
14						1	20
	3665	SUBTOTALS					
	3665	LINE TOTALS					
	916.25	LCL ADDER					
	4581.25	TOTAL VA/PHASE					
	17	LINE AMPS					

NOTES:
+ Via lighting control panel/system.
Refer to E6.* drawings for control system details.

Original Inverter Schedule

Inverter INV/H1B
Location: Elec. 1110
Mounting: Surface **277/480V, 1PH, 3W**

Circuit	Load	Description	LC Outlets	Poles	CB Trip
1	370	West Entry Emerg. (lvl 3)	1	1	20
2	-	Spares	-	1	20
3	-	Spares	-	1	20
4	-	Spares	-	1	20
5	595	Student Resource Centers (lvl 1)	7	1	20
6	80	South Entry (lvl 1)	1	1	20
7	255	East Roof Terrace (lvl 3)	3	1	20
8	-	Spares	-	1	20
9	700	South Site Lights	6	1	20
10	-	Spares	-	1	20
11	350	East Sight Lights (Alt. #6)	3	1	20
12	-	Spares	-	1	20
13	-	Spares	-	1	20
14	-	Spares	-	1	20
	2350	**Subtotal (VA)**			
	2350	**Line Totals (VA)**	**Load:**	12 A	
	916.25	**LCL Adder (VA)**		4 KVA	
	3266.25	**Total VA/ Phase**			
	12	**Line Amps**			

New Inverter Schedule

Forum

Out of all four redesigned spaces, the new lighting installation here uses the most power. A variety of different fixtures have been put in place to create the necessary ambience in this space. Like the fixtures in the other spaces, those of the same type have been put on the same zone via the Graphik Eye dimming panel "S-1". A localized dimmer control has been put in place to allow the user to adjust the level of task lighting required at the information desk. The following discussion summarizes the electrical load associated with the new design in this space.

Branch Lighting Circuit Capacity Calculations

The following is a summary of the different loads in each zone. Please refer to the proceeding circuit and power plan for reference.

Zone	Fixtures	Loads		
G	(9) F9	9 x 15 W/fixture = 135 W		
		135 W/ 1.00 = 135 VA (PF = 1.00)		
		135 VA / 277 V = 0.49 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
H	(10) F5	10 x 173 W/fixture = 1730 W		
		1730 W/ 0.90 = 1922.2 VA (PF = 0.90)		
		1922.2 VA / 277 V = 6.93 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
I	(84) F1	84 x 1 W/fixture = 84 W		
		84 W/1.00 = 84 VA (PF = 1.00)		
		84 VA / 277 V = 0.30 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C

J	(8) F7	8 x 33 W/fixture = 264 W 264 W/ 1.00 = 264 VA (PF = 1.00) 264 VA / 277 V = 0.96 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
K	(177) F6	177 x 8 W/fixture = 1416 W 1416 W/ 1.00 = 1416 VA (PF = 1.00) 1416 VA / 277 V = 5.11 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
L	(60) F1	60 x 1 W/fixture = 60 W 60 W/ 1.00 = 60 VA (PF = 1.00) 60 VA / 277 V = 0.22 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
M	(22) F2	22 x 50 W/fixture = 1100 W 1100 W/ 1.00 = 1100 VA (PF = 1.00) 1100 VA / 277 V =3.97 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C

20 A x 277 V x 0.8 (code limit) x 0.8 (contingency) = 3545.6 VA max per circuit

Therefore, **all designated zones satisfy this requirement**.

Branch Circuit Voltage Drop Calculation

Steel Conduit (magnetic), #12 THW,

p.f.	= 0.90
Length (L)	= 333 ft
*V_{drop}	= 1.749
Branch Current (I_L)	= 5.11 A
Single-Phase Circuit	= x2.0 factor

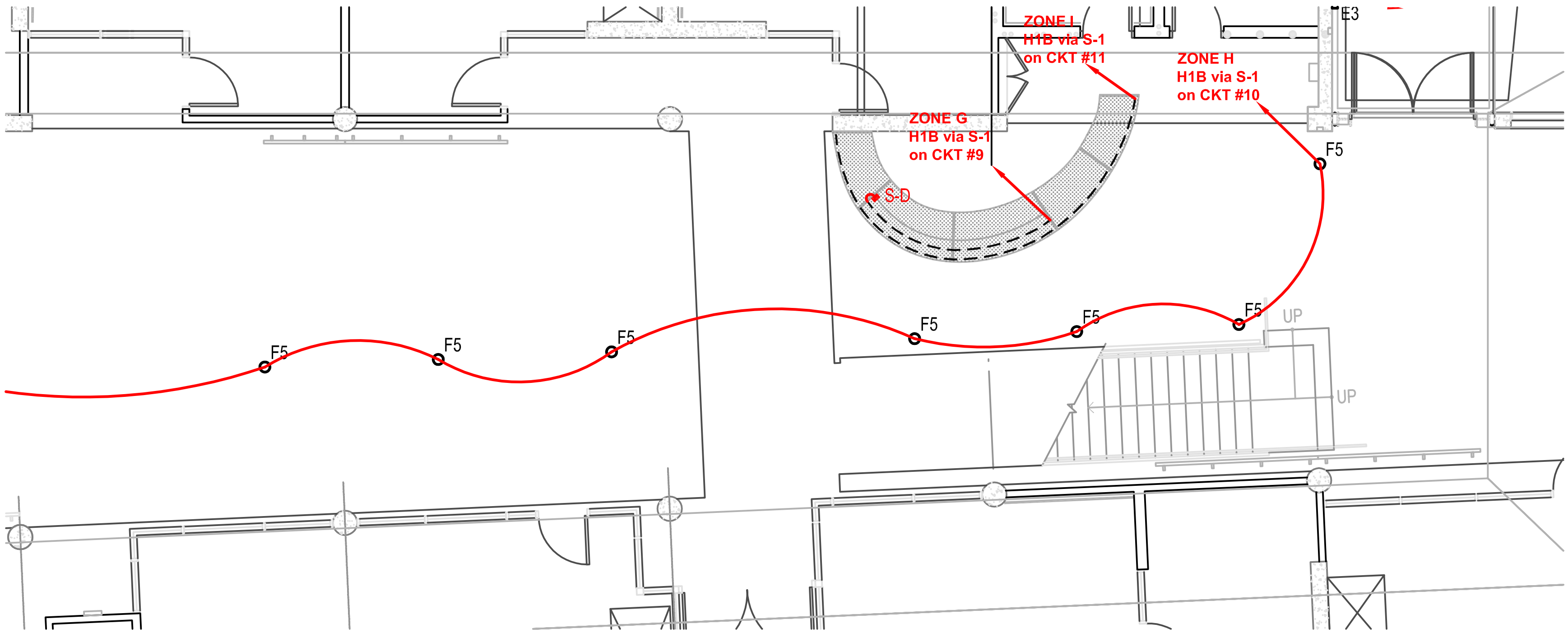
Amp-feet = I_L x L = 5.11 x 333 = 1701.63 = 1.701 x 1000 amp-ft

V_{drop} (l-n) = 1.701 x 1.749 = 2.97 V
= 2.97 x 2 = 5.95 V

V_{drop} (l-l) = $\sqrt{3}$ x 2.97 = 5.15 V
= 5.15 x 2 = 10.31 V

% Voltage Drop = 10.31 V / 480 V x 100% = **2.15% < 3% (NEC 2005 Recommendation)**

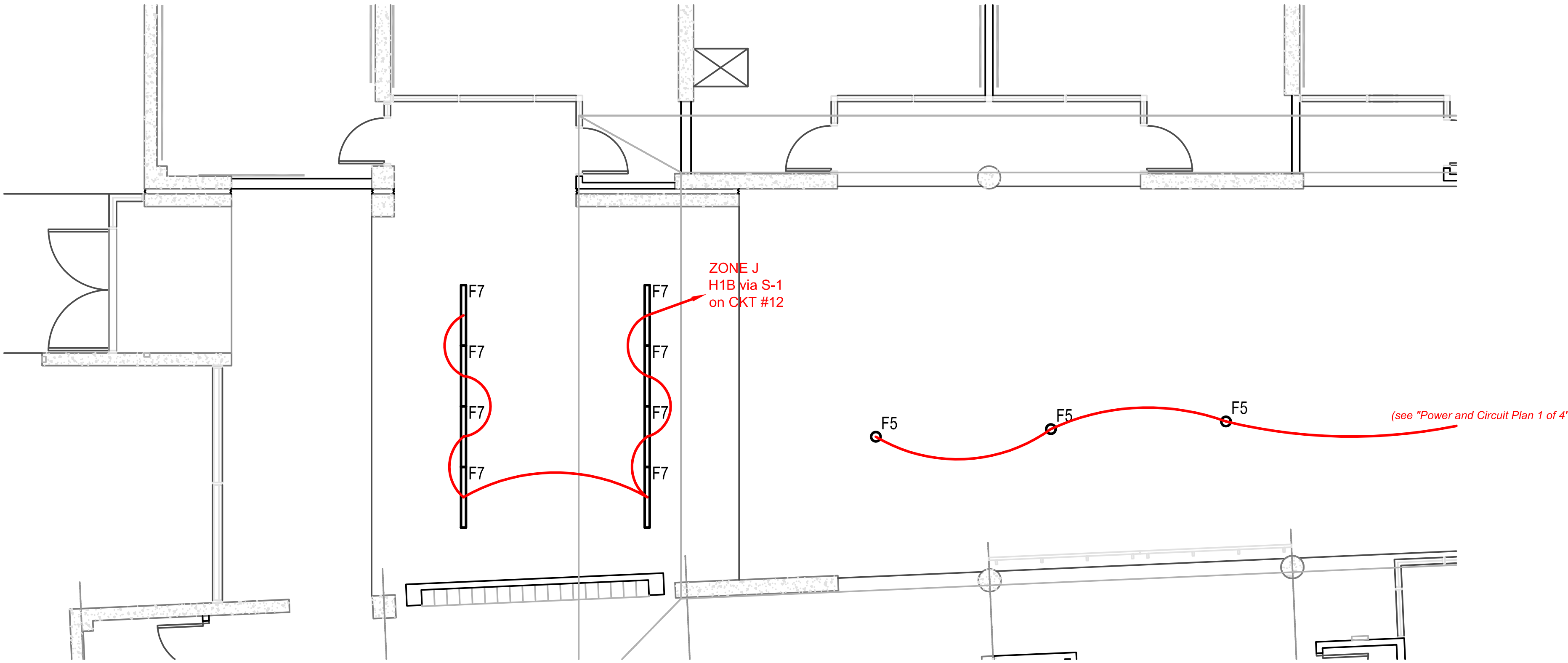
Note: ** Value per 1000 ampere-feet for three single conductors in conduit*



UCSB Student Resource Building

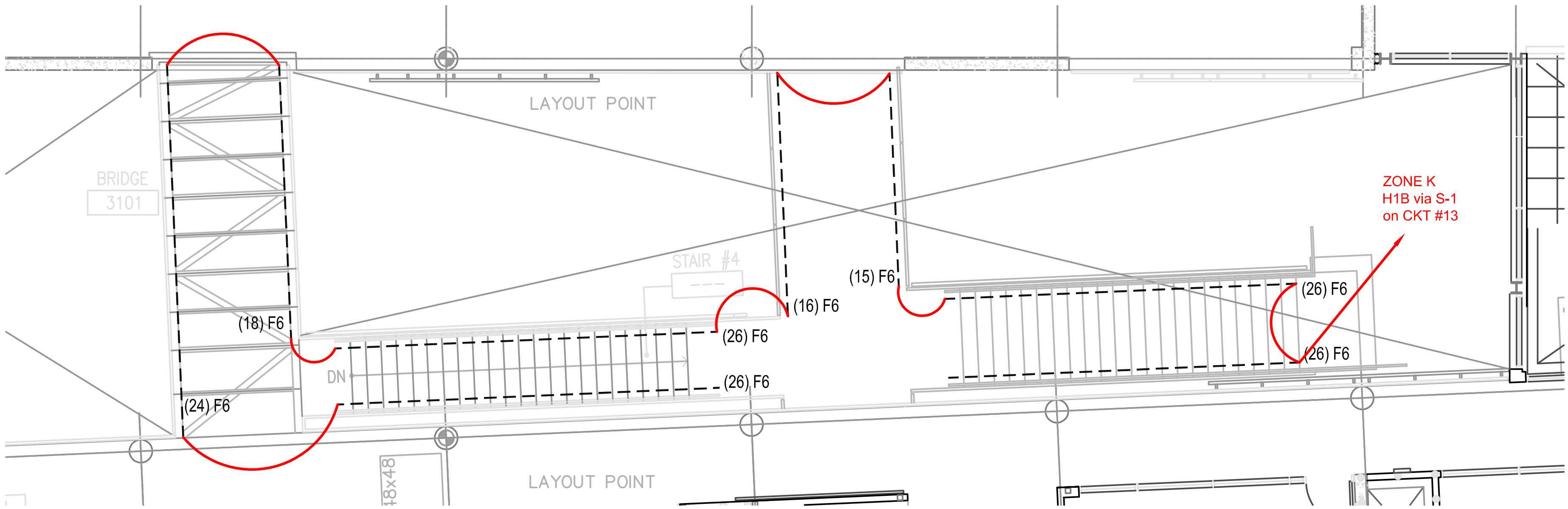
Forum - Power and Circuit Plan (1 of 4)

Scale: $\frac{3}{32}$" - 1'-0"



UCSB Student Resource Building

Forum - Power and Circuit Plan (2 of 4)
Scale: $\frac{3}{32}$" - 1'-0"



All F6 fixtures mounted @ 42" above tread height

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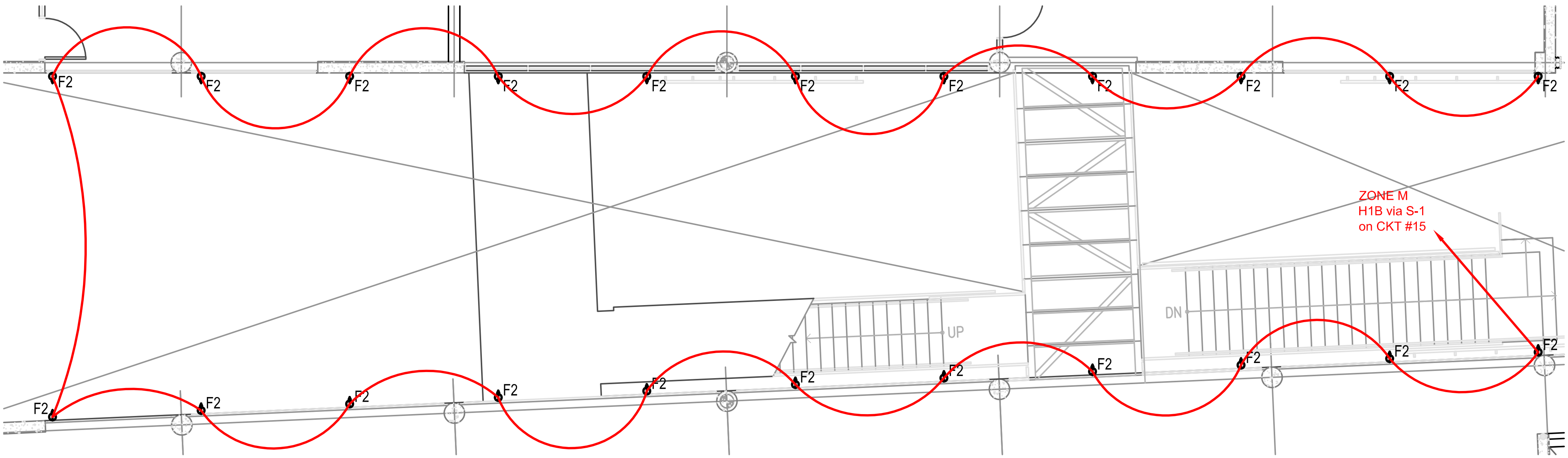
Forum - Power and Circuit Plan (3 of 4)

Scale: $\frac{3}{32}$" - 1'-0"



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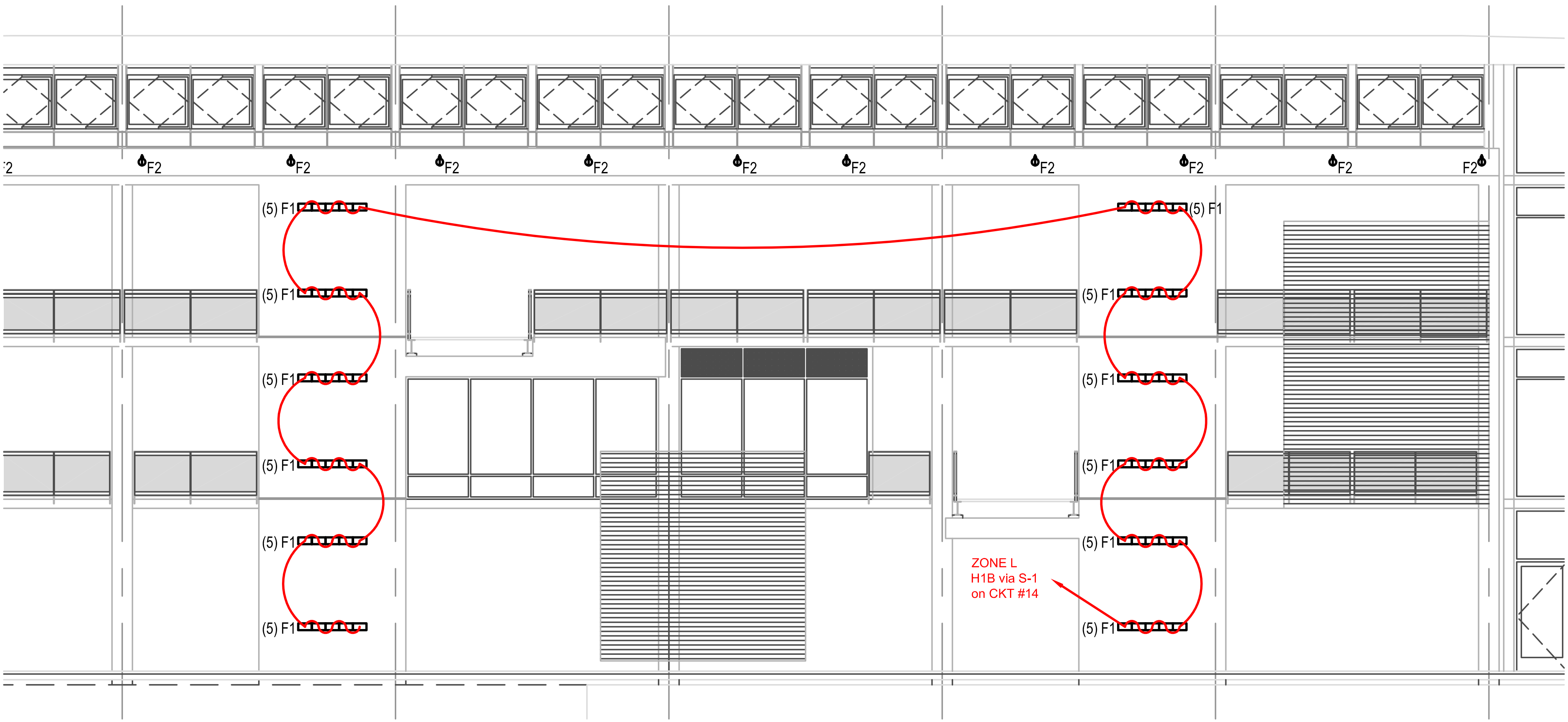
Forum - Power and Circuit Plan (4 of 4)

Scale: $\frac{3}{32}$" - 1'-0"



Please see "Power and Circuit Plan 4 of 4" for F2 information.

UCSB Student Resource Building

Forum -
Power and Circuit Detail for F1 Fixtures
Scale: $\frac{3}{32}$" - 1'-0"

Panelboard Schedules Comparison

The transfer of the new lighting load in the forum to panelboard H1B represent a reduction on panelboard H3Aa. Since this panelboard is connected to panel H1A via H2A, we have to calculate the load change on these affected panelboards. The following offers a comparison of these original and the new panelboard schedules for these items.

PANEL H1A 277/480 VOLT, 3PH, 4W 225 AMP COPPER BUS
LOCATION: Elect. Rm. 1214 MAIN C.B: 200 AMPS
MOUNTING: Surface LOAD: 50 AMP 42 KVA

CK #	LOAD (VA) LINE A	LINE B	LINE C	LOAD DESCRIPTION	OUTLETS	RC	LT	P	C.B. TRP	BUS ABC	C.B. TRP	P	OUTLETS LT	RC		LOAD DESCRIPTION	LOAD (VA) LINE A	LINE B	LINE C	CK #
1	2248			Infant Classrooms 1320,1325 +			56	1	20	A	20	1				Spare	0			2
3		2260		Toddler Classrms 1310,1315 +			48	1	20	B	20	1				Spare		0		4
5			2300	Restrooms 1209,1211			40	1	20	C	20	1				Spare			0	6
7	2428			Hall 1204, Library 1227 +			40	1	20	A	20	1				Spare	0			8
9		1584		Offices, Conf. 1238			19	1	20	B	20	1				Spare		0		10
11			1605	Open Office 1220 +			35	1	20	C	20	1				Spare			0	12
13	0			Spare				1	20	A	20	1				Spare	0			14
15		0		Spare				1	20	B	20	1				Spare		0		16
17			0	Spare				1	20	C	20	1				Spare			0	18
19	0			Spare				1	20	A	20	1				Spare	0			20
21		0		Spare				1	20	B	20	1				Spare		0		22
23			0	Spare				1	20	C	20	1				Spare			0	24
25	0			Spare				1	20	A	20	1				Spare	0			26
27		0		Spare				1	20	B	20	1				Spare		0		28
29			0	Spare				1	20	C	20	1				Spare			0	30
31	0			Spare				1	20	A	20	1				Spare	0			32
33		0		Spare				1	20	B	20	1				Spare		0		34
35			0	Spare				1	20	C	20	1				Spare			0	36
37	0			Spare				1	20	A	125	–			1	Panel H2A	8872			38
39		0		Spare				1	20	B	–	–			–	w/ Ckt. 38		8888		40
41			0	Spare				1	20	C	–	3			–	w/ Ckt. 38			8620	42
	4676	3844	3905	SUBTOTALS												SUBTOTALS:	8872	8888	8620	
																LINE TOTALS:	13548	12732	12525	
																LCL ADDER:	1169	961	976.3	
																TOTAL VA/PHASE:	14717	13693	13501	
																LINE AMPS:	53	49	49	

NOTES:
+ Via Lighting Control Panel/System

Original Panelboard "H1A" Schedule

P A N E L B O A R D S C H E D U L E

VOLTAGE: 480Y/277V,3PH,4W
SIZE/TYPE BUS: 100A
SIZE/TYPE MAIN: 100A/3P C/B

PANEL TAG: H1A
PANEL LOCATION: Elec. Rm 1214
PANEL MOUNTING: SURFACE

MIN. C/B AIC: 14K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	Infant.	2248	20A/1P	1	*			2	-	0	0	0
Lighting	Toddler.	2260	20A/1P	3		*		4	-	0	0	0
Lighting	Restrms.	2300	20A/1P	5			*	6	-	0	0	0
Lighting	Hall, Lib.	2428	20A/1P	7	*			8	-	0	0	0
Lighting	Office,Conf.	424	20A/1P	9		*		10	-	0	0	0
Lighting	Open Office	1605	20A/1P	11			*	12	-	0	0	0
0	0	0	-	13	*			14	-	0	0	0
0	0	0	-	15		*		16	-	0	0	0
0	0	0	-	17			*	18	-	0	0	0
0	0	0	-	19	*			20	-	0	0	0
0	0	0	-	21		*		22	-	0	0	0
0	0	0	-	23			*	24	-	0	0	0
0	0	0	-	25	*			26	-	0	0	0
0	0	0	-	27		*		28	-	0	0	0
0	0	0	-	29			*	30	-	0	0	0
0	0	0	-	31	*			32	-	0	0	0
0	0	0	-	33		*		34	-	0	0	0
0	0	0	-	35			*	36	-	0	0	0
0	0	0	-	37	*			38	50A/ 3P	12300	Elec. Rm.	Panel H2A
0	0	0	-	39		*		40	-	12300	-	w/ ckt 38
0	0	0	-	41			*	42	-	12300	-	w/ ckt 38

CONNECTED LOAD (KW) - A	16.98	TOTAL DESIGN LOAD (KW)	61.18
CONNECTED LOAD (KW) - B	14.98	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	16.21	TOTAL DESIGN LOAD (AMPS)	74

New Panelboard "H1A" Schedule

LIGHTING AND APPLIANCE PANELBOARD SIZING WORKSHEET

Panel Tag------------------------->	H1A	Panel Location:	Elec. Rm 1214
Nominal Phase to Neutral Voltage------->	277	Phase:	3
Nominal Phase to Phase Voltage-------->	480	Wires:	4

Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	Lighting	1	Infant.	2248	VA	1.00	2248	2248		
2	A					VA	1.00	0	0		
3	B	Lighting	1	Toddler.	2260	VA	1.00	2260	2260		
4	B					VA	1.00	0	0		
5	C	Lighting	1	Restrms.	2300	VA	1.00	2300	2300		
6	C					VA	1.00	0	0		
7	A	Lighting	1	Hall, Lib.	2428	VA	1.00	2428	2428		
8	A					VA	1.00	0	0		
9	B	Lighting	1	Office,Conf.	424	VA	1.00	424	424		
10	B					VA	1.00	0	0		
11	C	Lighting	1	Open Office	1605	VA	1.00	1605	1605		
12	C					VA	1.00	0	0		
13	A					W	0.95	0	0		
14	A					W	1.00	0	0		
15	B					W	1.00	0	0		
16	B					W	1.00	0	0		
17	C					VA	1.00	0	0		
18	C					VA	1.00	0	0		
19	A					VA	1.00	0	0		
20	A					VA	1.00	0	0		
21	B					VA	1.00	0	0		
22	B					VA	1.00	0	0		
23	C					VA	1.00	0	0		
24	C					VA	1.00	0	0		
25	A					VA	1.00	0	0		
26	A					VA	1.00	0	0		
27	B					VA	1.00	0	0		
28	B					VA	1.00	0	0		
29	C					VA	1.00	0	0		
30	C					VA	1.00	0	0		
31	A					VA	1.00	0	0		
32	A					VA	1.00	0	0		
33	B					VA	1.00	0	0		
34	B					VA	1.00	0	0		
35	C					VA	1.00	0	0		
36	C					VA	1.00	0	0		
37	A					VA	1.00	0	0		
38	A	Panel H2A	2	Elec. Rm.	12300	VA	1.00	12300	12300		
39	B					VA	1.00	0	0		
40	B	w/ ckt 38	2	-	12300	VA	1.00	12300	12300		
41	C					VA	1.00	0	0		
42	C	w/ ckt 38	2	-	12300	VA	1.00	12300	12300		
PANEL TOTAL								48.2	48.2	Amps=	58.0

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					17.0	17.0	35%	61.3
PHASE TOTAL	B					15.0	15.0	31%	54.1
PHASE TOTAL	C					16.2	16.2	34%	58.5

LOAD CATAGORIES			Connected			Demand				Ver. 1.01
			kW	kVA	DF	kW	kVA	PF		
1	Lighting		11.3	11.3	1.25	14.1	14.1	1.00		
2	Panel H2A		36.9	36.9	1.00	36.9	36.9	1.00		
3			0.0	0.0	1.00	0.0	0.0			
4			0.0	0.0	1.00	0.0	0.0			
5			0.0	0.0	1.00	0.0	0.0			
6			0.0	0.0	1.00	0.0	0.0			
7			0.0	0.0	1.00	0.0	0.0			
8			0.0	0.0	1.00	0.0	0.0			
Total Demand Loads						51.0	51.0			
Spare Capacity			20%			10.2	10.2			
Total Design Loads						61.2	61.2	1.00	Amps=	73.6

PANEL H2A — 277/480 VOLT, 3PH, 4W — 225 AMP COPPER BUS

LOCATION: Elect. Rm. 2214 — MAIN C.B: 125 AMPS

MOUNTING: Surface — LOAD: 35 AMP 29 KVA

CK #	LOAD (VA) LINE A	LINE B	LINE C	LOAD DESCRIPTION	OUTLETS	RC	LT	C.B. P	TRP	BUS ABC	C.B. TRP	P	OUTLETS LT	RC		LOAD DESCRIPTION	LOAD (VA) LINE A	LINE B	LINE C	CK #
1	1716			SE perimeter offices			15	1	20	A	20	1				Spare	0			2
3		1980		SE interior offices			30	1	20	B	20	1				Spare		0		4
5			1620	SE open offices +			33	1	20	C	20	1				Spare			0	6
7	2172			SW open offices +			48	1	20	A	20	1				Spare	0			8
9		1788		SW perimeter offices +			15	1	20	B	20	1				Spare		0		10
11			2334	SW interior offices +			39	1	20	C	20	1				Spare			0	12
13	0			Spare				1	20	A	20	1				Spare	0			14
15		0		Spare				1	20	B	20	1				Spare		0		16
17			0	Spare				1	20	C	20	1				Spare			0	18
19	0			Spare				1	20	A	20	1				Spare	0			20
21		0		Spare				1	20	B	20	1				Spare		0		22
23			0	Spare				1	20	C	20	1				Spare			0	24
25	0			Spare				1	20	A	20	1				Spare	0			26
27		0		Spare				1	20	B	20	1				Spare		0		28
29			0	Spare				1	20	C	20	1				Spare			0	30
31	0			Spare				1	20	A	20	1				Spare	0			32
33		0		Spare				1	20	B	20	1				Spare		0		34
35			0	Spare				1	20	C	20	1				Spare			0	36
37	0			Spare				1	20	A	70	–			1	Panel H3Aa	4984			38
39		0		Spare				1	20	B	–	–			–	w/ Ckt. 38		5120		40
41			0	Spare				1	20	C	–	3			–	w/ Ckt. 38			4666	42
	3888	3768	3954	SUBTOTALS												SUBTOTALS:	4984	5120	4666	

	LINE A	LINE B	LINE C
LINE TOTALS:	8872	8888	8620
LCL ADDER:	972	942	988.5
TOTAL VA/PHASE:	9844	9830	9609
LINE AMPS:	36	35	35

NOTES:
+ Via Lighting Control Panel/System

Original Panelboard "H2A" Schedule

PANELBOARD SCHEDULE

VOLTAGE: 480Y/277V,3PH,4W
SIZE/TYPE BUS: 100A
SIZE/TYPE MAIN: 60A/3P C/B

PANEL TAG: H2A
PANEL LOCATION: Elec. Rm 2214
PANEL MOUNTING: SURFACE

MIN. C/B AIC: 14K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	SE Offices	1716	20A/1P	1	*			2	-	0	0	0
Lighting	SE Offices	1980	20A/1P	3		*		4	-	0	0	0
Lighting	SE Offices	1620	20A/1P	5			*	6	-	0	0	0
Lighting	SW. Office	2172	20A/1P	7	*			8	-	0	0	0
Lighting	SW. Office	1788	20A/1P	9		*		10	-	0	0	0
Lighting	SW. Office	2334	20A/1P	11			*	12	-	0	0	0
0	0	0	-	13	*			14	-	0	0	0
0	0	0	-	15		*		16	-	0	0	0
0	0	0	-	17			*	18	-	0	0	0
0	0	0	-	19	*			20	-	0	0	0
0	0	0	-	21		*		22	-	0	0	0
0	0	0	-	23			*	24	-	0	0	0
0	0	0	-	25	*			26	-	0	0	0
0	0	0	-	27		*		28	-	0	0	0
0	0	0	-	29			*	30	-	0	0	0
0	0	0	-	31	*			32	-	0	0	0
0	0	0	-	33		*		34	-	0	0	0
0	0	0	-	35			*	36	-	0	0	0
0	0	0	-	37	*			38	20A/1P	5400	-	Panel H3Aa
0	0	0	-	39		*		40	-	5400	-	w/ ckt. 38
0	0	0	-	41			*	42	-	5400	-	w/ ckt. 38

CONNECTED LOAD (KW) - A	9.29	TOTAL DESIGN LOAD (KW)	36.86
CONNECTED LOAD (KW) - B	9.17	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	9.35	TOTAL DESIGN LOAD (AMPS)	44

New Panelboard "H2A" Schedule

LIGHTING AND APPLIANCE PANELBOARD SIZING WORKSHEET											
Panel Tag------------------------->					H2A	Panel Location:			Elec. Rm 2214		
Nominal Phase to Neutral Voltage------->					277	Phase:			3		
Nominal Phase to Phase Voltage-------->					480	Wires:			4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	Lighting	1	SE Offices	1716	VA	1.00	1716	1716	perimeter offices	
2	A					VA	1.00	0	0		
3	B	Lighting	1	SE Offices	1980	VA	1.00	1980	1980	interior office	
4	B					VA	1.00	0	0		
5	C	Lighting	1	SE Offices	1620	VA	1.00	1620	1620	open offices	
6	C					VA	1.00	0	0		
7	A	Lighting	1	SW. Office	2172	VA	1.00	2172	2172	open offices	
8	A					VA	1.00	0	0		
9	B	Lighting	1	SW. Office	1788	VA	1.00	1788	1788	perimeter offices	
10	B					VA	1.00	0	0		
11	C	Lighting	1	SW. Office	2334	VA	1.00	2334	2334	interior offices	
12	C					VA	1.00	0	0		
13	A					W	0.95	0	0		
14	A					W	1.00	0	0		
15	B					W	1.00	0	0		
16	B					W	1.00	0	0		
17	C					VA	1.00	0	0		
18	C					VA	1.00	0	0		
19	A					VA	1.00	0	0		
20	A					VA	1.00	0	0		
21	B					VA	1.00	0	0		
22	B					VA	1.00	0	0		
23	C					VA	1.00	0	0		
24	C					VA	1.00	0	0		
25	A					VA	1.00	0	0		
26	A					VA	1.00	0	0		
27	B					VA	1.00	0	0		
28	B					VA	1.00	0	0		
29	C					VA	1.00	0	0		
30	C					VA	1.00	0	0		
31	A					VA	1.00	0	0		
32	A					VA	1.00	0	0		
33	B					VA	1.00	0	0		
34	B					VA	1.00	0	0		
35	C					VA	1.00	0	0		
36	C					VA	1.00	0	0		
37	A					VA	1.00	0	0		
38	A	Panel H3Aa	2	-	5400	VA	1.00	5400	5400		
39	B					VA	1.00	0	0		
40	B	w/ ckt. 38	2	-	5400	VA	1.00	5400	5400		
41	C					VA	1.00	0	0		
42	C	w/ ckt. 38	2	-	5400	VA	1.00	5400	5400		
PANEL TOTAL								27.8	27.8	Amps=	33.5
PHASE LOADING								kW	kVA	%	Amps
PHASE TOTAL			A					9.3	9.3	33%	33.5
PHASE TOTAL			B					9.2	9.2	33%	33.1
PHASE TOTAL			C					9.4	9.4	34%	33.8
LOAD CATAGORIES				Connected			Demand				Ver. 1.01
				kW	kVA	DF	kW	kVA	PF		
1		Lighting		11.6	11.6	1.25	14.5	14.5	1.00		
2		Panel H3Aa		16.2	16.2	1.00	16.2	16.2	1.00		
3				0.0	0.0	1.00	0.0	0.0			
4				0.0	0.0	1.00	0.0	0.0			
5				0.0	0.0	1.00	0.0	0.0			
6				0.0	0.0	1.00	0.0	0.0			
7				0.0	0.0	1.00	0.0	0.0			
8				0.0	0.0	1.00	0.0	0.0			
Total Demand Loads							30.7	30.7			
Spare Capacity				20%			6.1	6.1			
Total Design Loads							36.9	36.9	1.00	Amps=	44.4

PANEL H3Aa 277/480 VOLT, 3PH, 4W 225 AMP COPPER BUS

LOCATION: Elect. Rm. 3243 MAIN C.B: 70 AMPS

MOUNTING: Surface LOAD: 22 AMP 18 KVA

CK	LOAD (VA)			LOAD DESCRIPTION	OUTLETS		C.B.		BUS	C.B.		OUTLETS		LOAD DESCRIPTION	LOAD (VA)			CK
#	LINE A	LINE B	LINE C		RC	LT	P	TRP	ABC	TRP	P	LT	RC		LINE A	LINE B	LINE C	#
1	1788			Open Office 3210 +		38	1	20	A	20	1			Spare	0			2
3		1686		Tutorial Rms 3276,3278		37	1	20	B	20	1			Spare		0		4
5			1518	Seminar Room 3231 +		10	1	20	C	20	1			Spare			0	6
7	1188			SW Offices		9	1	20	A	20	1			Spare	0			8
9		1584		Tutorial Rms 3270,3272,3274		35	1	20	B	20	1			Spare		0		10
11			928	Hall 3260 +		24	1	20	C	20	1			Spare			0	12
13	2008			Seminar Room 3263 +		28	1	20	A	20	1			Spare	0			14
15		1850		Main Forum +		5	1	20	B	20	1			Spare		0		16
17			2220	Main Forum +		6	1	20	C	20	1			Spare			0	18
19	0			Spare			1	20	A	20	1			Spare	0			20
21		0		Spare			1	20	B	20	1			Spare		0		22
23			0	Spare			1	20	C	20	1			Spare			0	24
25	0			Spare			1	20	A	20	1			Spare	0			26
27		0		Spare			1	20	B	20	1			Spare		0		28
29			0	Spare			1	20	C	20	1			Spare			0	30
31	0			Spare			1	20	A	20	1			Spare	0			32
33		0		Spare			1	20	B	20	1			Spare		0		34
35			0	Spare			1	20	C	20	1			Spare			0	36
37	0			Spare			1	20	A	20	1			Spare	0			38
39		0		Spare			1	20	B	20	1			Spare		0		40
41			0	Spare			1	20	C	20	1			Spare			0	42
	4984	5120	4666	SUBTOTALS										SUBTOTALS:	0	0	0	
														LINE TOTALS:	4984	5120	4666	
														LCL ADDER:	1246	1280	1167	
														TOTAL VA/PHASE:	6230	6400	5833	
														LINE AMPS:	22	23	21	

NOTES:
+ Via Lighting Control Panel/System

Original Panelboard "H3Aa" Schedule

PANELBOARD SCHEDULE

VOLTAGE: 480Y/277V,3PH,4W SIZE/TYPE BUS: 100A SIZE/TYPE MAIN: 50A/3P C/B	PANEL TAG: H3Aa PANEL LOCATION: Elec. Rm 3243 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 14K OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	Open Office.	1788	20A/1P	1	*			2	-	0	0	0
Lighting	Tutorial Rms.	1686	20A/1P	3		*		4	-	0	0	0
Lighting	Seminar Rm.	1518	20A/1P	5			*	6	-	0	0	0
Lighting	SW. Office	1188	20A/1P	7	*			8	-	0	0	0
Lighting	Tutorial Rms.	1584	20A/1P	9		*		10	-	0	0	0
Lighting	Hall 3260	928	20A/1P	11			*	12	-	0	0	0
Lighting	Seminar Rm.	2008	20A/1P	13	*			14	-	0	0	0
0	0	0	-	15		*		16	-	0	0	0
0	0	0	-	17			*	18	-	0	0	0
0	0	0	-	19	*			20	-	0	0	0
0	0	0	-	21		*		22	-	0	0	0
0	0	0	-	23			*	24	-	0	0	0
0	0	0	-	25	*			26	-	0	0	0
0	0	0	-	27		*		28	-	0	0	0
0	0	0	-	29			*	30	-	0	0	0
0	0	0	-	31	*			32	-	0	0	0
0	0	0	-	33		*		34	-	0	0	0
0	0	0	-	35			*	36	-	0	0	0
0	0	0	-	37	*			38	-	0	0	0
0	0	0	-	39		*		40	-	0	0	0
0	0	0	-	41			*	42	-	0	0	0

CONNECTED LOAD (KW) - A	4.98		TOTAL DESIGN LOAD (KW)	16.05
CONNECTED LOAD (KW) - B	3.27		POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	2.45		TOTAL DESIGN LOAD (AMPS)	19

New Panelboard "H3Aa" Schedule

LIGHTING AND APPLIANCE PANELBOARD SIZING WORKSHEET

Panel Tag------------------------->	H3Aa	Panel Location:	Elec. Rm 3243	
Nominal Phase to Neutral Voltage------->	277	Phase:	3	
Nominal Phase to Phase Voltage-------->	480	Wires:	4	

Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	Lighting	1	Open Office	1788	VA	1.00	1788	1788		
2	A					VA	1.00	0	0		
3	B	Lighting	1	Tutorial Rms	1686	VA	1.00	1686	1686		
4	B					VA	1.00	0	0		
5	C	Lighting	1	Seminar Rm	1518	VA	1.00	1518	1518		
6	C					VA	1.00	0	0		
7	A	Lighting	1	SW. Office	1188	VA	1.00	1188	1188		
8	A					VA	1.00	0	0		
9	B	Lighting	1	Tutorial Rms	1584	VA	1.00	1584	1584		
10	B					VA	1.00	0	0		
11	C	Lighting	1	Hall 3260	928	VA	1.00	928	928		
12	C					VA	1.00	0	0		
13	A	Lighting	1	Seminar Rm	2008	W	1.00	2008	2008		
14	A					W	1.00	0	0		
15	B					W	1.00	0	0		
16	B					W	1.00	0	0		
17	C					VA	1.00	0	0		
18	C					VA	1.00	0	0		
19	A					VA	1.00	0	0		
20	A					VA	1.00	0	0		
21	B					VA	1.00	0	0		
22	B					VA	1.00	0	0		
23	C					VA	1.00	0	0		
24	C					VA	1.00	0	0		
25	A					VA	1.00	0	0		
26	A					VA	1.00	0	0		
27	B					VA	1.00	0	0		
28	B					VA	1.00	0	0		
29	C					VA	1.00	0	0		
30	C					VA	1.00	0	0		
31	A					VA	1.00	0	0		
32	A					VA	1.00	0	0		
33	B					VA	1.00	0	0		
34	B					VA	1.00	0	0		
35	C					VA	1.00	0	0		
36	C					VA	1.00	0	0		
37	A					VA	1.00	0	0		
38	A					VA	1.00	0	0		
39	B					VA	1.00	0	0		
40	B					VA	1.00	0	0		
41	C					VA	1.00	0	0		
42	C					VA	1.00	0	0		
PANEL TOTAL								10.7	10.7	Amps=	12.9

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					5.0	5.0	47%	18.0
PHASE TOTAL	B					3.3	3.3	31%	11.8
PHASE TOTAL	C					2.4	2.4	23%	8.8

LOAD CATAGORIES			Connected			Demand				Ver. 1.01
			kW	kVA	DF	kW	kVA	PF		
1	Lighting		10.7	10.7	1.25	13.4	13.4	1.00		
2			0.0	0.0	1.00	0.0	0.0			
3			0.0	0.0	1.00	0.0	0.0			
4			0.0	0.0	1.00	0.0	0.0			
5			0.0	0.0	1.00	0.0	0.0			
6			0.0	0.0	1.00	0.0	0.0			
7			0.0	0.0	1.00	0.0	0.0			
8			0.0	0.0	1.00	0.0	0.0			
Total Demand Loads						13.4	13.4			
Spare Capacity			20%			2.7	2.7			
Total Design Loads						16.1	16.1	1.00	Amps=	19.3

New Feeder Sizes:

Panelboard H1A	4 - #3 THW – 1¼" C and 1 #8 G
Panelboard H2A	4 - #6 THW – 1" C and 1 #10 G
Panelboard H3Aa	4 - #12 THW – ¾" C and 1 #12 G

Notes:

1. Calculations per NEC 2005: Tables 310-16, C8.

2. Only copper wires specified.

3. Changes on panelboard H1A also reflect the change in the lighting installation in the "Student Resource Center" discussed in this report

4. NEC 80% current-carrying capacity included.

H1A, H2A,	**Eaton Cutler-Hammer, PRL2a, Pow-R-Line C Panelboards**
H3Aa	480Y/277 V AC
	Price: 1,344 USD

H1A - Feeder Voltage Drop Calculation

Steel Conduit (magnetic), #3 THW

p.f. = 0.90
Length (L) = 116 ft
*V_{drop} = 0.300
Feeder Current (I_L) = 73.6 A

Amp-feet = I_L x L = 73.6 x 116 = 8537.6 = 8.54 x 1000 amp-ft
V_{drop} (l-n) = 8.54 x 0.300 = 2.56 V
V_{drop} (l-l) = √3 x 2.56 = 4.44 V

% Voltage Drop = 4.44 V / 480 V x 100% = **0.92% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*

H2A - Feeder Voltage Drop Calculation

Steel Conduit (magnetic), #6 THW

p.f. = 0.90
Length (L) = 13 ft
*V_{drop} = 0.462
Feeder Current (I_L) = 44.4 A

Amp-feet = I_L x L = 44.4 x 13 = 576.99 = 0.577 x 1000 amp-ft
V_{drop} (l-n) = 0.577 x 0.462 = 0.27 V
V_{drop} (l-l) = √3 x 0.27 = 0.46 V

% Voltage Drop = 0.46 V / 480 V x 100% = **0.10% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*

H3Aa - Feeder Voltage Drop Calculation

Steel Conduit (magnetic), #12 THW

p.f. = 0.90

Length (L) = 13 ft

*V_{drop} = 1.749

Feeder Current (I_L) = 19.3 A

Amp-feet = I_L x L = 19.3 x 13 = 250.9 = 0.251 x 1000 amp-ft

V_{drop} (l-n) = 0.251 x 1.749 = 0.44 V

V_{drop} (l-l) = $\sqrt{3}$ x 0.44 = 0.76 V

% Voltage Drop = 0.76 V / 480 V x 100% = **0.16% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*

Multipurpose Room

In this space, it was crucial to optimize the ratio of artificial and daylight available. All linear fixtures in this space are grouped in a single zone with 2-lamp dimming ballasts provided for each one. Under Section 119 of California's Title 24, it is mandatory that a lighting controller device be implemented in such a space. As this space will only be utilized during special events, in addition to the occupant control provided by the Graphik Eye control unit in this space, a single 360° coverage occupancy sensor is installed in the center of the room to minimize wasted light.

Scene Presets

The following table summarizes the three different scenes intended for this space.

Scene	Description	Zones	Fixtures	Remarks
1	Full System On	A,B,C,D	F1, F3A, F4	
2	Exhibition Mode	A*,B,C,D	F1, F3A, F4*	*Dim as needed to suit occupancy needs
3	Night-time	B	F1	

Please see lighting depth for visuals.

Branch Lighting Circuit Capacity Calculations

The following is a summary of the different loads in each zone. Please refer to the proceeding circuit and power plan for reference.

Zone	Fixtures	Loads		
A	(16) F4	16 x 66 W/fixture = 1056 W 1056 W/ 0.95 = 1111.6 VA (PF = 0.95) 1111.6 VA / 277 V = 4.01 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
B	(133) F1	133 x 1 W/fixture = 133 W 133 W/1.00 = 133 VA (PF = 1.00) 133 VA / 277 V = 0.48 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
C	(6) F3A	6 x 71 W/fixture = 426 W 426 W/ 1.00 = 426 VA (PF = 1.00) 426 VA / 277 V = 1.54 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
D	(4) F3A	4 x 71 W/fixture = 284 W 284 W/ 1.00 = 284 VA (PF = 1.00) 284 VA / 277 V = 1.02 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C

20 A x 277 V x 0.8 (code limit) x 0.8 (contingency) = 3545.6 VA max per circuit

Therefore, **all designated zones satisfy this requirement**.

Branch Circuit Voltage Drop Calculation

Steel Conduit (magnetic), #12 THW,

p.f.	= 0.90
Length (L)	= 227 ft
*V_{drop}	= 1.749
Branch Current (I_L)	= 4.01 A
Single-Phase Circuit	= x2.0 factor

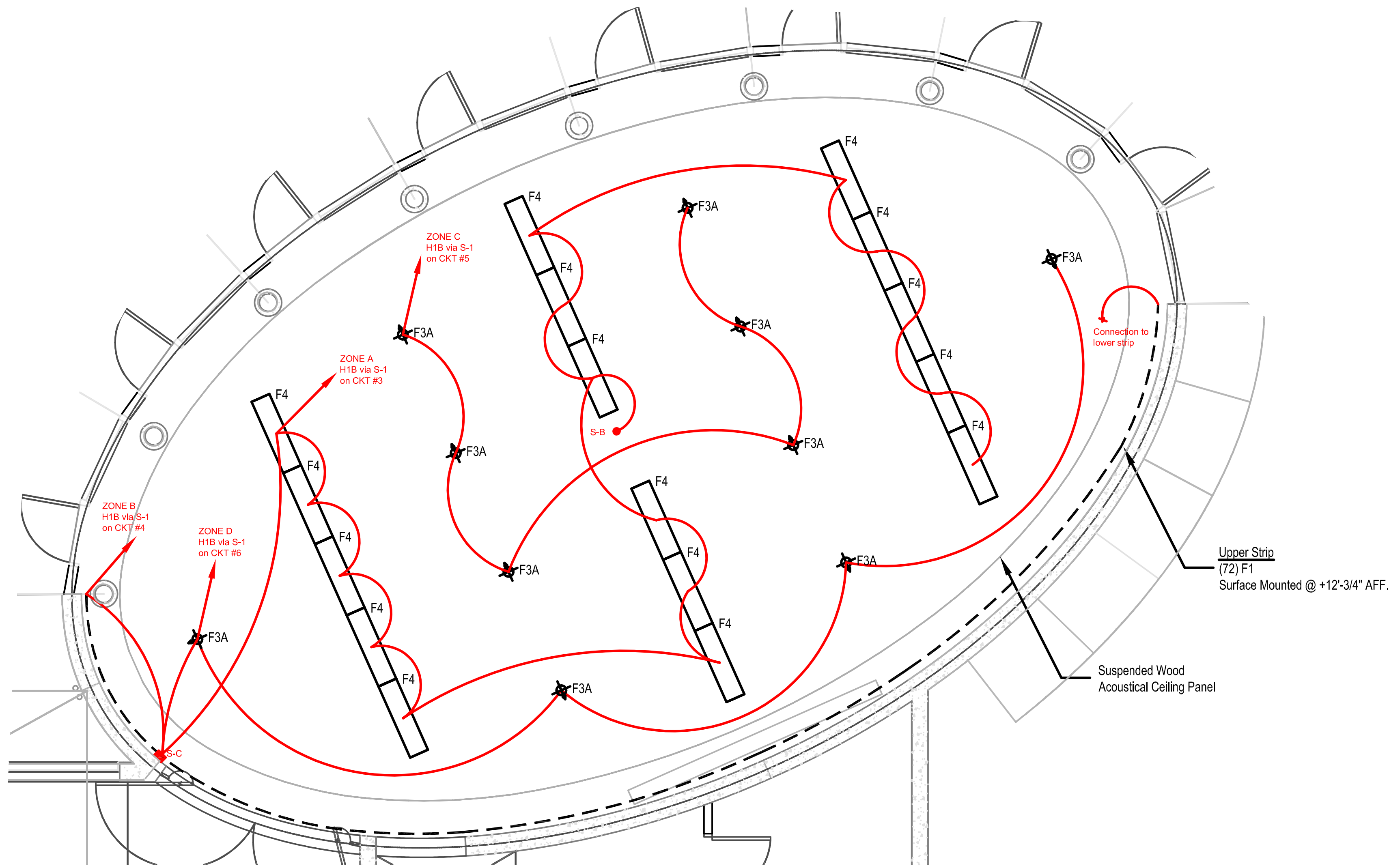
Amp-feet = I_L x L = 4.01 x 227 = 910.27 = 0.91 x 1000 amp-ft

V_{drop} (l-n) = 0.91 x 1.749 = 1.59 V
= 1.59 x 2 = 3.18 V

V_{drop} (l-l) = √3 x 1.59 = 1.92 V
= 2.76 x 2 = 5.51 V

% Voltage Drop = 5.51 V / 480 V x 100% = **1.15% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*



UCSB Student Resource Building

Multipurpose Room - Power and Circuit Plan

Scale: $\frac{1}{8}$" - 1'-0"

Panelboard Schedules Comparison

The following compares the original panelboard schedules with the new that has been changed to accommodate the new lighting installation in the Multipurpose Rm. The existing lighting installation was connected via dimming panel “DPL1B” which was a small version of the Graphik Eye dimming panel. To accommodate for the increased in lighting load as well as the addition of the lighting loads in Student Resource Center as discussed in the proceeding section, a bigger Graphik Eye dimming panel was specified as a replacement. Please see the preceding section “Lighting Control Intent” for a comparison of the original and new dimming panels schedule. Changes made to the original panelboard schedule can also be found in the previous discussion on the North East Plaza.

Student Resource Center

The room is located on the south side of the building on the ground floor. Calculations show that a large quantity of daylight is available in the space year round through the floor to ceiling windows on the south façade. As such, it is crucial that daylight controls be implemented into this design. To facilitate this process, a photosensor and occupancy sensor has been mounted on the suspended ceiling.

Branch Lighting Circuit Capacity Calculations

The following is a summary of the different loads in each zone. Please refer to the proceeding circuit and power plan for reference.

Zone	Fixtures	Loads		
E	(4) F8	4 x 125 W/fixture = 500 W		
		500 W/ 0.95 = 526.3 VA (PF = 0.95)		
		526.3 VA / 277 V = 1.90 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C
F	(4) F3B	6 x 35 W/fixture = 210 W		
		210 W/ 1.00 = 426 VA (PF = 1.00)		
		210 VA / 277 V = 0.76 A		
		Wire Size:	**Breaker Size:**	**Conduit Size:**
		2-#12 THW	20A/ 1P	¾" C

20 A x 277 V x 0.8 (code limit) x 0.8 (contingency) = 3545.6 VA max per circuit

Therefore, **all designated zones satisfy this requirement**.

Branch Circuit Voltage Drop Calculation

Steel Conduit (magnetic), #12 THW,

p.f.	= 0.90
Length (L)	= 47 ft
*V_{drop}	= 1.749
Branch Current (I_L)	= 1.90 A
Single-Phase Circuit	= x2.0 factor

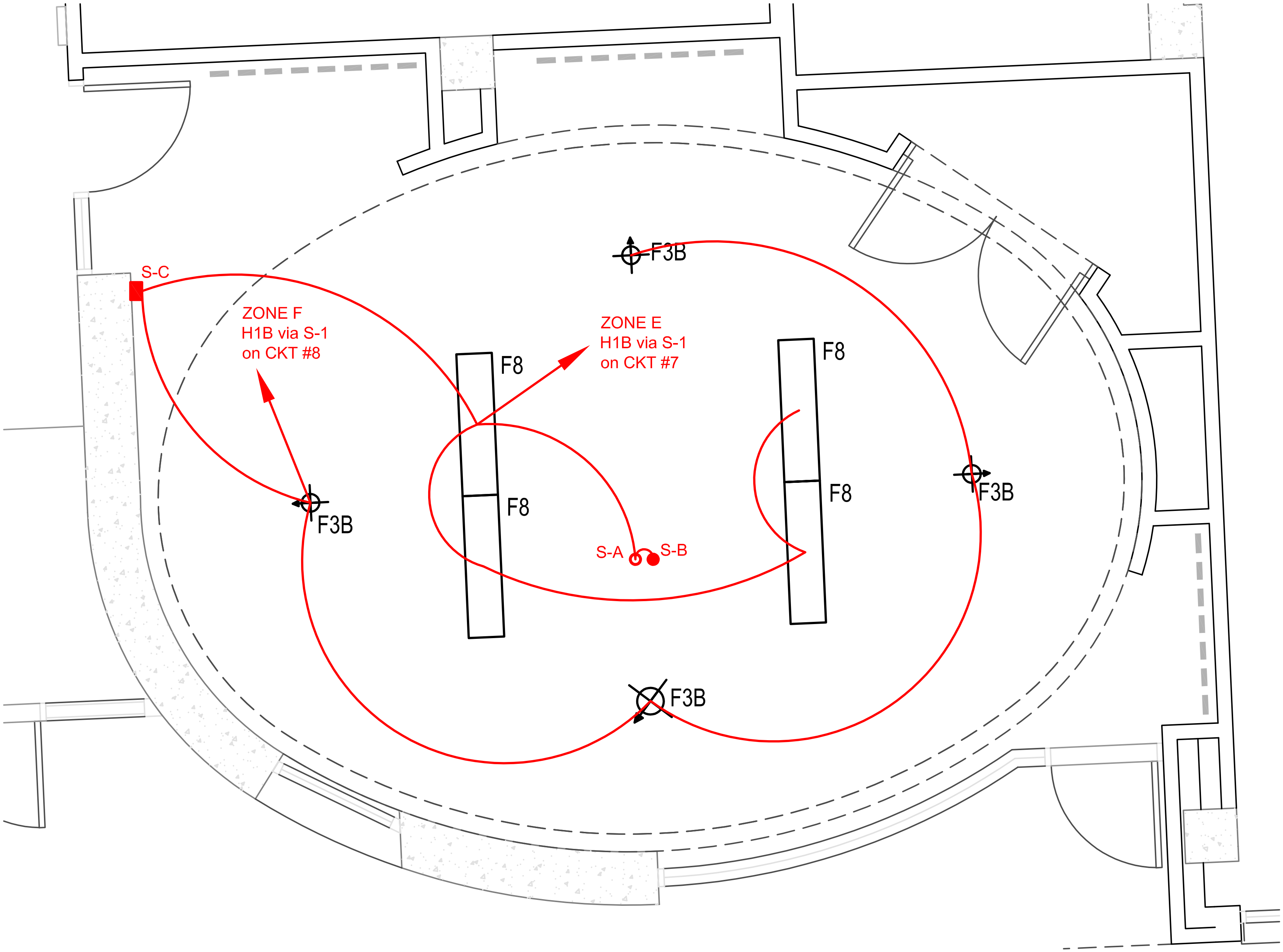
Amp-feet = I_L x L = 1.90 x 47 = 89.3 = 0.0893 x 1000 amp-ft

V_{drop} (l-n) = 0.0893 x 1.749 = 0.16 V
= 0.16 x 2 = 0.32 V

V_{drop} (l-l) = √3 x 0.16 = 0.28 V
= 0.28 x 2 = 0.55 V

% Voltage Drop = 0.55 V / 480 V x 100% = **0.12% < 3% (NEC 2005 Recommendation)**

Note: ** Value per 1000 ampere-feet for three single conductors in conduit*



UCSB Student Resource Building

Student Resource Center - Power Plan

Scale: $\frac{1}{4}$" - 1'-0"

Panelboard Schedules Comparison

As the existing lighting system will no longer be used, it is imperative that we find out how much load can be removed from the existing panelboard H1A. This is shown in the calculation below:

Fixture Type	Description	Quantity	Load (VA)
F4	(3)-32W T8 Fixture	10	10 x 107 W/Fixture = 1070 W 1070 W/0.95 = 1126 VA
F12	(1)-32W T4Triple Tube CFL	1	1 x 32 W/Fixture = 32 W 32 W/0.95 = 34 VA
			Total: 1160 VA

As shown above, the original lighting solution for this space represents approximately 1160 VA load on branch circuit #9. The new design shall eliminate this and transfer the new design load onto dimming panel S-1 which is subsequently connected to panelboard H1B. Please refer to the dimming panel S-1 load schedule as mentioned in the discussion of the Multipurpose Rm. for more load information.

To see the updated panelboard H1A panelboard schedule, please refer to the previous discussion on the “Forum”.

Photovoltaic Array Study

In a climate like Santa Barbara, the area experiences large amounts of daylight on a daily basis throughout the year. As such, a cost-feasibility study was performed using RETScreen ® to see if it may be possible to implement a building-integrated photovoltaic system (BIPV) into this building. The system proposed shall use a BIPV product (product number "SI816G1") developed by "Solar Integrated", a company based in Los Angles, California and is engineered by combining commercial roofing structure with a thin-film photovoltaic membrane that consist of low maintenance industrial fabrics and lightweight amorphous PV cells. Unlike standard crystalline structure panels, amorphous panels are more efficient because they are capable of utilizing under a wider spectrum of light waves and as such, are capable of functioning during some periods of the day when standard panels cannot. Each module has a nominal output of 816 W.

As a PV array produces DC power, an interface is required to convert the electricity produced to AC power to satisfy the building's needs. First, all the DC power generated by the BIPV array is fed to an inverter via a DC disconnects through conduits that are embedded into their custom roofing structure. At the inverter, DC power is converted to AC before being distributed to the electrical system via AC disconnects. It is important to note that a net meter that monitors the amount of power supplied by the PV array and the utility will be put in place at this point of the PV system. Power from the BIPV will take precedence after which the required difference to meet building demands will be determined by the net meter and subsequently be drawn from the utility.

To approximate the gross roof coverage of the proposed BIPV system, Solar Integrated has recommended an 80% roof coverage. Using this value, the following calculation on the following page illustrates the power generation potential of this system:

A. Upper Roof Area	*5342 sf*
B. Total Lower Roof Area	*11060 sf*
	6149 sf
C. Lower Roof Pen Area	*718 sf (North Roof)*
	716 sf (North Roof)
	853 sf (South Roof)
	2030 sf (South Roof)
Usable Roof Area	A + B – C = 18234 sf
Assume 80% coverage:	18234 sf x 0.8 = 14587 sf
Module Area	200 sf (816 W max per module)
Total Modules on Roof	14587 sf / 200 sf = 72
Max Possible Power Generation:	72 x 816 = 58 752 W = **58.8 KW**

As RETscreen® had no direct weather data for Santa Barbara, the data for Los Angles was used instead due to its close proximity. Simulations show that given the turnkey cost of the system as quoted by Solar-Integrated and the incentive package calculated below, the approximate payback period for this installation will be approximately 8.3 years. During this period, energy production cost is approximately $0.17 / KWh, after which besides maintenance, the system will essentially be “cost-free”. Annual savings over a 20 year period is approximated to be $17,109.

The following is a summary of the system characteristics:

RETScreen® Energy Model - Photovoltaic Project | *Training & Support*

Site Conditions		Estimate	Notes/Range
Project name		Student Resource Building	See Online Manual
Project location		UC Santa Barbara	
Nearest location for weather data	-	Los Angeles, CA	Complete SR&SL sheet
Latitude of project location	°N	34.4	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.81	
Annual average temperature	°C	16.7	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	User-defined	
PV module manufacturer / model #		Solar Integrated/ SI816G1	See Product Database
Nominal PV module efficiency	%	4.4%	4.0% to 15.0%
NOCT	°C	48	40 to 55
PV temperature coefficient	% / °C	0.35%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	58.80	
PV array area	m²	1,336.4	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	52.9	
Inverter capacity	kW (AC)	60.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	64.6	
Overall PV system efficiency	%	3.6%	
PV system capacity factor	%	16.8%	
Renewable energy collected	MWh	95.910	
Renewable energy delivered	MWh	86.319	
	kWh	86,319	
Excess RE available	MWh	0.000	
			Complete Cost Analysis sheet

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Turn Key System Cost Breakdown (from Solar Integrated)

Roofing Structure:	$5.00 / SF x 14587	= $ 72,935
PV Side:	$7.25/W x 58.8 KW	= $ 426,300
Miscellaneous Cost[b]:		= $ 25,371

Total Installed System First Cost **= $ 524,607(A)**

Periodic Inverter Replacement Cost[a] *= $ 60,000*

Annual O+M: *= $ 880*

California Energy Commission: Incentives and Grants[c]

California State Rebate (Performance Based Initiative) [d]	= $ 146,150
Federal 10% Tax Credit	= $ 37,845.70
7.5% Tax Credit	= $ 25,545.85
5-year Federal Accelerated Depreciation Savings (34% Tax Rate)	= $ 122,241.61
State Depreciation Savings (6.5% Tax Rate)	= $ 22,939.22
Total Incentives and Grants Package	= $ 354,723 (B)

Final System Cost (A-B) = $169,884

Notes:

a. Assumed to be $1/W per NREL recommendation. "A Review of PV Inverter Technology Cost and Performance Projections, 2006)

b. Simulation assumes a $65/person-hour training costs at 6 hours and a %5 contingency.

c. Incentive package calculated per CEC publication "CEC-300-2006-005-FS"

d. All BIPV systems are required to participate in the Performance Based Initiative program. Rebate Value calculated per CEC "Emerging Renewables Program Guide Book", publication "CEC-300-2006-001-ED6F"

In addition to the incentive and grants package as calculated above, under the Energy Policy Act of 2005, the Federal Energy Regulatory Commission will also provide a renewable energy production credit of 1.5 cents/kWh.

Without the incentive package, it was determined that energy production cost will be approximately $0.46/kWh. This is significantly more then the cost of electricity directly from the utility. Based on this simulation, it is recommended that the pre-described system be installed.

Based on the current 530.83 KVA, demand load of the existing system the proposed PV array will offset approximately 11% of the total power required from the utility and provide a renewable source of energy instead. This is represents a considerable energy cost savings and reduction in greenhouse gas emissions that would have been required to produce this difference using fossil fuels.

Energy Efficient Transformers Study

A cost-feasibility study was done using Powersmiths's "Energy Savings Payback Calculator" to see if this facility would reap any benefits if the currently proposed transformers were replaced with their T-1000 series of energy efficient transformers. Their 75 KVA model is quoted to have an efficiency of over 98.6%. The facility currently utilizes the following transformer types by Eaton-Cutler Hammer:

UCSB STUDENT RESOURCE CENTER - TRANSFORMER SCHEDULE

TAG	PRIMARY VOLTAGE	SECONDARY VOLTAGE	SIZE	TYPE	TEMP. RISE	TAPS	MOUNTING	REMARKS
-	12470V,3PH,4W	480Y/277V,3PH,4W	N/A	N/A	N/A	N/A	PAD MOUNTED ON GRADE	1
T-1A	480V,3PH,4W.	208Y/120V,3PH,4W	225	DRY TYPE	115 DEGREE C	(4) 2.5%	FLOOR MOUNTED	-
T-1B	480V,3PH,4W.	208Y/120V,3PH,4W	112.5	DRY TYPE	115 DEGREE C	(4) 2.5%	FLOOR MOUNTED	-
T-1C	480V,3PH,4W.	208Y/120V,3PH,4W	75	DRY TYPE	115 DEGREE C	(4) 2.5%	FLOOR MOUNTED	-
T-3A	480V,3PH,4W.	208Y/120V,3PH,4W	30	DRY TYPE	115 DEGREE C	(4) 2.5%	SURFACE MOUNTED	-
ET-1A	480V,3PH,4W.	208Y/120V,3PH,4W	30	DRY TYPE	115 DEGREE C	(4) 2.5%	SURFACE MOUNTED	-
ET-1B	480V,3PH,4W.	208Y/120V,3PH,4W	30	DRY TYPE	115 DEGREE C	(4) 2.5%	SURFACE MOUNTED	-
ET-3A	480V,3PH,4W.	208Y/120V,3PH,4W	30	DRY TYPE	115 DEGREE C	(4) 2.5%	SURFACE MOUNTED	-
ET-3B	480V,3PH,4W.	208Y/120V,3PH,4W	30	DRY TYPE	115 DEGREE C	(4) 2.5%	SURFACE MOUNTED	-

NOTE:
1. Liquid Filled Pad Mount

T-1A : **Eaton Cutler-Hammer, 225 KVA** General Purpose Transformer (Dry Type)
480 Δ Volts to 208Y/120 Volts. 60 Hz
Style Number: V48M28T22L
Price Comparison: 7,900 USD (Powersmiths T-1000: 28,000 USD)

T-1B : **Eaton Cutler-Hammer, 112.5 KVA** General Purpose Transformer (Dry Type)
480 Δ Volts to 208Y/120 Volts. 60 Hz
Catalog Number: V48M28T12H
Price: 4,300 USD (Powersmiths T-1000: 16,000 USD)

T-1C : **Eaton Cutler-Hammer, 75 KVA** General Purpose Transformer (Dry Type)
480 Δ Volts to 208Y/120 Volts. 60 Hz
Style Number: V48M28T75J
Price: 2,970 USD (Powersmiths T-1000: 12,000USD)

All Others: **Eaton Cutler-Hammer, 30 KVA** General Purpose Transformer (Dry Type)
480 Δ Volts to 208Y/120 Volts. 60 Hz
Style Number: V48M28T30K
Price: 1,725 USD (Powersmiths T-1000: 7,000USD)

Assuming 70% loading during normal operating hours and 20% outside, a value recommended by Powersmiths, the current arrangement has an annual electric bill of approximately $393,363. By switching to the T1000 transformers with the same KVA ratings, it was determined that this would be reduced by 9% to $359,776.

Though the initial cost of implementing energy efficient transformers is higher, $63,000 as opposed to $16,895 the payback period is approximately 1.37 years. Annual operating cost savings by switching to energy efficient transformers are calculated to be approximately $33,587. This represents a considerable savings over the life cycle of the product. Based on these variables and an energy cost inflation rate of 5%, the system will have saved approximately $1,782,344 over a 20 year period.

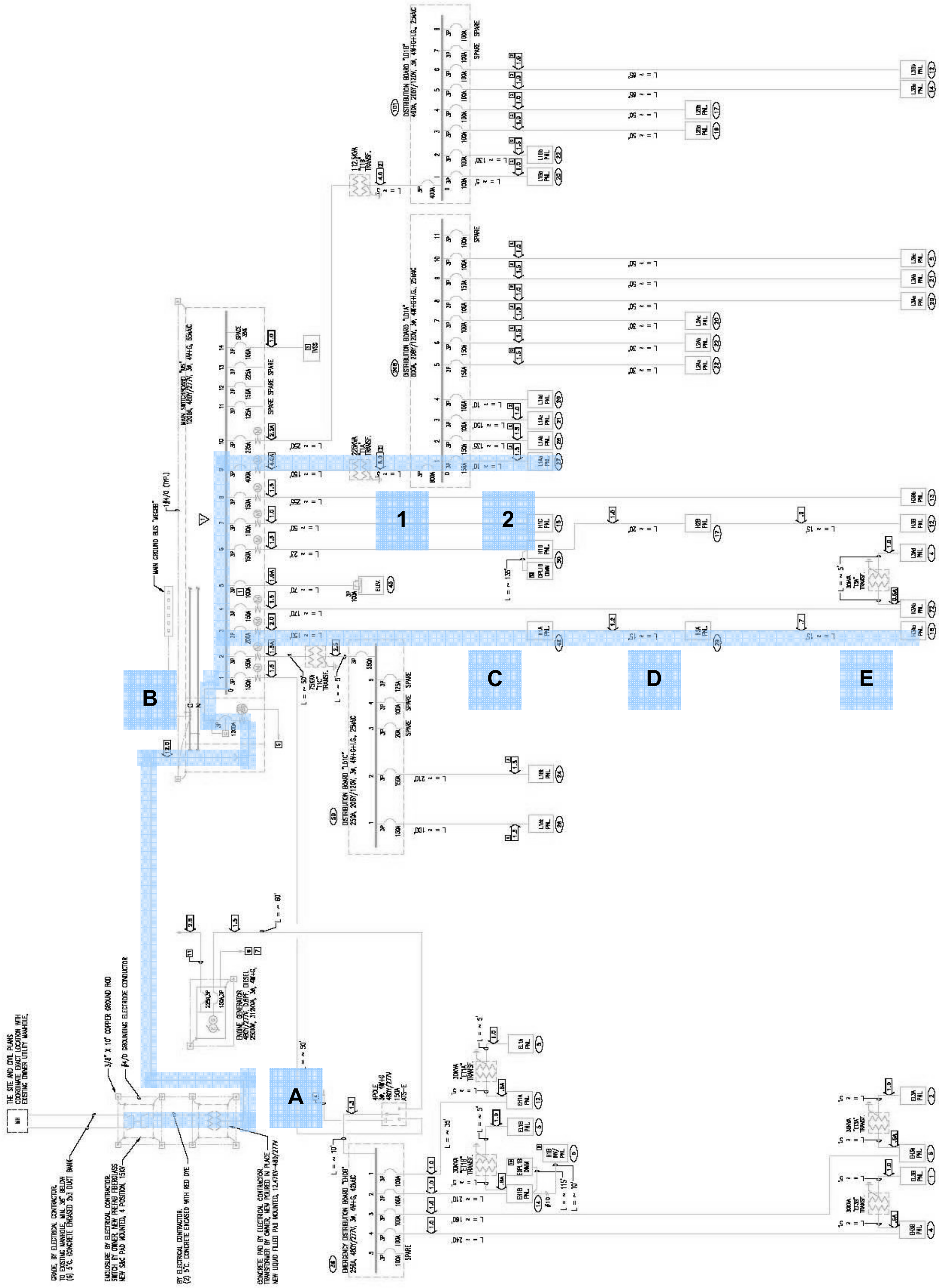
The program also determines the equivalent environmental benefits of implementing energy efficient transformers based on the pre-defined parameters. These are as follows:

Annual Reduction in Greenhouse Gases (Per EPA)	**Equivalence**
124 tons of CO_2	23 acres of trees planted
400 tons of coal	16 car emissions
968 kg of SO_x	17 homes heated
417 kg of NO_x	

Given these benefits, it is recommended that the energy efficient transformers be implemented into this facility.

Protective Device Coordination Study

The following diagram illustrates the paths that were studied.



Point A: Available Fault Current at the Secondary of the Utility's Transformer

Utility System
15 KV
500 MVA
X/R = 12

Utility Transformer
12.47 KV, 480Y/277, 3Φ
2500 KVA
X/R = 6.61
%Z = 5.75

$\mathbf{I_{sc}}$ = KVA_{sys} / √3 x KV

$\mathbf{Z_{util}}$ (per phase) = (KV / √3) x 1000 / I_{SC} = KV^2 x 10^6 / KVA_{util}
= (0.48 KV) x 10^6 / 500,000 KVA
= 0.461 mΩ

$\mathbf{R_{util}}$ = Z_{util} x cos(tan^{-1}X/R) = 0.461cos(tan^{-1}6.61) = 0.038 mΩ
$\mathbf{X_{util}}$ = Z_{util} x sin(tan^{-1}X/R) = 0.461sin(tan^{-1}12) = 0.459 mΩ

$\mathbf{R_{xfrmr}}$ = KV^2 x %Z x 10^4 x cos(tan^{-1}X/R) / KVA_{xfrmr}
= $(0.48\ KV)^2$ x 5.75 x 10^4 x cos(tan^{-1}6.61) / 2500 KVA
= 0.79 mΩ

$\mathbf{X_{xfrmr}}$ = KV^2 x %Z x 10^4 x sin(tan^{-1}X/R) / KVA_{xfrmr}
= $(0.48\ KV)^2$ x 5.75 x 10^4 x sin(tan^{-1}6.61) / 2500 KVA
= 5.24 mΩ

$\mathbf{Z_{total}}$ = Z_{util} + Z_{xfrmr}
= (0.038 + j0.459) + (0.79 + j5.24) = 0.828 + j5.699 mΩ = Z_{sys}

$\mathbf{I_{sc}}$ = $V_{l\text{-}n}$ x 1000 / $|Z_{total}|$
= 277 x 1000 / √ (0.828^2 + 5.699^2)
= **46,884 A**

Main Feeder: (3) 4-#600 MCM- (3) 4"C + (3) 3/0 G

Point B: Fault Current at Main Switchboard (MS)

Feeder Contribution

L = 50 ft

Note: R and X from "ANSI/IEEE Std. 242-1986"

R = 2.09 mΩ/100 ft

X = 4.01 mΩ/100 ft

Main Breaker: 1200 A, 3P

$\mathbf{R_{conductor}}$ = (L / 100) x R x 1 / # of sets
= (50 / 100) x 2.09 x 1 / 3
= 0.348 mΩ

$\mathbf{X_{conductor}}$ = (L / 100) x X_L x 1 / # of sets
= (50 / 100) x 4.01 x 1 / 3
= 0.668 mΩ

$\mathbf{Z_{MDP}}$ = Z_{sys} + Z_{feeder}
= (0.828 + j5.699) + (0.348 + j0.668) = 1.176 + j6.367 mΩ

$\mathbf{I_{sc}}$ = $V_{l\text{-}n}$ x 1000 / $|Z_{MDP}|$
= 277 x 1000 / $\sqrt{(1.176^2 + 6.367^2)}$
= **42,781 A**

Therefore, interrupting rating of the protective device must be at least 42,781 A at Point B.

Point C: Fault Current at Panelboard (H1A)

Feeder Contribution

4 - #3 THW – 1¼" C and 1 #8 G *Note: R and X from "ANSI/IEEE Std. 242-1986"*

L = 150 ft

R = 20.50 mΩ/100 ft

X = 4.58 mΩ/100 ft

Main Breaker: 100 A, 3P

$\mathbf{R_{conductor}}$ = (L / 100) x R x 1 / # of sets
= (150 / 100) x 20.50 x 1 / 1
= 30.75 mΩ

$\mathbf{X_{conductor}}$ = (L / 100) x X_L x 1 / # of sets
= (150 / 100) x 4.58 x 1 / 1
= 6.87 mΩ

$\mathbf{Z_{Total}}$ = $Z_{\mathbf{MDP}}$ + Z_{feeder}
= (1.176 + j6.367) + (30.75 + j6.87) = 32.926 + j13.237 mΩ

$\mathbf{I_{sc}}$ = $V_{l\text{-}n}$ x 1000 / $|Z_{MDP}|$
= 277 x 1000 / $\sqrt{(32.926^2 + 13.237^2)}$
= <u>**8015 A**</u>

Therefore, interrupting rating of the protective device must be at least 8015 A at Point C.

Point D: Fault Current at Panelboard (H2A)

Feeder Contribution

4 - #6 THW – 1" C and 1 #10 G *Note: R and X from "ANSI/IEEE Std. 242-1986"*

L = 15 ft

R = 41.00 mΩ/100 ft

X = 5.04 mΩ/100 ft

Main Breaker: 100 A, 3P

$\mathbf{R_{conductor}}$ = (L / 100) x R x 1 / # of sets
= (15 / 100) x 41.0 x 1 / 1
= 6.15 mΩ

$\mathbf{X_{conductor}}$ = (L / 100) x X_L x 1 / # of sets
= (15 / 100) x 5.04 x 1 / 1
= 0.756 mΩ

$\mathbf{Z_{Total}}$ = $Z_{\mathbf{Sys}}$ + Z_{feeder}
= (32.926 + j13.237) + (6.15 + j0.756) = 39.076 + j13.993 mΩ

$\mathbf{I_{sc}}$ = $V_{l\text{-}n}$ x 1000 / $|Z_{MDP}|$
= 277 x 1000 / $\sqrt{(39.076^2 + 13.993^2)}$
= **6673 A**

Therefore, interrupting rating of the protective device must be at least 6673 A at Point D.

Point E: Fault Current at Panelboard (H3Aa)

Feeder Contribution

4 - #12 THW – ¾" C and 1 #12 G *Note: R and X from "ANSI/IEEE Std. 242-1986"*

L = 15 ft

R = 162 mΩ/100 ft

X = 5.23 mΩ/100 ft

Main Breaker: 100 A, 3P

$\mathbf{R}_{\mathbf{conductor}}$ = (L / 100) x R x 1 / # of sets
= (15 / 100) x 162 x 1 / 1
= 24.3 mΩ

$\mathbf{X}_{\mathbf{conductor}}$ = (150 / 100) x X_L x 1 / # of sets
= (15 / 100) x 5.23 x 1 / 1
= 0.785 mΩ

$\mathbf{Z}_{\mathbf{Total}}$ = $Z_{\mathbf{Sys}}$ + Z_{feeder}
= (39.076 + j13.993) + (24.3 + j0.785) = 63.376 + j14.778 mΩ

$\mathbf{I}_{\mathbf{sc}}$ = $V_{l\text{-}n}$ x 1000 / $|Z_{MDP}|$
= 277 x 1000 / $\sqrt{(63.376^2 + 14.778^2)}$
= **4257 A**

Therefore, interrupting rating of the protective device must be at least 4257 A at Point E.

Point 1: Fault Current at Distribution Board LD1a

Sub Feeder Contribution: Primary

4-#500 MCM- 4"C + #1/0 G *Note: R and X from "ANSI/IEEE Std. 242-1986"*

L = 150 ft

R = 2.44 mΩ/100 ft

X = 3.96 mΩ/100 ft

Breaker: 400A, 3P

<u>Primary feeder contribution from MS, point B to transformer T1A:</u>

$\mathbf{R}_{\mathbf{conductor}}$ = (L / 100) x R x 1 / # of sets
= (150 / 100) x 2.44 x 1 / 1
= 3.66 mΩ

$\mathbf{X}_{\mathbf{conductor}}$ = (L / 100) x X_L x 1 / # of sets
= (150 / 100) x 3.96 x 1 / 1
= 5.94 mΩ

$\mathbf{Z}_{\mathbf{Total}}$ = Z_{MDP} + Z_{feeder}
= (1.176 + j6.367) + (3.66 + j5.94) = 4.836 + j12.307 mΩ = $\mathbf{Z}_{\mathbf{primary}}$

α = $V_{primary}$ / $V_{secondary}$ = 480 V / 208 V = 2.308
$1/\alpha^2$ = $1/(2.308)^2$ = 0.188

$\mathbf{Z}_{\mathbf{secondary}}$ = $1/\alpha^2$ x $Z_{primary}$
= 0.188 x (4.836 + j12.307)
= 0.909 + j2.313 mΩ

Contribution from transformer T1A:

Transformer T1A

225 KVA, 3Φ

%Z = 6.6

X/R = 2.0

Note: %Z and X/R from "ANSI/IEEE Std. 242-1986"

$\mathbf{R_{xfrmr}} = KV^2 \times \%Z \times 10^4 \times \cos(\tan^{-1}X/R) / KVA_{xfrmr}$

$= (0.208\ KV)^2 \times 6.6 \times 10^4 \times \cos(\tan^{-1}2) / 225\ KVA$

$= 5.68\ m\Omega$

$\mathbf{X_{xfrmr}} = KV^2 \times \%Z \times 10^4 \times \sin(\tan^{-1}X/R) / KVA_{xfrmr}$

$= (0.208\ KV)^2 \times 6.6 \times 10^4 \times \sin(\tan^{-1}2) / 225\ KVA$

$= 11.35\ m\Omega$

$\mathbf{Z_{total}} = Z_{secondary} + Z_{xfrmr}$

$= (0.909 + j2.313) + (5.68 + j11.35) = 6.589 + j13.663\ m\Omega$

Fault current at the primary of transformer T1A:

$\mathbf{I_{sc}} = V_{l\text{-}n} \times 1000 / |Z_{total}|$

$= 120 \times 1000 / \sqrt{(6.589^2 + 13.663^2)}$

= **7,910 A**

Impedance of Secondary Feeder:

Sub Feeder Contribution: Secondary

(2) 4-#600 MCM- (2) 4"C + (2) #1/0 G

Note: R and X from "ANSI/IEEE Std. 242-1986"

L = 5 ft

R = 2.09 mΩ/100 ft

X = 4.01 mΩ/100 ft

Breaker: 800A, 3P

$\mathbf{R_{conductor}}$ = (L / 100) x R x 1 / # of sets
= (5 / 100) x 2.09 x 1 / 2
= 0.052 mΩ

$\mathbf{X_{conductor}}$ = (L / 100) x X_L x 1 / # of sets
= (5 / 100) x 4.01 x 1 / 2
= 0.100 mΩ

$\mathbf{Z_{Total}}$ = Z_{MDP} + $Z_{secondary}$
= (6.589 + j13.663) + (0.052 + j0.100) = 6.641 + j13.763 mΩ

$\mathbf{I_{sc}}$ = $V_{l\text{-}n}$ x 1000 / $|Z_{Total}|$
= 120 x 1000 / $\sqrt{(6.641^2 + 13.763^2)}$
= **7,852 A**

Therefore, interrupting rating of the protective device must be at least 7,852 A at Point 1.

Point 2: Fault Current at Panel Board L1Aa

Sub Feeder Contribution

4-#1/0 THW - 2"C + #6 G *Note: R and X from "ANSI/IEEE Std. 242-1986"*

L = 10 ft

R = 10.40 mΩ/100 ft

X = 4.46 mΩ/100 ft

Breaker: 150A, 3P

$$\mathbf{R_{conductor}} = (L / 100) \times R \times 1 / \#\text{ of sets}$$
$$= (10 / 100) \times 10.4 \times 1 / 1$$
$$= 1.04\ m\Omega$$

$$\mathbf{X_{conductor}} = (L / 100) \times X_L \times 1 / \#\text{ of sets}$$
$$= (10 / 100) \times 4.46 \times 1 / 1$$
$$= 0.446\ m\Omega$$

$$\mathbf{Z_{Total}} = Z_{MDP} + Z_{secondary}$$
$$= (6.641 + j13.763) + (1.04 + j0.446) = 7.681 + j14.209\ m\Omega$$

$$\mathbf{I_{sc}} = V_{l\text{-}n} \times 1000 / |Z_{Total}|$$
$$= 120 \times 1000 / \sqrt{(7.681^2 + 14.209^2)}$$
$$= \underline{\mathbf{7{,}429\ A}}$$

Therefore, interrupting rating of the protective device must be at least 7,429 A at Point 2.

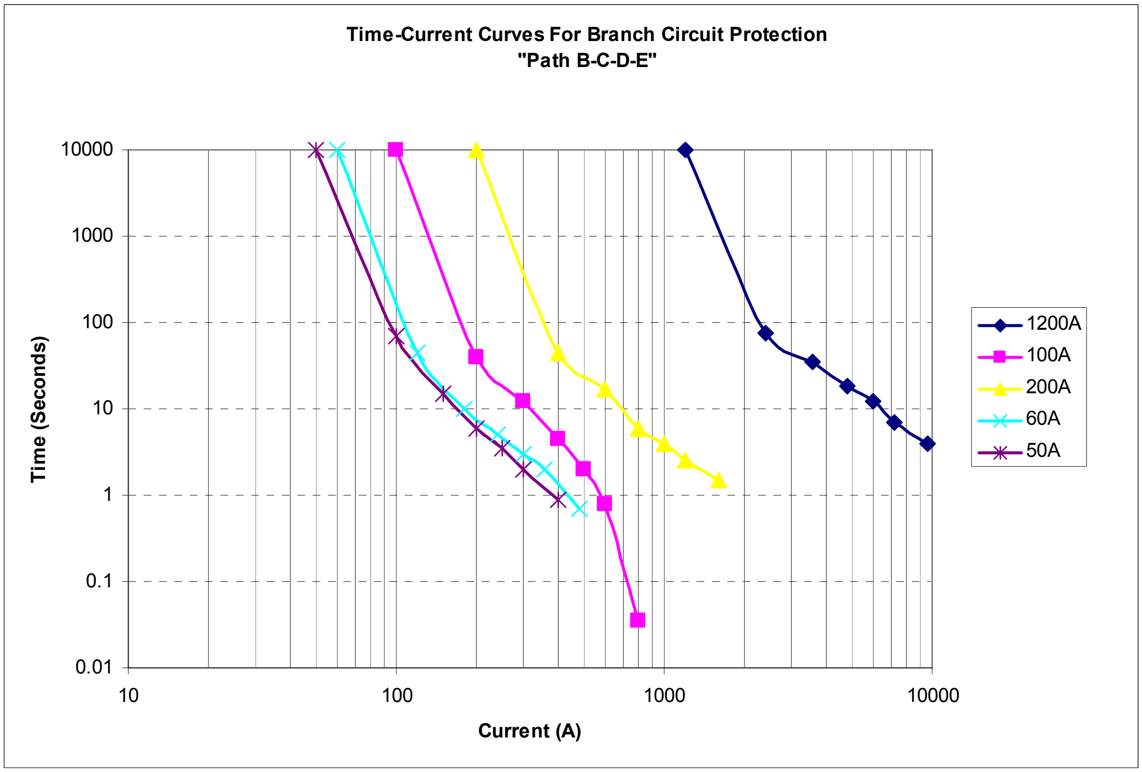
Fault Analysis Summary

Point	Location	Available Fault (A)	Standard Breaker Rating (A)
A	Utility Transformer Secondary	46,884	65,000
B	MS	42,781	50,000
C	Panelboard H1A	8,015	14,000
D	Panelboard H2A	6,673	14,000
E	Panelboard H3Aa	4,257	14,000
1	T1A Secondary	7,852	30,000
2	Panelboard L1Aa	7,429	14,000

All protective devices sized appropriately per NEC 2005.

Branch Circuit Overcurrent Protection Illustrations

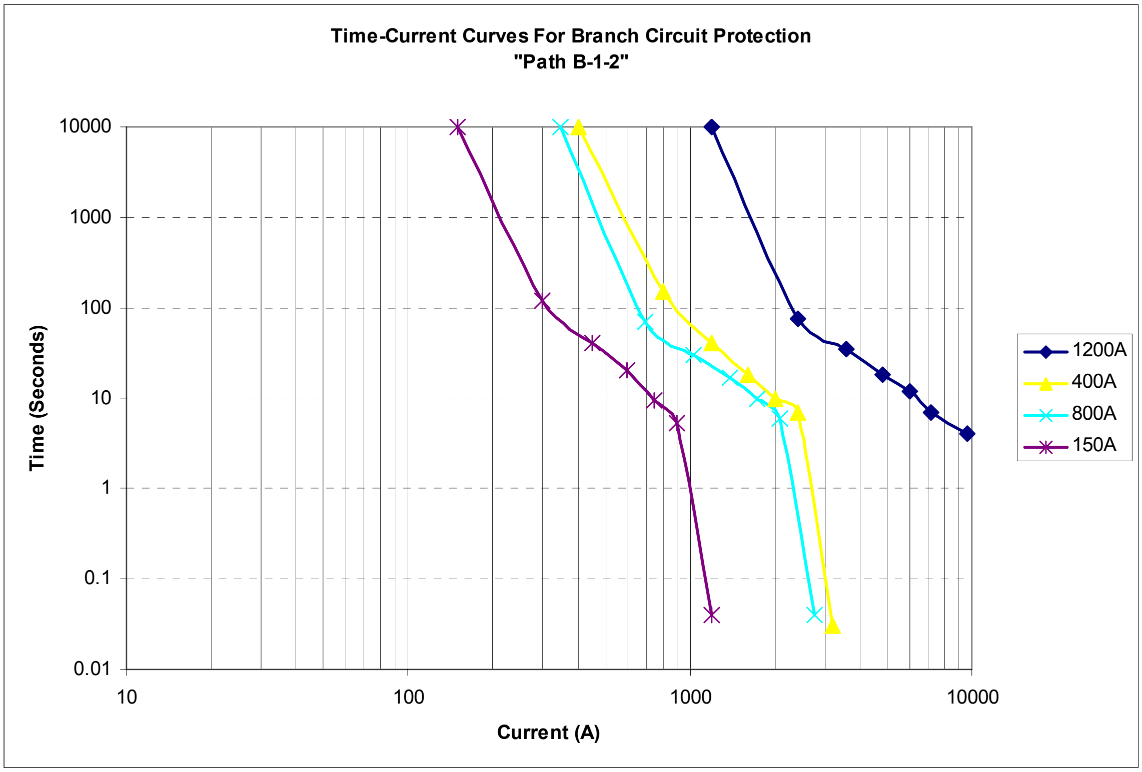
All logarithmic curves produced by determining the trip time at breaker trip ratings between 100-800% of unit rating.



Circuit breakers are coordinated.

Notes:

1. *For protection device specifications, please refer to Appendix E.*



Circuit breakers are coordinated.

Notes:

2. For overcurrent protection device specifications, please refer to Appendix E.

3. 400A circuit breaker located on primary of transformer T1A.

4. 800A circuit breaker located on secondary of transformer T1A. Fault currents multiplied using the following formula as recommended by Cutler-Hammer to reflect protection given by the primary.

$$I_{480} = 207\ V / 480\ V \times I_{207}$$

Evaluation

The newly redesigned electrical distribution system meets the requirements as outlined in NEC 2005. All newly designed lighting loads were grouped on the Lutron Graphik Eye Dimming Panel system (S-1) for better lighting load management in the four spaces that are part of the scope of this report. As the original system was significantly oversized, the newly designed lighting loads did not have much affect on the sizes of the electrical distribution equipment. All branch circuits complied with NEC voltage drop requirements and the protective device coordination study showed that the panelboards that were resized per the changes implemented all met NEC requirements.

Cost feasibility studies also showed that the proposed BIPV system and the potential implementation of energy efficient transformers resulted in reasonable payback periods and cost savings in addition to environmental benefits.