APPENDIX

A : EXISTING LOAD, CASE 1

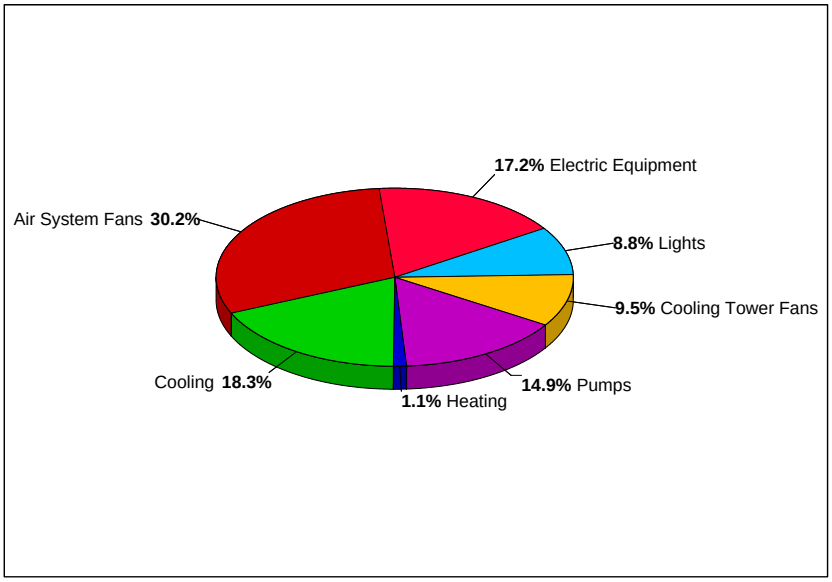


Figure A.1: Annual Component Costs, Case 1

Table A.1 : Annual Component Costs, Case 1

Case 1			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	292,714	3.465	30.2
Cooling	177,009	2.095	18.3
Heating	11,094	0.131	1.1
Pumps	144,445	1.71	14.9
Cooling Tower Fans	91,760	1.086	9.5
HVAC Sub-Total	**717,021**	**8.488**	**74**
Lights	85,243	1.009	8.8
Electric Equipment	166,278	1.968	17.2
Misc. Electric	0	0	0
Misc. Fuel Use	0	0	0
Non-HVAC Sub-Total	**251,521**	**2.977**	**26**
Grand Total	**968,542**	**11.465**	**100**

B : ALTERED LOAD, CASE 2

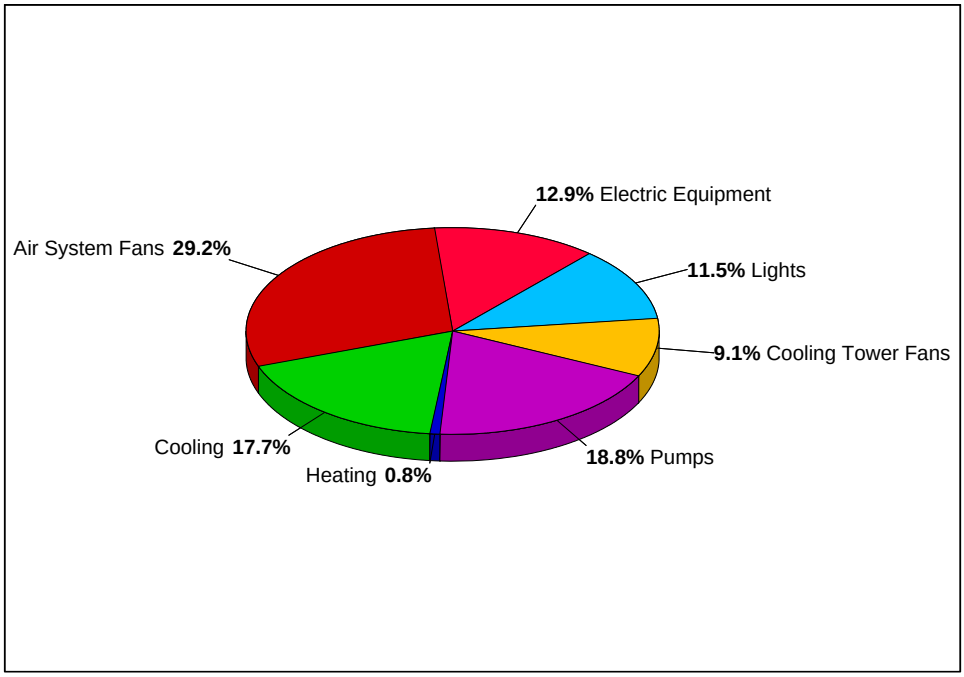


Figure A.2: Annual Component Costs, Case 2

Table A.2 : Annual Component Costs, Case 2

Case 2			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	221,498	2.622	29.2
Cooling	134,357	1.59	17.7
Heating	5,954	0.071	0.8
Pumps	142,650	1.689	18.8
Cooling Tower Fans	69,291	0.82	9.1
HVAC Sub-Total	**573,750**	**6.792**	**75.5**
Lights	87,521	1.036	11.5
Electric Equipment	98,300	1.164	12.9
Misc. Electric	0	0	0
Misc. Fuel Use	0	0	0
Non-HVAC Sub-Total	**185,821**	**2.2**	**24.5**
Grand Total	**759,571**	**8.991**	**100**

C : ALTERED LOAD, CASE 3

Table A.3 Adjusted Lighting Loads by Room

ZONE	ROOM	SPACE NAME	SPACE AREA A_z [SF]	Original Design			New Design	
				Lamps	Lighting Power [W]	Lighting Power Density [W/sf]	Lighting Power [W]	Lighting Power Density [W/sf]
2A	L295	LABORATORY	1,428	40-L1A, 16-L1, 2-L36	3,648	2.55	2,818	1.97
2A	S295	FUTURE CELL ARCHIVE	693	6-A	768	1.11	768	1.11
2A/B	L285	LABORATORY	3,010	80-L1A, 32-L1, 4-L36	7,296	2.42	5,940	1.97
2A	S285C	DARK ROOM	90	2-L8A	320	3.56	320	3.56
2A	S285D	SMALL COLD ROOM	90	0	0	0.00	0	0.00
2A	S285E	LARGE COLD ROOM	189	0	0	0.00	0	0.00
2A	S285F	MEDIUM SUPPORT	210	4-L8A	640	3.05	640	3.05
2A	S285G	MEDIUM SUPPORT	210	4-L8A	640	3.05	640	3.05
2B	S285S	SHELL SPACE	945	8-A	1,024	1.08	1,024	1.08
2B	L283	PANTRY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
2B	L282	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
2B	L281	OPEN FLEX	90	4-L8	256	2.84	108	1.20
2B	L275	LABORATORY	2,905	80-L1A, 32-L1, 4-L36	7,296	2.51	5,940	2.04
2B	S275D	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2B	S275E	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2B	S275F	MEDIUM SUPPORT	160	4-L8A	640	4.00	640	4.00
2B	S275G	MEDIUM SUPPORT	160	4-L8A	640	4.00	640	4.00
2B	S275H	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2B	S275J	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2B	S275K	LARGE SUPPORT	441	16-L8	2,560	5.80	1,024	2.32
2B	S275M	MEDIUM SUPPORT	120	4-L8A	640	5.33	640	5.33
2B	S275N	MEDIUM SUPPORT	120	4-L8A	640	5.33	640	5.33
2C	L270	LABORATORY	1,020	25-LIA, 10-L1, 1-L36	2,272	2.23	2,013	1.97
2C	S270A	LARGE SUPPORT	420	16-L8	2,560	6.10	1,024	2.44
2C	S270B	MEDIUM SUPPORT	150	4-L8A	640	4.27	640	4.27
2C	S270C	MEDIUM SUPPORT	150	4-L8A	640	4.27	640	4.27
2C	S275A	DARK ROOM	90	2-L8A	320	3.56	320	3.56
2C	S275B	SMALL COLD ROOM	90	0	0	0.00	0	0.00
2C	L272	COPY SUPPLY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
2C	L273	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
2C	L271	OPEN FLEX	90	4-L8	256	2.84	108	1.20
2C	S275C	LARGE COLD ROOM	160	0	0	0.00	0	0.00
2C	L265	LABORATORY	1,020	25-LIA, 10-L1, 1-L36	2,272	2.23	2,013	1.97
2C	S265A	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2C	S265B	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2C	S265C	MEDIUM SUPPORT	130	4-L8A	640	4.92	640	4.92
2C	S265D	MEDIUM SUPPORT	125	4-L8A	640	5.12	640	5.12
2C	S265E	AUTOCLAVE/SMALL GW	150	2-N1	128	0.85	128	0.85
2C	S265F	ISOTROPE LAB	115	3-L8A	480	4.17	320	2.78
2C	L263	CENTRAL SUPPLY	105	4-L8	256	2.45	125	1.20
2C	L262	COPY SUPPLY	313	4-L47, 2-L45B, 2L45	256	0.82	375	1.20
2C	L261	OPEN FLEX	114	4-L8	256	2.25	137	1.20
2C/D	L255	LABORATORY	3,010	90-L1A, 32-L1, 4-L36	7,936	2.64	5,940	1.97
2C/D	S255G	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2C/D	S255H	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2C	S255J	LARGE COLD ROOM	189	0	0	0.00	0	0.00
2C	S255K	DARK ROOM	100	2-L8A	320	3.20	320	3.20
2C	S255M	SMALL COLD ROOM	100	0	0	0.00	0	0.00
2D	S255	SHELL SPACE	987	8-A	1,024	1.04	1,024	1.04
2D	S255E	MEDIUM SUPPORT	170	4-L8A	640	3.76	640	3.76
2D	S255F	MEDIUM SUPPORT	170	4-L8A	640	3.76	640	3.76
2D	L253	CENTRAL SUPPLY	105	4-L8	256	2.45	125	1.20
2D	L252	PANTRY	313	4-L47, 2-L45B, 2L45	256	0.82	375	1.20
2D	L251	OPEN FLEX	114	4-L8	256	2.25	137	1.20

Table A.3 (cont'd) : Adjusted Lighting Loads by Room

ZONE	ROOM	SPACE NAME	SPACE AREA A_z [SF]	Original Design			New Design	
				Lamps	Lighting Power [W]	Lighting Power Density [W/sf]	Lighting Power [W]	Lighting Power Density [W/sf]
2D	S245H	MEDIUM SUPPORT	160	4-L8A	640	4.00	640	4.00
2D	S245J	MEDIUM SUPPORT	160	4-L8A	640	4.00	640	4.00
2D	S245K	LARGE SUPPORT	441	16-L8	2,560	5.80	1,024	2.32
2D	S245M	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2D	S245N	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2E	S245A	DARK ROOM	90	2-L8A	320	3.56	320	3.56
2E	S245B	SMALL COLD ROOM	99	0	0	0.00	0	0.00
2E	S245C	LARGE COLD ROOM	189	0	0	0.00	0	0.00
2E	S245D	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2E	S245E	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2E	S245F	MEDIUM SUPPORT	193	4-L8A	640	3.32	640	3.32
2E	S245G	MEDIUM SUPPORT	193	4-L8A	640	3.32	640	3.32
2E	L243	CENTRAL SUPPLY	105	4-L8	256	2.45	125	1.20
2E	L242	COPY SUPPLY	313	4-L47, 2-L45B, 2L45	256	0.82	375	1.20
2E	L241	OPEN FLEX	114	4-L8	256	2.25	137	1.20
2E	L240	LABORATORY	1,020	25-LIA, 10-L1, 1-L36	2,272	2.23	2,013	1.97
2E	S240A	AUTOCLAVE/SMALL GW	165	2-N1	128	0.78	128	0.78
2E	S240B	ISOTOPE LAB	143	3-L8A	480	3.36	320	2.24
2E	S240C	MEDIUM SUPPORT	154	4-L8A	640	4.16	640	4.16
2E	S240D	MEDIUM SUPPORT	143	4-L8A	640	4.48	640	4.48
2E	S240E	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2E	S240F	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2E	L235	LABORATORY	1,020	25-LIA, 10-L1, 1-L36	2,272	2.23	2,013	1.97
2E	S235C	LARGE SUPPORT	441	16-L8	2,560	5.80	1,024	2.32
2F	S235A	MEDIUM SUPPORT	150	4-L8A	640	4.27	640	4.27
2F	S235B	MEDIUM SUPPORT	150	4-L8A	640	4.27	640	4.27
2F	L225	LABORATORY	3,010	90-L1A, 32-L1, 4-L36	7,936	2.64	5,940	1.97
2F	S225E	MEDIUM SUPPORT	187	4-L8A	640	3.42	640	3.42
2F	S225F	MEDIUM SUPPORT	187	4-L8A	640	3.42	640	3.42
2F	S225G	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2F	S225H	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2F	S225J	LARGE COLD ROOM	189	0	0	0.00	0	0.00
2F	S225K	DARK ROOM	100	2-L8A	320	3.20	320	3.20
2F	S225M	SMALL COLD ROOM	99	0	0	0.00	0	0.00
2F	S255S	SHELL SPACE	987	8-A	1,024	1.04	1,024	1.04
2F	L223B	CENTRAL SUPPLY	105	4-L8	256	2.45	125	1.20
2F/G	L223A	PANTRY	313	4-L47, 2-L45B, 2L45	256	0.82	375	1.20
2F/G	L221	OPEN FLEX	114	4-L8	256	2.25	137	1.20
2G	L215	LABORATORY	3,010	85-L1A, 34-L1, 4-L36	7,744	2.57	5,940	1.97
2G	S215A	MEDIUM SUPPORT	165	4-L8A	640	3.88	640	3.88
2G	S215B	MEDIUM SUPPORT	165	4-L8A	640	3.88	640	3.88
2G	S215E	LARGE COLD ROOM	189	0	0	0.00	0	0.00
2G	S215F	DARK ROOM	100	2-L8A	320	3.20	320	3.20
2G	S215G	SMALL COLD ROOM	99	0	0	0.00	0	0.00
2G	S215H	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2G	S215J	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
2G	S215K	LARGE SUPPORT	441	16-L8	2,560	5.80	1,024	2.32
2G	S215M	MEDIUM SUPPORT	226	4-L8A	640	2.84	640	2.84
2G	S215N	MEDIUM SUPPORT	226	4-L8A	640	2.84	640	2.84
2G	L210	LABORATORY	1,242	35-LIA,14-LA, 4-L36	3,264	2.63	2,451	1.97
2G	S210	SHELL SPACE	609	8-A	1,024	1.68	1,024	1.68

Table A.3(cont'd) : Adjusted Lighting Loads by Room

ZONE	ROOM	SPACE NAME	SPACE AREA A_z [SF]	Original Design			New Design	
				Lamps	Lighting Power [W]	Lighting Power Density [W/sf]	Lighting Power [W]	Lighting Power Density [W/sf]
3A	S390B	LARGE COLD ROOM	189	0	0	0.00	0	0.00
3A	S390C	MEDIUM SUPPORT	226	4-L8A	640	2.84	640	2.84
3A	S388	CHEMISTY LAB	483	12-L8	768	1.59	768	1.59
3A	L388	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
3A/B	L387	COPY SUPPLY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
3A/B	L386	OPEN FLEX	90	4-L8	256	2.84	108	1.20
3B	L380	LABORATORY	3,003	90-L1A,36-LA,3-L36	8,160	2.72	5,926	1.97
3B	S380A	CHEMISTY LAB	483	12-L8	768	1.59	768	1.59
3B	S380B	CHEMISTY LAB	483	12-L8	768	1.59	768	1.59
3B	S380C	CHEMISTY LAB	483	12-L8	768	1.59	768	1.59
3B	S380D	CHEMISTY LAB	483	12-L8	768	1.59	768	1.59
3B	S380E	CHEMISTY LAB	483	12-L8	768	1.59	768	1.59
3B	L375	PANTRY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
3B	L378	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
3B	L376	OPEN FLEX	90	4-L8	256	2.84	108	1.20
3B/C	L370	LABORATORY	2,760	75-LAI,30-LA,4-L36	6,848	2.48	5,447	1.97
3B	S370G	LARGE COLD ROOM	147	0	0	0.00	0	0.00
3B	S375	TISSUE CULTURE	441	16-L8	1,024	2.32	1,024	2.32
3B/C	S370D	MEDIUM SUPPORT	165	4-L8A	640	3.88	640	3.88
3B/C	S370E	MEDIUM SUPPORT	165	4-L8A	640	3.88	640	3.88
3C	S370A	LARGE SUPPORT	441	16-L8	2,560	5.80	1,024	2.32
3C	S370B	MEDIUM SUPPORT	140	4-L8A	640	4.57	640	4.57
3C	S370C	MEDIUM SUPPORT	140	4-L8A	640	4.57	640	4.57
3D/C	L360	LABORATORY	2,760	75-LAI,30-LA,4-L36	6,848	2.48	5,447	1.97
3C	S360D	MEDIUM SUPPORT	205	4-L8A	640	3.12	640	3.12
3C	S360E	MEDIUM SUPPORT	205	4-L8A	640	3.12	640	3.12
3C	S360F	MEDIUM SUPPORT	205	4-L8A	640	3.12	640	3.12
3C	S360G	MEDIUM SUPPORT	205	4-L8A	640	3.12	640	3.12
3C	S360H	AUTOCLAVE/SMALL GW	120	2-N1	128	1.07	128	1.07
3C	S360J	ISOTOPE LAB	120	3-L8A	480	4.00	320	2.67
3D	S360C	LARGE COLD ROOM	180	0	0	0.00	0	0.00
3D	S360A	DARK ROOM	90	2-L8A	320	3.56	320	3.56
3D	S360B	SMALL COLD ROOM	90	0	0	0.00	0	0.00
3C	L357	PANTRY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
3C	L358	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
3C	L356	OPEN FLEX	90	4-L8	256	2.84	108	1.20
3D	L350	LABORATORY	2,760	75-LAI,30-LA,4-L36	6,848	2.48	5,447	1.97
3D	S355	SHELL SPACE	882	8-A	1,024	1.16	1,024	1.16
3D	S350A	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3D	S350B	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3D	S350C	LARGE SUPPORT	441	16-L8	2,560	5.80	1,024	2.32
3D	S350D	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3D	S350E	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3D	L348	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
3D/E	L347	COPY SUPPLY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
3D/E	L346	OPEN FLEX	90	4-L8	256	2.84	108	1.20
3E	L340	LABORATORY	2,760	75-LAI,30-LA,2-L36	6,784	2.46	5,447	1.97
3E	S340A	LARGE SUPPORT	441	16-L8	1,024	2.32	1,024	2.32
3E	S340B	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3E	S340C	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3E	S340D	MEDIUM SUPPORT	231	4-L8A	640	2.77	640	2.77
3E	S340E	MEDIUM SUPPORT	231	4-L8A	640	2.77	640	2.77
3E	S340F	LARGE COLD ROOM	189	0	0	0.00	0	0.00
3E	S340G	DARK ROOM	100	2-L8A	320	3.20	320	3.20
3E	S340H	SMALL COLD ROOM	99	0	0	0.00	0	0.00

Table A.3 (cont'd) : Adjusted Lighting Loads by Room

ZONE	ROOM	SPACE NAME	SPACE AREA A_z [SF]	Original Design			New Design	
				Lamps	Lighting Power [W]	Lighting Power Density [W/sf]	Lighting Power [W]	Lighting Power Density [W/sf]
3E/F	L330	LABORATORY	2,275	75-LAI,30-LA,4-L36	6,848	3.01	4,490	1.97
3E	S330H	AUTOCLAVE/SMALL GW	100	2-N1	128	1.28	128	1.28
3E	S330J	ISOTOPE LAB	100	3-L8A	480	4.80	320	3.20
3F	S330A	DARK ROOM	100	2-L8A	320	3.20	320	3.20
3F	S330B	SMALL COLD ROOM	99	0	0	0.00	0	0.00
3F	S330C	LARGE COLD ROOM	189	0	0	0.00	0	0.00
3F	S330D	MEDIUM SUPPORT	220	4-L8A	640	2.91	640	2.91
3F	S330E	MEDIUM SUPPORT	220	4-L8A	640	2.91	640	2.91
3F	S330F	MEDIUM SUPPORT	220	4-L8A	640	2.91	640	2.91
3F	S330G	MEDIUM SUPPORT	220	4-L8A	640	2.91	640	2.91
3F	L326	OPEN FLEX	90	4-L8	256	2.84	108	1.20
3F	L327	PANTRY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
3F	L328	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
3F/G	L320	LABORATORY	2,870	80-LAI,32-LA,4-L36	7,296	2.54	5,664	1.97
3F	S325	SHELL SPACE	882	8-A	1,024	1.16	1,024	1.16
3G	S320A	DARK ROOM	100	2-L8A	320	3.20	320	3.20
3G	S320B	SMALL COLD ROOM	99	0	0	0.00	0	0.00
3G	S320C	LARGE COLD ROOM	189	0	0	0.00	0	0.00
3G	S320D	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3G	S320E	SMALL SUPPORT	100	2-L8A	320	3.20	320	3.20
3G	L317	COPY SUPPLY	352	4-L47, 2-L45B, 2L45	256	0.73	422	1.20
3G	L318	CENTRAL SUPPLY	90	4-L8	256	2.84	108	1.20
3G	L316	OPEN FLEX	90	4-L8	256	2.84	108	1.20
3G	L315	LABORATORY	1,260	25-L1A, 10-LA, 2-L36	2,304	1.83	2,487	1.97
3G	S315	SHELL SPACE	693	8-A	1,024	1.48	1,024	1.48
TOTAL			**81,456**		**188,064**	**2.31**	**152,341**	**1.87**

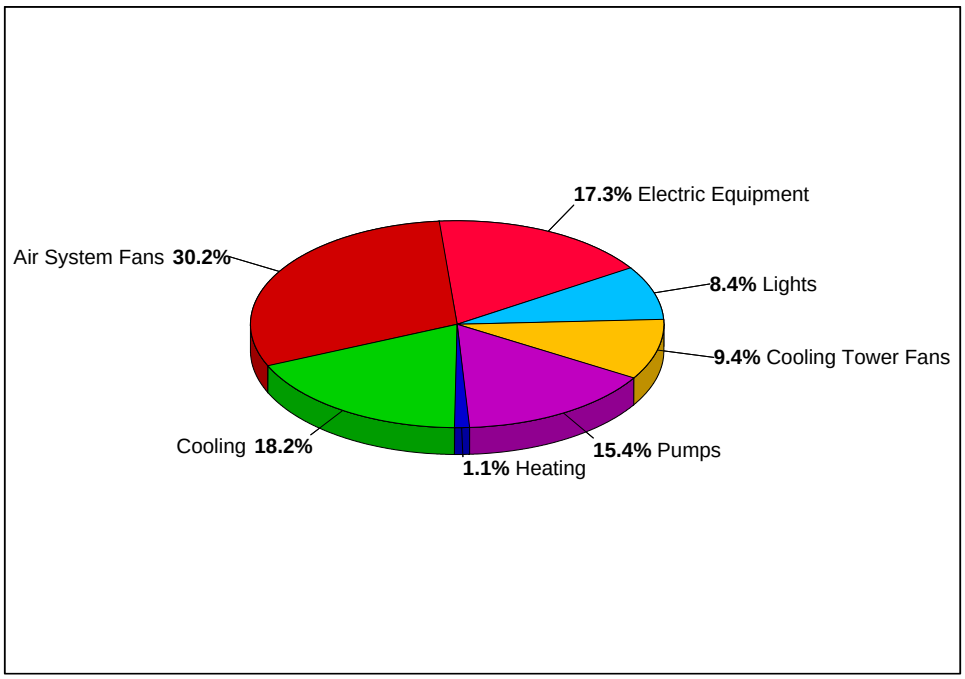


Figure A.3: Annual Component Costs, Case 3

Table A.4 : Annual Component Costs, Case 3

Case 3			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	290,539	3.439	30.2
Cooling	175,252	2.075	18.2
Heating	10,801	0.128	1.1
Pumps	147,764	1.749	15.4
Cooling Tower Fans	90,798	1.075	9.4
HVAC Sub-Total	**715,154**	**8.465**	**74.3**
Lights	80,959	0.958	8.4
Electric Equipment	166,321	1.969	17.3
Misc. Electric	0	0	0
Misc. Fuel Use	0	0	0
Non-HVAC Sub-Total	**247,280**	**2.927**	**25.7**
Grand Total	**962,434**	**11.393**	**100**

D : ALTERED LOAD, CASE 4

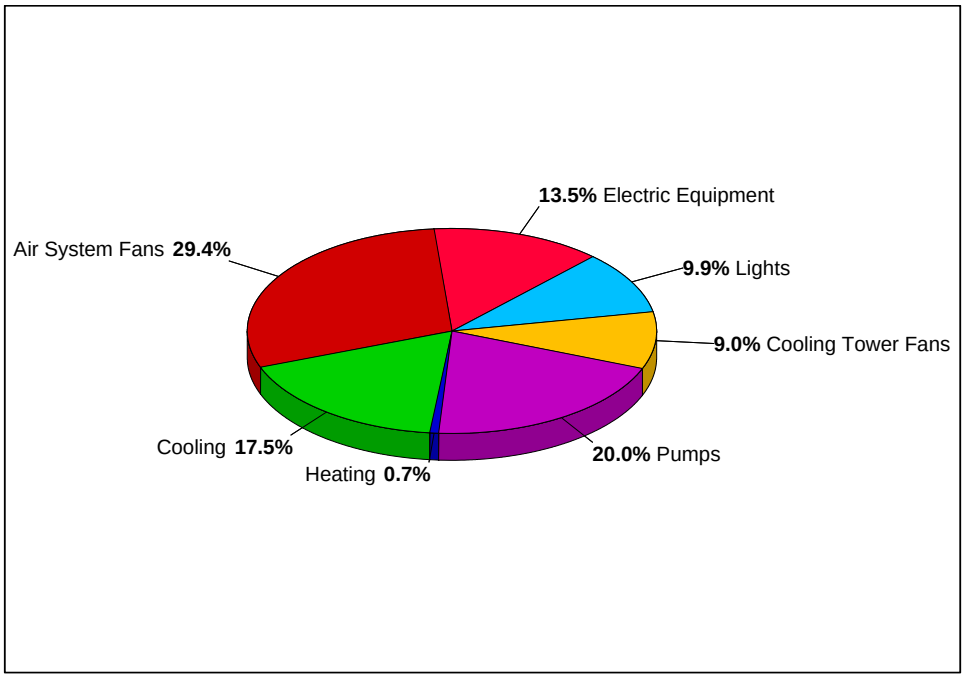


Figure A.4: Annual Component Costs, Case 4

Table A.5 : Annual Component Costs, Case 4

Case 4			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	213,669	2.529	29.4
Cooling	127,372	1.508	17.5
Heating	5,004	0.059	0.7
Pumps	145,725	1.725	20
Cooling Tower Fans	65,475	0.775	9
HVAC Sub-Total	**557,245**	**6.596**	**76.6**
Lights	71,930	0.851	9.9
Electric Equipment	98,290	1.164	13.5
Misc. Electric	0	0	0
Misc. Fuel Use	0	0	0
Non-HVAC Sub-Total	**170,220**	**2.015**	**23.4**
Grand Total	**727,465**	**8.611**	**100**

E : GROUND-COUPLED CALCULATION, CASE 5

RETScreen® International Ground-Source Heat Pump Project Model was used to aid in the design process. This program uses the building's heating and cooling loads, local weather data, and ground data to calculate an approximate system. The following tables summarize design information for a closed loop vertical system.

Table A.6

Ground Exchanger System	
System Type	Vertical closed-loop
Design Criteria	Cooling
Typcial Land Area Required [SF]	280,500
Ground Loop Layout	Standard
Total Bore Length [FT]	61,185

Table A.7

Cost Analysis			
	Quantity	**Unit Cost**	**Total [$]**
Energy Equipment			
Well Pumps	7	6,150	43,050
Heat Exchangers	4	6,636	26,544
Drilling & Backfill [ft]	61,185	3.66	223,815
Ground Loop Pipes	61,185	11	673,035
Fittings and valves [kW cooling]	2,403	12	28,841
Subtotal			**995,284**
Balance System			
Supplemental Heating System [kW]	0.0	--	0.00
Supplememtal Heat Rejection [kW]	0.0	--	0.00
Supplemental Cooling System [kW]	0.0	--	0.00
Internal Piping & Insulation [kW cooling]	2,403	60	144,203
Subtotal			144,203
Total First Cost			**1,139,488**

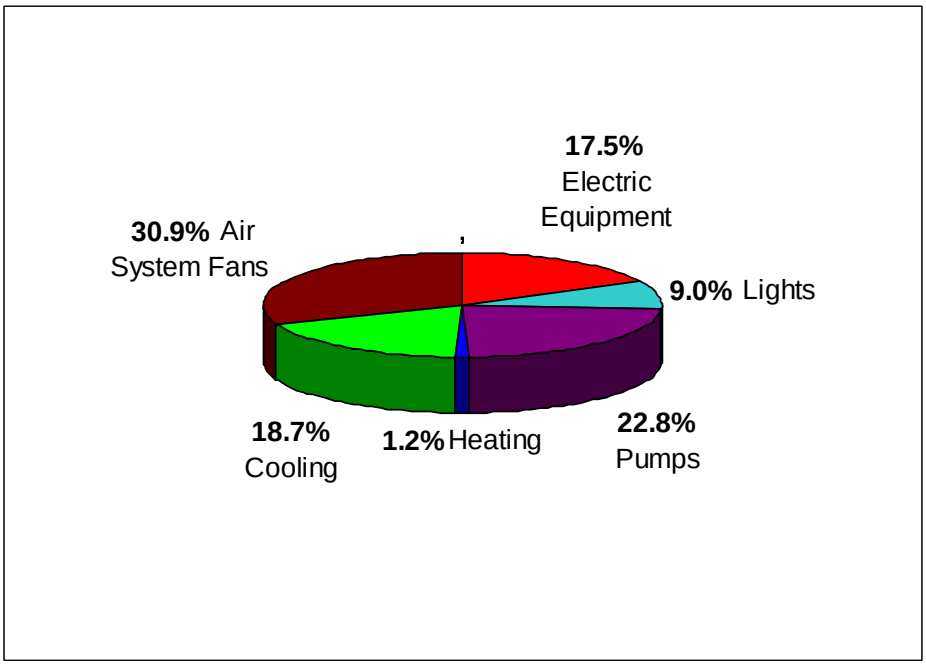


Figure A.5 : Annual Component Costs, Case 5

Table A.8 : Annual Component Costs, Case 5

Case 5			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	292,714	3.465	30.9
Cooling	177,009	2.095	18.7
Heating	11,094	0.131	1.2
Pumps	216,458	2.562	22.8
Cooling Tower Fans	0	0.000	0.0
HVAC Sub-Total	**697,275**	8.254	73.5
Lights	85,243	1.009	9.0
Electric Equipment	166,278	1.968	17.5
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**251,521**	2.977	26.5
Grand Total	**948,796**	11.232	100.0

Table A.9

Ground Loop System Pump for Case 5				
	Description	**Loss**	**Units**	**Notes**
Pipe Friction Loss	Total Building Height	--	ft	Basement to pump
	Bore Length	61,184	ft	Assumed distance from Upper Pond to HTX
	Friction Rate	2.5	ft/100 ft	Assumed
	Multiplier	1.25		Accounts for piping and fittings
	Pipe friction loss	**1,912**	**ft wg**	
	Pipe friction loss = 1.25 x system length (ft) x friction rate (ft/100 ft)			
Other Head Loss	HTX Head Loss	4.8	ft wg	Given by equipment cut sheet
	Control Valve Head Loss	10	ft wg	Assumed
	Total Other Losses	**14.8**	**ft wg**	
Total Pump Head	Pipe Friction Loss	1,912	ft wg	
	Other Head Losses	14.8	ft wg	
	Subtotal	1,927	ft wg	
	Safety Factor	15	%	Assumed
	Total Pump Head	**2,216**	**ft wg**	

F : GROUND-COUPLED CALCULATION, CASE 6

Table A.10

Cost Analysis			
	Quantity	**Unit Cost**	**Total [$]**
Energy Equipment			
Well Pumps	4	3,050	12,200
Heat Exchangers	4	6,636	26,544
Drilling & Backfill [ft]	300	3.66	1,097
Fittings and valves [kW cooling]	2,403	12	28,841
Subtotal			**68,682**
Balance System			
Supplemental Heating System [kW]	0.0	--	0.00
Supplememtal Heat Rejection [kW]	0.0	--	0.00
Supplemental Cooling System [kW]	0.0	--	0.00
Internal Piping & Insulation [kW cooling]	2,403	60	144,203
Subtotal			144,203
Total First Cost			**212,885**

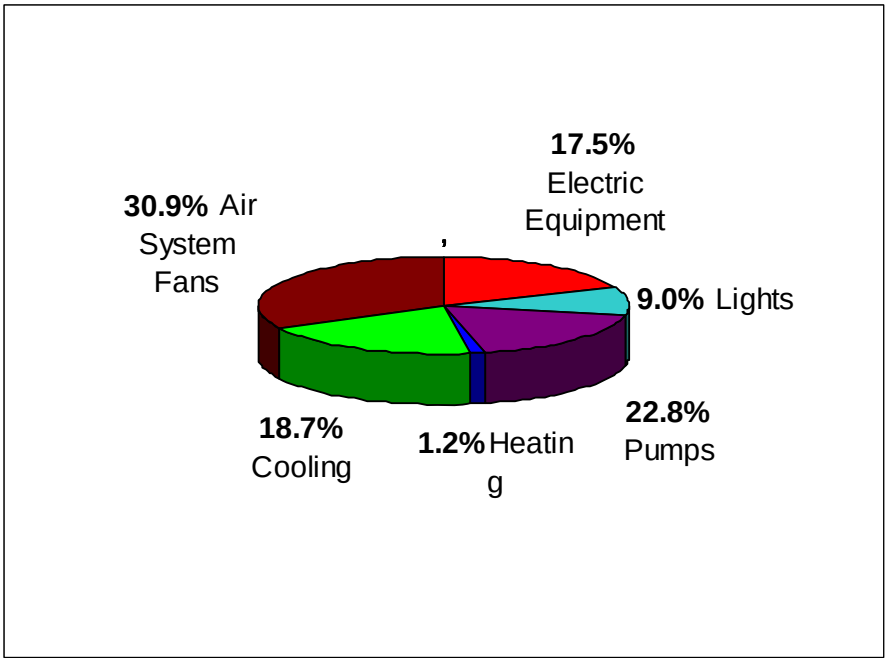


Figure A.6 : Annual Component Costs, Case 6

Table A.11 : Annual Component Costs, Case 6

Case 6			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	292,714	3.465	32.6
Cooling	177,009	2.095	19.7
Heating	11,094	0.131	1.2
Pumps	166,553	1.972	18.5
Cooling Tower Fans	0	0.000	0.0
HVAC Sub-Total	**647,370**	7.664	72.0
Lights	85,243	1.009	9.5
Electric Equipment	166,278	1.968	18.5
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**251,521**	2.977	28.0
Grand Total	**898,891**	10.641	94.7

Table A.12

Ground Loop System Pump for Pond Loop				
	Description	**Loss**	**Units**	**Notes**
Pipe Friction Loss	Total Building Height	20	ft	Bottom of Upper Pond to pump
	Supply Distance	560	ft	Assumed distance from Upper Pond to HTX
	Discharge Distance	280	ft	Assumed distance from HTX to Lower Pond
	Net Verticle Discharge Height	-34	ft	Pressure of pond on top of discharge pipe
	System Length	860		Omitting negative vertical head as a saftey
	Friction Rate	2.5	ft/100 ft	Assumed
	Multiplier	1.25		Accounts for piping and fittings
	Pipe friction loss	**26.9**	**ft wg**	
	Pipe friction loss = 1.25 x system length (ft) x friction rate (ft/100 ft)			
Other Head Loss	HTX Head Loss	10	ft wg	Given by equipment cut sheet
	Control Valve Head Loss	10	ft wg	Assumed
	Total Other Losses	**20**	**ft wg**	
Total Pump Head	Pipe Friction Loss	26.9	ft wg	
	Other Head Losses	20	ft wg	
	Subtotal	46.9	ft wg	
	Safety Factor	15	%	Assumed
	Total Pump Head	**53.9**	**ft wg**	
Pipe Friction Loss	Total Height	14	ft	Bottom of Lower Pond to Bottom of Upper Pond
	Distance	92	ft	Distance Between Ponds
	System Length	106	ft	Total Length of Pipe
	Friction Rate	2.5	ft/100 ft	Assumed
	Multiplier	1.25		Accounts for piping and fittings
	Pipe friction loss	**3.3**	**ft wg**	
	Pipe friction loss = 1.25 x system length (ft) x friction rate (ft/100 ft)			
Other Head Loss	HTX Head Loss	10	ft wg	Given by equipment cut sheet
	Control Valve Head Loss	10	ft wg	Assumed
	Total Other Losses	**20**	**ft wg**	
Total Pump Head	Pipe Friction Loss	3.3	ft wg	
	Other Head Losses	20	ft wg	
	Subtotal	23.3	ft wg	
	Safety Factor	15	%	Assumed
	Total Pump Head	**26.8**	**ft wg**	

G : GROUND-COUPLED CALCULATION, CASE 7

Table A.13

Cost Analysis			
	Quantity	**Unit Cost**	**Total [$]**
Energy Equipment			
Well Pumps	4	3,050	12,200
Heat Exchangers	4	6,636	26,544
Drilling & Backfill [ft]	300	3.66	1,097
Fittings and valves [kW cooling]	1,729	12	20,753
Subtotal			**60,595**
Balance System			
Supplemental Heating System [kW]	0.0	--	0.00
Supplememtal Heat Rejection [kW]	0.0	--	0.00
Supplemental Cooling System [kW]	0.0	--	0.00
Internal Piping & Insulation [kW cooling]	1,729	60	103,767
Subtotal			103,767
Total First Cost			**164,362**

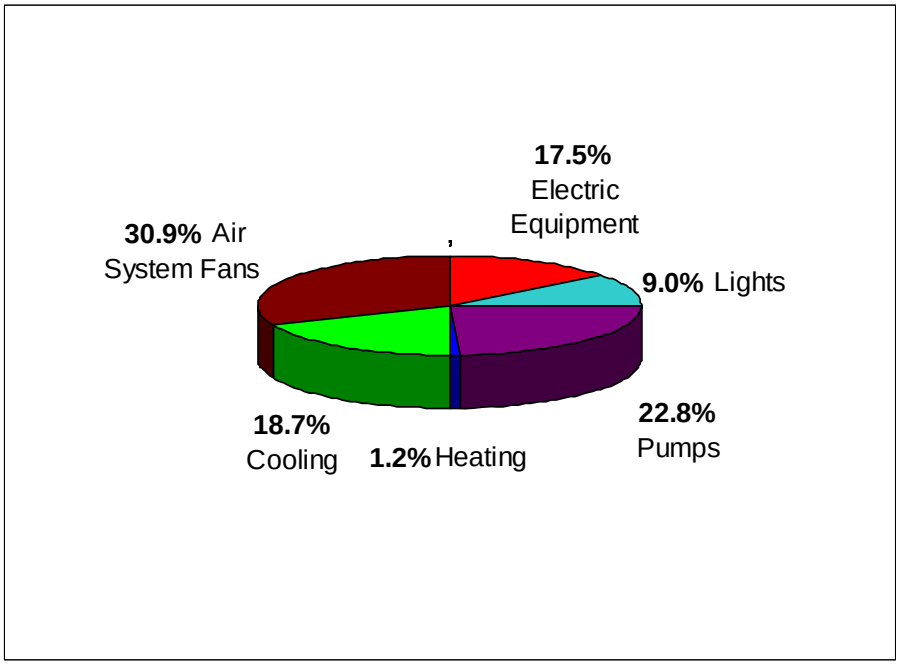


Figure A.7 : Annual Component Costs, Case 7

Table A.14 : Annual Component Costs, Case 7

Case 7			
Component	**Annual Cost [$]**	**($/ft²)**	**Percent of Total [$]**
Air System Fans	213,669	2.529	31.3
Cooling	127,372	1.508	18.7
Heating	5,004	0.059	0.7
Pumps	166,553	1.972	24.4
Cooling Tower Fans	0	0.000	0.0
HVAC Sub-Total	**512,598**	6.068	75.1
Lights	71,930	0.852	10.5
Electric Equipment	98,290	1.164	14.4
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**170,220**	2.015	24.9
Grand Total	**682,818**	8.083	100.0

H : EMISSIONS

CASE 1

Table A.15

Annual Energy Consumption : Case 1	
HVAC Components	
Electric [kWh]	9,353,516
Natural Gas [Therm]	19,462
Non-HVAC Components	
Electric [kWh]	3,502,690
Totals	
Electric [kWh]	12,856,210
Natural Gas [Therm]	19,462

Table A.15

Emissions : Case 1	
CO2 [lb]	17,767,460
SO2 [kg]	43,968
NOx [kg]	25,863

CASE 4

Table A.16

Annual Energy Consumption : Case 4	
HVAC Components	
Electric [kWh]	7,366,263
Natural Gas [Therm]	8,780
Non-HVAC Components	
Electric [kWh]	2,375,036
Totals	
Electric [kWh]	9,741,298
Natural Gas [Therm]	8,780

Table A.17

Emissions : Case 4	
CO2 [lb]	13,454,910
SO2 [kg]	33,316
NOx [kg]	19,590

CASE 5

Table A.18

Annual Energy Consumption : Case 5	
HVAC Components	
Electric [kWh]	9,200,894
Natural Gas [Therm]	19,462
Non-HVAC Components	
Electric [kWh]	3,502,690
Totals	
Electric [kWh]	12,703,584
Natural Gas [Therm]	19,462

Table A.19

Emissions : Case 1	
CO2 [lb]	17,037,615
SO2 [kg]	42,166
NOx [kg]	24,802

CASE 6

Table A.20

Annual Energy Consumption : Case 6	
HVAC Components	
Electric [kWh]	8,581,234
Natural Gas [Therm]	19,462
Non-HVAC Components	
Electric [kWh]	3,502,690
Totals	
Electric [kWh]	12,083,924
Natural Gas [Therm]	19,462

Table A.21

Emissions : Case 6	
CO2 [lb]	16,149,600
SO2 [kg]	39,966
NOx [kg]	23,508

CASE 7

Table A.22

Annual Energy Consumption : Case 7	
HVAC Components	
Electric [kWh]	6,817,169
Natural Gas [Therm]	8,780
Non-HVAC Components	
Electric [kWh]	2,375,036
Totals	
Electric [kWh]	9,192,205
Natural Gas [Therm]	8,780

Table A.23

Emissions : Case 7	
CO2 [lb]	12,357,992
SO2 [kg]	30,600
NOx [kg]	17,993

I : CUT SHEETS

- Original Design
  - Marley NC Class Cooling Tower
- Ground Loop Design
  - Armstrong Series 4300 Split Coupled Pumps
  - SWEP Heat Exchanger Diagram
- Pond Loop Design
  - Bell & Gossett 1050 Series 4BC Pumps
  - Bell & Gossett 1050 Series 5A Pumps

Marley UPDATE™ Version 4.7.0
Product Data: 3/22/2006

4/1/2006 8:16:53 PM

Job Information

Thesis
Julie Thorpe
State College

Selected By

Penn State
104 Engineering Unit A
University Park, PA
wpb5@psu.edu

PSUAE
Tel 814-863-2076

SPX Cooling Technologies Contact

H & H Associates, Inc.
4510 Westport Drive
Mechanicsburg, PA 17055
frank@hhassociates.com

Tel 717-796-2401
Fax 717-796-9717

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm
Product	NC Class	Fan Motor Capacity per cell	75.00 BHp
Model	NC8311J1	Fan Motor Output per cell	75.00 BHp
Cells	1	Fan Motor Output total	75.00 BHp
CTI Certified	Yes	Air Flow per cell	258300 cfm
Fan	11.00 ft, 7 Blades	Air Flow total	258300 cfm
Fan Speed	323 rpm, 11162 fpm	ASHRAE 90.1 Performance	46.0 gpm/Hp
Fans per cell	1		

Sound Pressure Level 84 dBA/Cell, 5.00 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	2400 gpm	Air Density In	0.07094 lb/ft³
Hot Water Temperature	99.50 °F	Air Density Out	0.07053 lb/ft³
Range	14.50 °F	Humidity Ratio In	0.01712
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.03323
Approach	7.00 °F	Wet-Bulb Temp. Out	91.93 °F
Wet-Bulb Temperature	78.00 °F	Estimated Evaporation	34 gpm
Relative Humidity	50 %	Total Heat Rejection	17332000 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	17220 lb	17220 lb
Max Operating Weight	36620 lb	36620 lb
Width	22.42 ft	22.42 ft
Length	11.90 ft	11.90 ft
Height	19.81 ft	
Static Lift	19.07 ft	

Minimum Enclosure Clearance

Clearance required on air inlet sides of tower without altering performance. Assumes no air from below tower.

Solid Wall	9.49 ft
50 % Open Wall	7.31 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8311.dxf

Cold Weather Operation

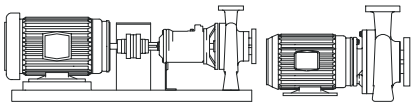
Heater Sizing (to prevent freezing in the collection basin during periods of shutdown)

Heater kW/Cell	24.0	18.0	15.0	12.0	9.0	7.5	6.0
Ambient Temperature °F	-15.76	-0.75	6.76	14.26	21.77	25.52	29.27

ARMSTRONG®

PERFORMANCE CURVES

Performance Guaranteed Only At Operating Point Indicated



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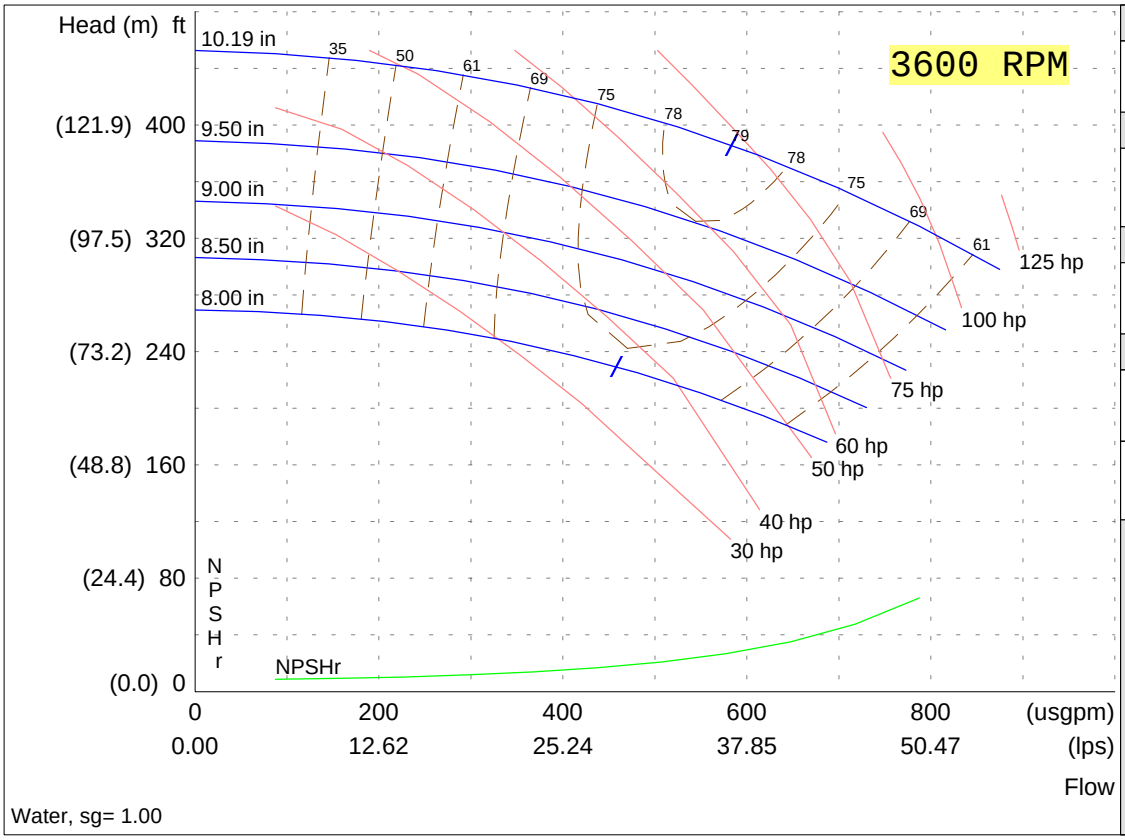
Supersedes:	NEW
Date:	NEW



CURVE NO.
PT53-1-0-3600
SERIES
4030 4280
SIZE
3x2.5x10
RPM
3600
BHP based on shown Fluid's sp. gr.

AVAILABILITY

4030 All Ratings
4280 All Ratings

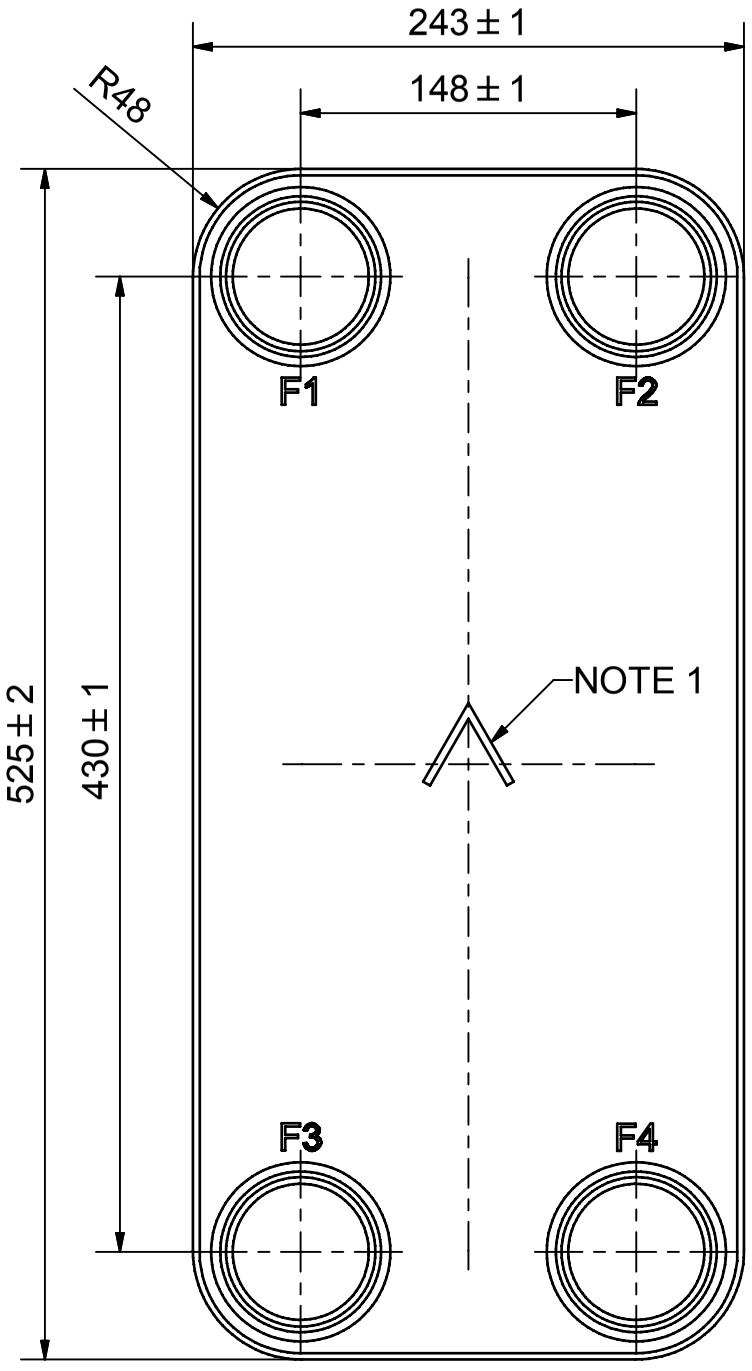
S.A. Armstrong Limited
23 Bertrand Ave.
Toronto, Ontario
Canada, M1L 2P3
Tel: (416) 755-2291
Fax: (416) 759-9101

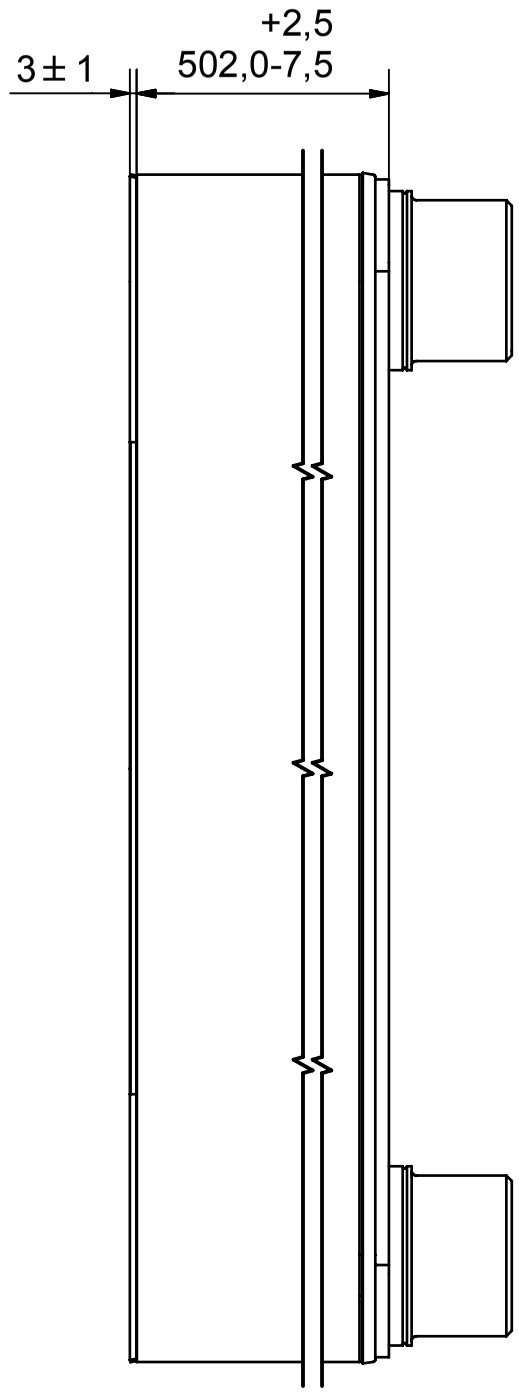
Armstrong Pumps Limited
Peartree Road, Stanway
Colchester, Essex
United Kingdom, C03 5JX
Tel: 01206-579491
Fax: 01206-760532

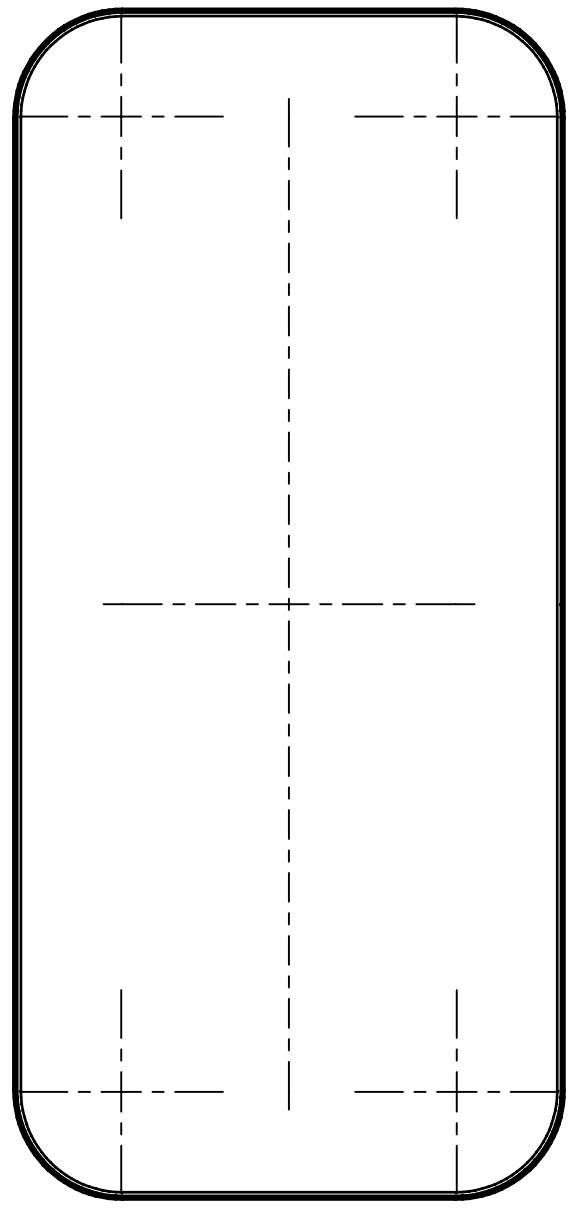
Armstrong Pumps Inc.
93 East Avenue
Buffalo, New York
USA, 14120-6594
Tel: (716) 693-8813
Fax: (716) 693-8970

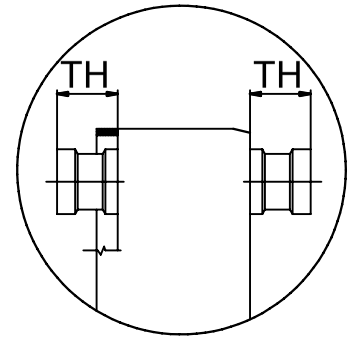
Armstrong Darling Inc.
2200 Place Transcanadienne
Montreal, Quebec
Canada, H9P 2X5
Tel: (514) 421-2424
Fax: (514) 421-2436

Visit us at www.armstrongpumps.com









NOTE 1 ALTERNATE MARKING: STICKER OR STAMP

Pos	Article No	Title / Denomination, code, material, dimension etc	Drawing No./ref
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F2	46098	NPT 2 1/2-8, TH = 54,2	CD000295
F3	46098	NPT 2 1/2-8, TH = 54,2	CD000295
F4	46098	NPT 2 1/2-8, TH = 54,2	CD000295

Pos	Article No	Title / Denomination, code, material, dimension etc	Drawing No./ref

Title: B56Hx200/1P-SC-S 4*2 1/2"NPT

A DOVER COMPANY

Created Date	Created By
2006-03-31	AU

Article/Configuration number	Drawing number
11487-200	AU00005186

Bell & Gossett

SUBMITTAL

B-225.1F

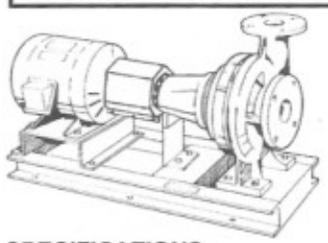
JOB: Thesis Report

REPRESENTATIVE: Cummins-Wagner Co., Inc.

UNIT TAG: P-3
ENGINEER:
CONTRACTOR:

ORDER NO.
SUBMITTED BY:
APPROVED BY:

DATE: 3/31/2006
DATE:
DATE:



4BC
Series 1510
Centrifugal Pumps - Base Mounted

SPECIFICATIONS

FLOW 570 (GPM) HEAD 54 (FT)
HP 15 RPM 1800
VOLTS 230/460
CYCLE 60 PHASE 3
Lincoln ODP Inverter Duty
APPROX. WEIGHT 439
SPECIALS Special Coupling(Dodge Paraflex)

Note: Equipped with EPDM coupling

MATERIALS OF CONSTRUCTION

☒ BRONZE FITTED ☐ ALL IRON

FEATURES

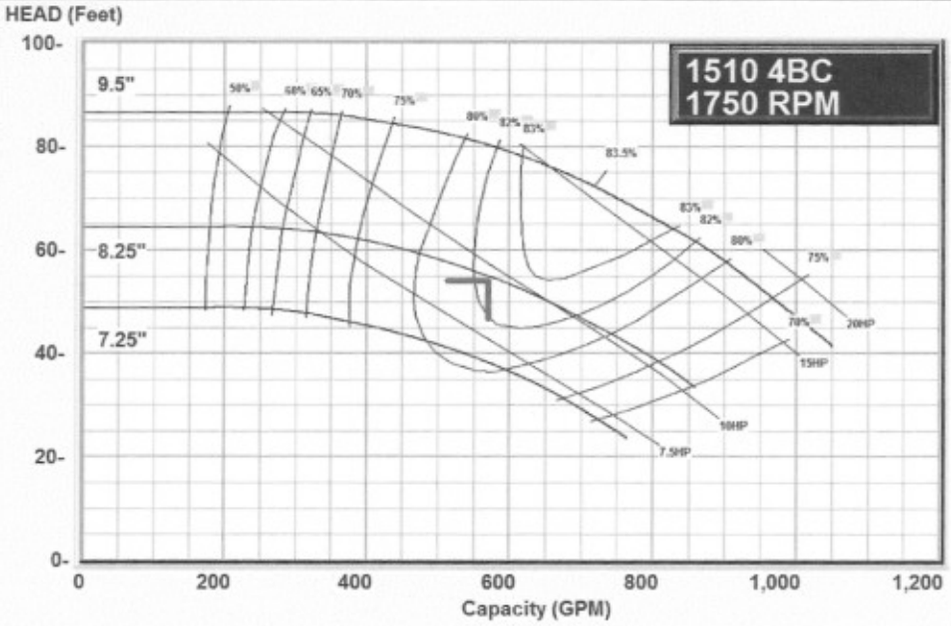
☒ ANSI/OSHA Coupling Guard
☒ Center Drop Out Spacer Coupling
☒ Fabricated Heavy Duty Baseplate

MAXIMUM WORKING PRESSURE

☒ 175 psi (12 bar) W.P.
w/ 125# ANSI flange drilling

TYPE OF SEAL

☒ 1510 Standard Seal
(Buna-Carbon/Ceramic)
☐ 1510 -F Standard Seal w/ Flush Line
(Buna-Carbon/Ceramic)
☐ 1510 -S Stuffing Box construction w/ Flushe
Mechanical Single Seal
(EPR-Tungsten Carbide/Carbon)
☐ 1510 -D Stuffing Box construction w/
Flushed Double Mechanical Seal
(EPR-Carbon/Ceramic)
Requires external water source
☐ 1510 -PF Stuffing Box Construction w/
Packing
(Graphite Impregnated Teflon)



Design Capacity =570.0 GPM
Design Head =54.0 Feet

Suction Size = 5 "
Suct. Velocity = 9.1 fps
Discharge Size = 4 "
Disc. Velocity = 14.4 fps

Min. Imp. Dia. = 7.25 "
Max. Imp. Dia. = 9.5 "
Cut Dia. = 8.25 "

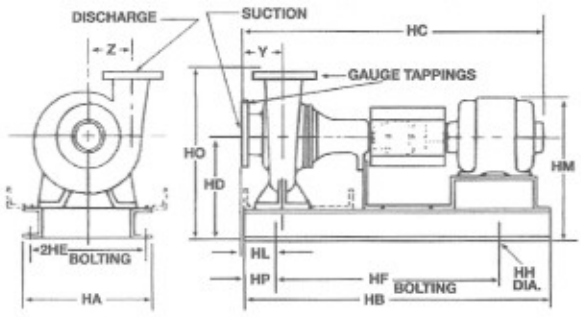
Max. Flow = 892 GPM
B.E.P. Flow = 607 GPM

Eff. @ Duty-Point = 82.32 %
Motor Size =15 HP

B.H.P. @
Duty-Point = 9.55 BHP
Max. B.H.P. for
Imp. Cut = 10.45 BHP

Series 1510 4BC Centrifugal Pump Submittal

B-225.1F



FLANGE DIMENSIONS IN INCHES (MM)			
	SIZE	THICKNESS	O.D.
Discharge	4" (102)	1-1/4" (32)	9-1/2" (241)
Suction	5" (127)	1-3/8" (35)	10-3/4" (273)

FLANGES ARE 125# ANSI - STANDARD

DIMENSIONS – Inches (mm) STANDARD SEAL 1510, 1510-F

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF	HH	HL	HM MAX	HO	HP	Y	Z
	"S" FRAME												
213T	14-5/8 (371)	34-5/8 (879)	37-3/4 (959)	12-3/4 (324)	12-7/8 (327)	28-5/8 (727)	3/4 (19)	4 (102)	18-5/8 (473)	20-3/4 (527)	3 (76)	5 (127)	7 (178)
215T	14-5/8 (371)	34-5/8 (879)	39-1/4 (997)	12-3/4 (324)	12-7/8 (327)	28-5/8 (727)	3/4 (19)	4 (102)	18-5/8 (473)	20-3/4 (527)	3 (76)	5 (127)	7 (178)
254T	14-5/8 (371)	39-3/8 (1000)	43 (1092)	12-3/4 (324)	12-7/8 (327)	33-3/8 (848)	3/4 (19)	4 (102)	19-5/8 (498)	20-3/4 (527)	3 (76)	5 (127)	7 (178)
	"L" FRAME												
256T	16 (406)	46-1/2 (1181)	49-1/8 (1248)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	5-1/8 (130)	20-7/8 (530)	22 (559)	5 (127)	5 (127)	7 (178)
284TS	16 (406)	46-1/2 (1181)	48-1/2 (1232)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	5-1/8 (130)	22 (559)	22 (559)	5 (127)	5 (127)	7 (178)
286TS	16 (406)	46-1/2 (1181)	50 (1270)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	5-1/8 (130)	22 (559)	22 (559)	5 (127)	5 (127)	7 (178)
324TS	16 (406)	51-3/4 (1314)	51-7/8 (1318)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	5-1/8 (130)	23-1/8 (587)	22 (559)	5 (127)	5 (127)	7 (178)
326TS	16 (406)	51-3/4 (1314)	53-5/8 (1362)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	5-1/8 (130)	23-1/8 (587)	22 (559)	5 (127)	5 (127)	7 (178)
364TS	24 (610)	56 (1422)	55-1/4 (1403)	16-1/2 (419)	21-1/2 (546)	44 (1118)	1 (25)	5-3/4 (146)	26-3/4 (679)	24-1/2 (622)	6 (152)	5 (127)	7 (178)
365TS	24 (610)	56 (1422)	55-7/8 (1419)	16-1/2 (419)	21-1/2 (546)	44 (1118)	1 (25)	5-3/4 (146)	26-3/4 (679)	24-1/2 (622)	6 (152)	5 (127)	7 (178)
404TS	24 (610)	56 (1422)	58-1/8 (1476)	16-1/2 (419)	21-1/2 (546)	44 (1118)	1 (25)	5-3/4 (146)	28-3/8 (721)	24-1/2 (622)	6 (152)	5 (127)	7 (178)

STUFFING BOX 1510-PF, 1510-S, 1510-D

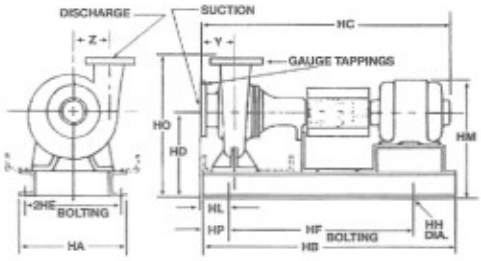
MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF	HH	HL	HM MAX	HO	HP	Y	Z
	"L" FRAME												
213T	16 (406)	46-1/2 (1181)	44-1/2 (1130)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	5-1/8 (130)	19-7/8 (505)	22 (559)	5 (127)	5 (127)	7 (178)
215T	16 (406)	46-1/2 (1181)	46 (1168)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	5-1/8 (130)	19-7/8 (505)	22 (559)	5 (127)	5 (127)	7 (178)
254T	16 (406)	51-3/4 (1314)	49-3/4 (1264)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	5-1/8 (130)	20-7/8 (530)	22 (559)	5 (127)	5 (127)	7 (178)
256T	16 (406)	51-3/4 (1314)	51-1/2 (1308)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	5-1/8 (130)	20-7/8 (530)	22 (559)	5 (127)	5 (127)	7 (178)

Dimensions are subject to change. Not to be used for construction purposes unless certified.
Box type pumps should not be operated at 3500 RPM.

ITT Industries

Series 1510 5A Centrifugal Pump Submittal

B-225.4B



FLANGE DIMENSIONS IN INCHES (MM)			
	SIZE	THICKNESS	O.D.
Discharge	5" (127)	1-3/8 (35)	10-3/4 (273)
Suction	6" (152)	1-7/16 (37)	12-1/8 (308)

FLANGES ARE 125# ANSI - STANDARD
250# ANSI - AVAILABLE

DIMENSIONS - Inches (mm)

STANDARD SEAL 1510, 1510-F

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF	HH	HL	HM MAX	HO	HP	Y	Z
	"S" FRAME												
182T	14-5/8 (371)	31 (787)	36-1/4 (921)	12-3/4 (324)	12-7/8 (327)	25 (635)	3/4 (19)	5-3/4 (146)	18 (457)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
184T	14-5/8 (371)	31 (787)	37 (940)	12-3/4 (324)	12-7/8 (327)	25 (635)	3/4 (19)	5-3/4 (146)	18 (457)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
213T	14-5/8 (371)	34-5/8 (879)	39-1/2 (1003)	12-3/4 (324)	12-7/8 (327)	28-5/8 (727)	3/4 (19)	5-3/4 (146)	18-5/8 (473)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
215T	14-5/8 (371)	34-5/8 (879)	41 (1041)	12-3/4 (324)	12-7/8 (327)	28-5/8 (727)	3/4 (19)	5-3/4 (146)	18-5/8 (473)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
	"L" FRAME												
254T	16 (406)	46-1/2 (1181)	49-1/8 (1248)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	6-7/8 (175)	20-7/8 (530)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
256T	16 (406)	46-1/2 (1181)	50-7/8 (1292)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	6-7/8 (175)	20-7/8 (530)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
284TS	16 (406)	46-1/2 (1181)	50-1/4 (1276)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	6-7/8 (175)	22 (559)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
286TS	16 (406)	46-1/2 (1181)	51-3/4 (1314)	14 (356)	14 (356)	36-1/2 (927)	7/8 (22)	6-7/8 (175)	22 (559)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
324TS	16 (406)	51-3/4 (1314)	53-5/8 (1362)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (175)	23-1/8 (587)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
326TS	16 (406)	51-3/4 (1314)	55-3/8 (1407)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (175)	23-1/8 (587)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
364TS	16 (406)	51-3/4 (1314)	57 (1448)	14-1/4 (362)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (175)	24-1/4 (616)	22-3/4 (578)	5 (127)	5-13/16 (148)	6-1/4 (159)

STUFFING BOX 1510-PF, 1510-S, 1510-D

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF	HH	HL	HM MAX	HO	HP	Y	Z
	"S" FRAME												
182T	14-5/8 (371)	34-5/8 (879)	39-3/4 (1010)	12-3/4 (324)	12-7/8 (327)	28-5/8 (727)	3/4 (19)	5-3/4 (146)	18 (457)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
184T	14-5/8 (371)	34-5/8 (879)	37 (940)	12-3/4 (324)	12-7/8 (327)	28-5/8 (727)	3/4 (19)	5-3/4 (146)	18 (457)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
213T	14-5/8 (371)	39-3/8 (1000)	43-1/8 (1095)	12-3/4 (324)	12-7/8 (327)	33-3/8 (848)	3/4 (19)	5-3/4 (146)	18-5/8 (473)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
215T	14-5/8 (371)	39-3/8 (1000)	44-5/8 (1133)	12-3/4 (324)	12-7/8 (327)	33-3/8 (848)	3/4 (19)	5-3/4 (146)	18-5/8 (473)	21-1/4 (540)	3 (76)	5-13/16 (148)	6-1/4 (159)
	"L" FRAME												
254T	16 (406)	51-3/4 (1314)	51-1/2 (1308)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	20-7/8 (530)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
256T	16 (406)	51-3/4 (1314)	53-1/4 (1353)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	20-7/8 (530)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
284TS	16 (406)	51-3/4 (1314)	52-5/8 (1337)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	22 (559)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
286TS	16 (406)	51-3/4 (1314)	54-1/8 (1375)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	22 (559)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
324TS	16 (406)	51-3/4 (1314)	56 (1422)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	23-1/8 (587)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
326TS	16 (406)	51-3/4 (1314)	57-3/4 (1467)	14 (356)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	23-1/8 (587)	22-1/2 (572)	5 (127)	5-13/16 (148)	6-1/4 (159)
364TS	16 (406)	51-3/4 (1314)	59-3/8 (1508)	14-1/4 (362)	14 (356)	41-3/4 (1060)	7/8 (22)	6-7/8 (174)	24-1/4 (616)	22-3/4 (578)	5 (127)	5-13/16 (148)	6-1/4 (159)

Dimensions are subject to change. Not to be used for construction purposes unless certified.

ITT Industries

Bell & Gossett

SUBMITTAL

B-225.4E

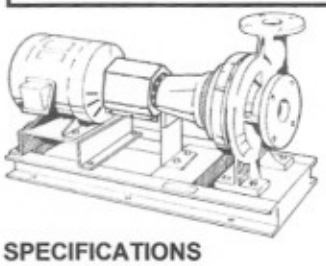
JOB: Thesis Report

REPRESENTATIVE: Cummins-Wagner Co., Inc.

UNIT TAG: P-5
ENGINEER:
CONTRACTOR:

ORDER NO.
SUBMITTED BY:
APPROVED BY:

DATE: 3/31/2006
DATE:
DATE:



5A
Series 1510
Centrifugal Pumps - Base Mounted

SPECIFICATIONS

FLOW 570 (GPM) HEAD 27 (FT)
HP 7.5 RPM 1800
VOLTS 230/460
CYCLE 60 PHASE 3
Lincoln TEFC Inverter Duty
APPROX. WEIGHT 452
SPECIALS Special Coupling(Dodge Paraflex)

Note: Equipped with EPDM coupling

MATERIALS OF CONSTRUCTION

☒ BRONZE FITTED ☐ ALL IRON

FEATURES

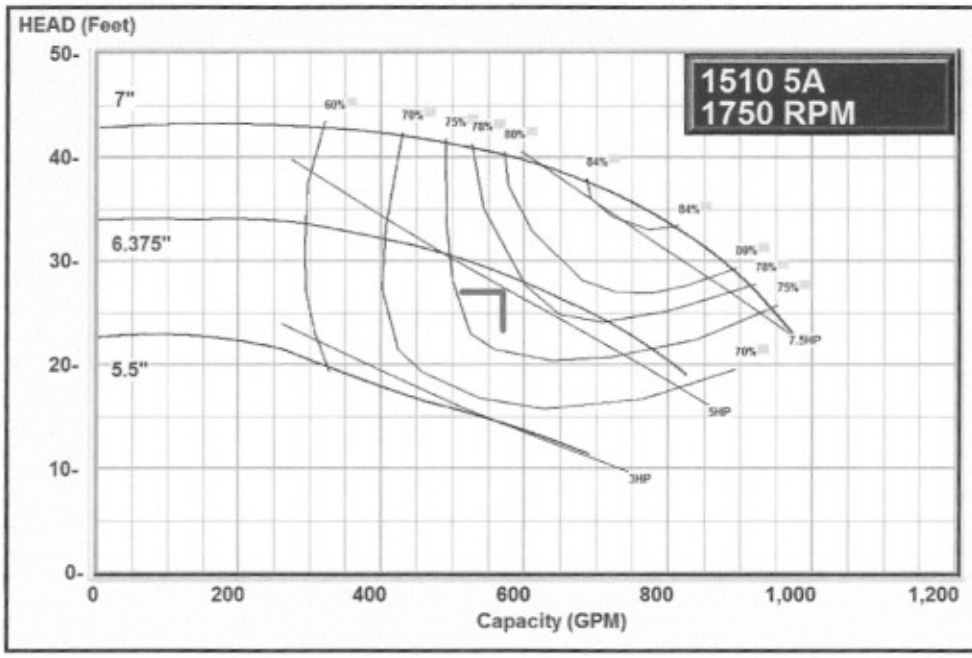
☒ ANSI/OSHA Coupling Guard
☒ Center Drop Out Spacer Coupling
☒ Fabricated Heavy Duty Baseplate

MAXIMUM WORKING PRESSURE

☒ 175 psi (12 bar) W.P.
w/ 125# ANSI flange drilling
☐ 250 psi (17 bar) W.P.
w/ 250# ANSI flange drilling (requires 1510-S)

TYPE OF SEAL

☒ 1510 Standard Seal
(Buna-Carbon/Ceramic)
☐ 1510 -F Standard Seal w/ Flush Line
(Buna-Carbon/Ceramic)
☐ 1510 -S Stuffing Box construction w/ Flushe Mechanical Single Seal
(EPR-Tungsten Carbide/Carbon)
☐ 1510 -D Stuffing Box construction w/ Flushed Double Mechanical Seal
(EPR-Carbon/Ceramic)
Requires external water source
☐ 1510 -PF Stuffing Box Construction w/ Packing
(Graphite Impregnated Teflon)



Design Capacity =570.0 GPM
Design Head =27.0 Feet

Suction Size = 6 "
Suct. Velocity = 6.3 fps
Discharge Size = 5 "
Disc. Velocity = 9.1 fps

Min. Imp. Dia. = 5.5 "
Max. Imp. Dia. = 7 "
Cut Dia. = 6.375 "

Max. Flow = 845 GPM
B.E.P. Flow = 654 GPM

Eff. @ Duty-Point = 77.27 %
Motor Size =7.5 HP

B.H.P. @
Duty-Point = 5.18 BHP
Max. B.H.P. for
Imp. Cut = 5.59 BHP

J : LIGHTING ANALYSIS

ORIGINAL LIGHTING DESIGN

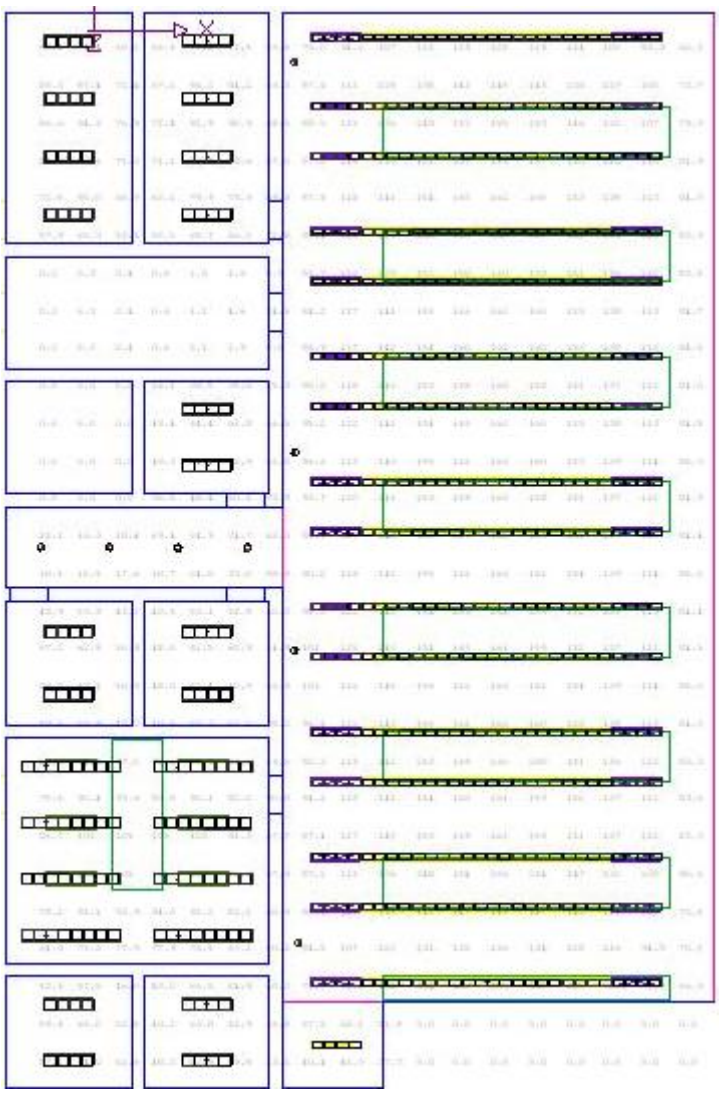


Figure A.8 : Original Lighting Layout for Laboratory 285 and Support Spaces

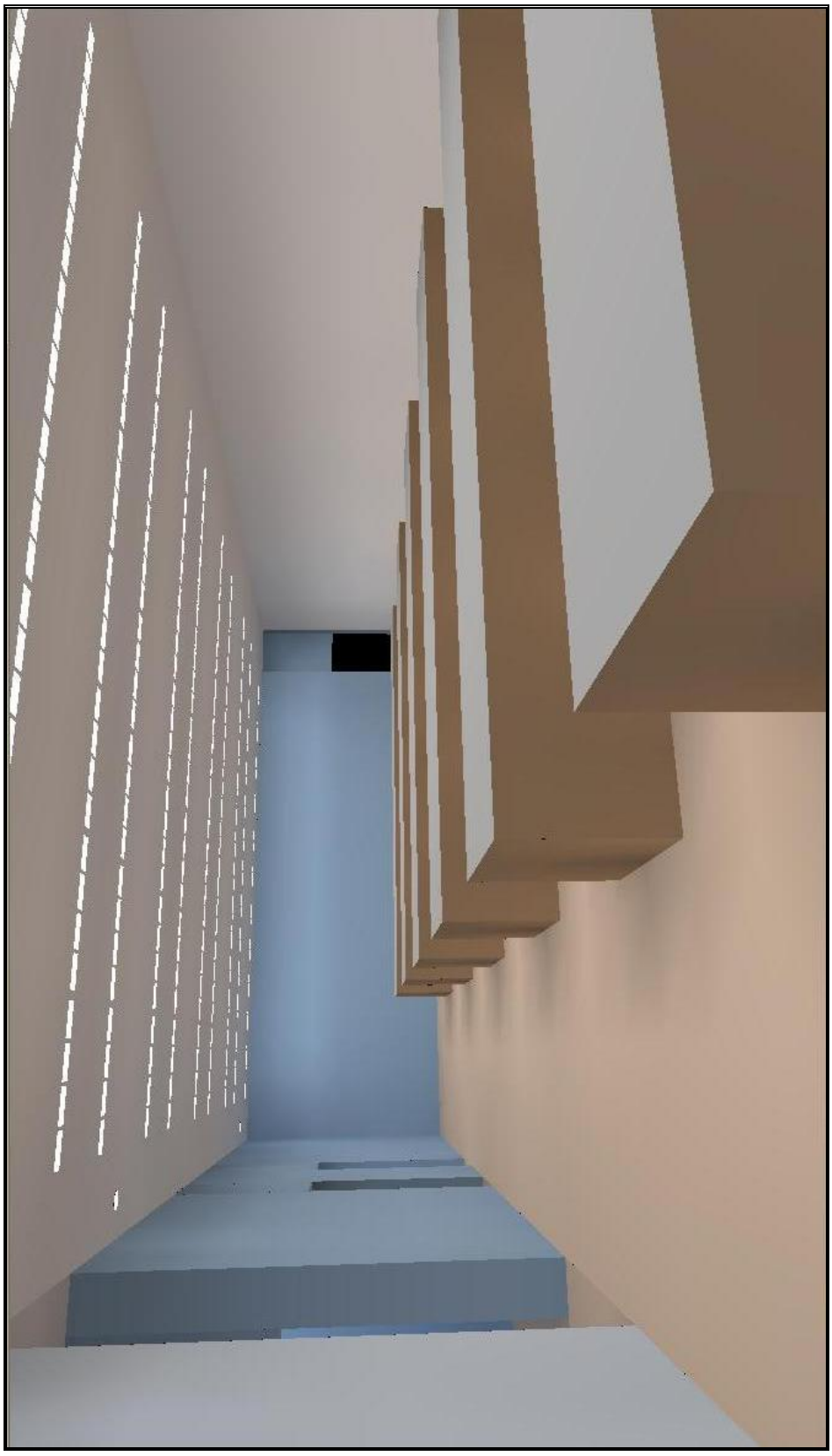


Figure A.9 : Original Laboratory 285 Rendering

Figure A.10 : Large Support Space Rendering, Original Design

Figure A.11 : Hallway Rendering, Original Design

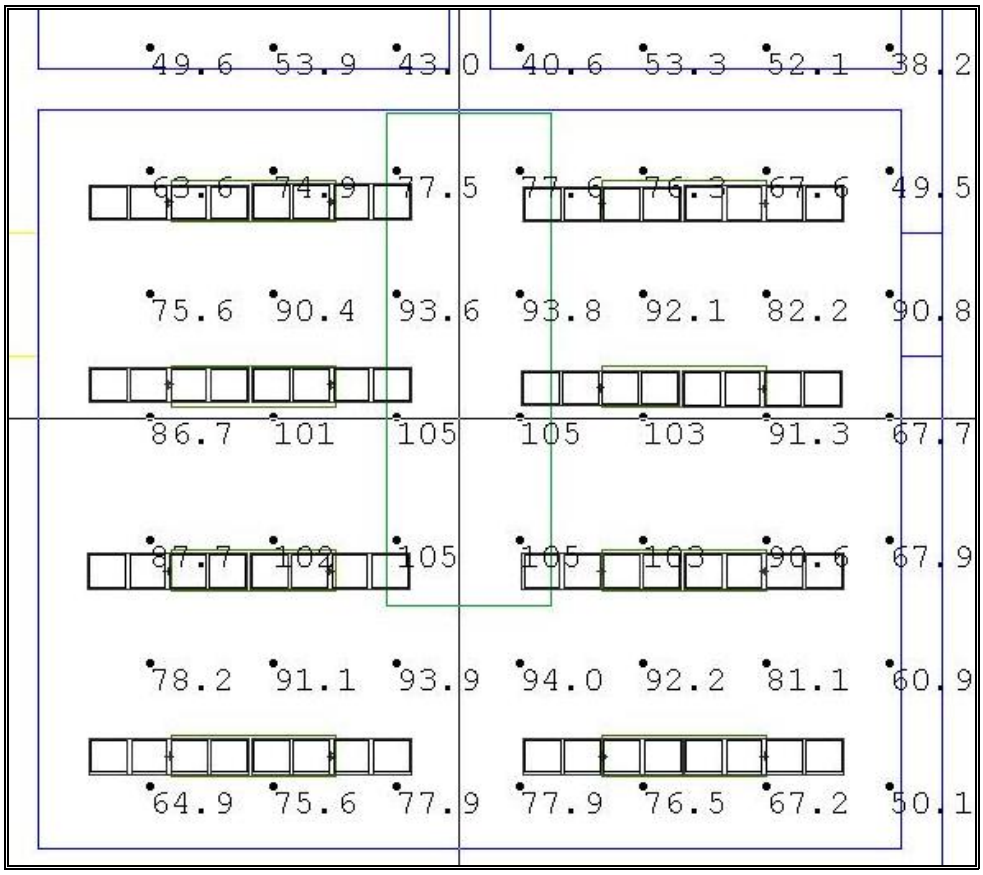


Figure A.12 : Large Support Space Illuminance Levels, Original Design

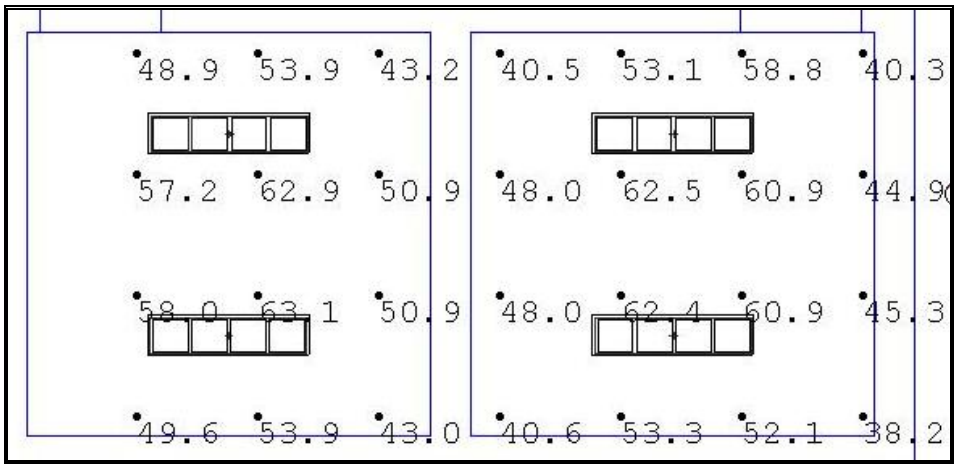


Figure A.13 : Small Support Space Illuminance Levels, Original Design

NEW LIGHTING DESIGN

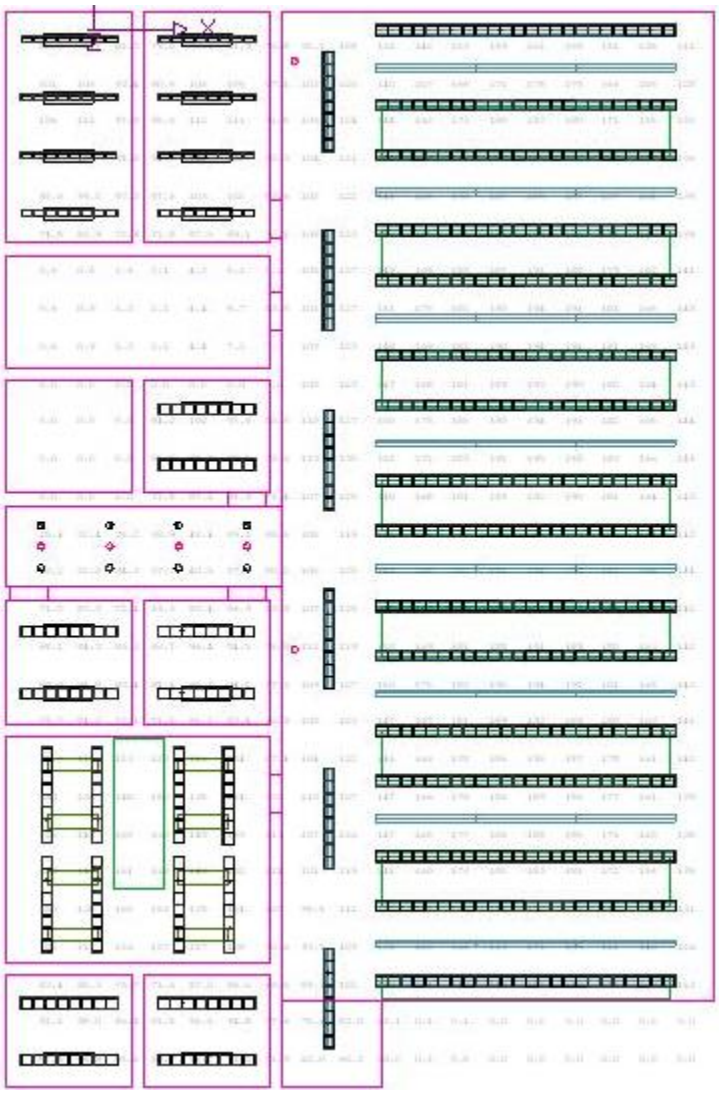


Figure A.14 : Lighting Layout for Laboratory 285, New Design

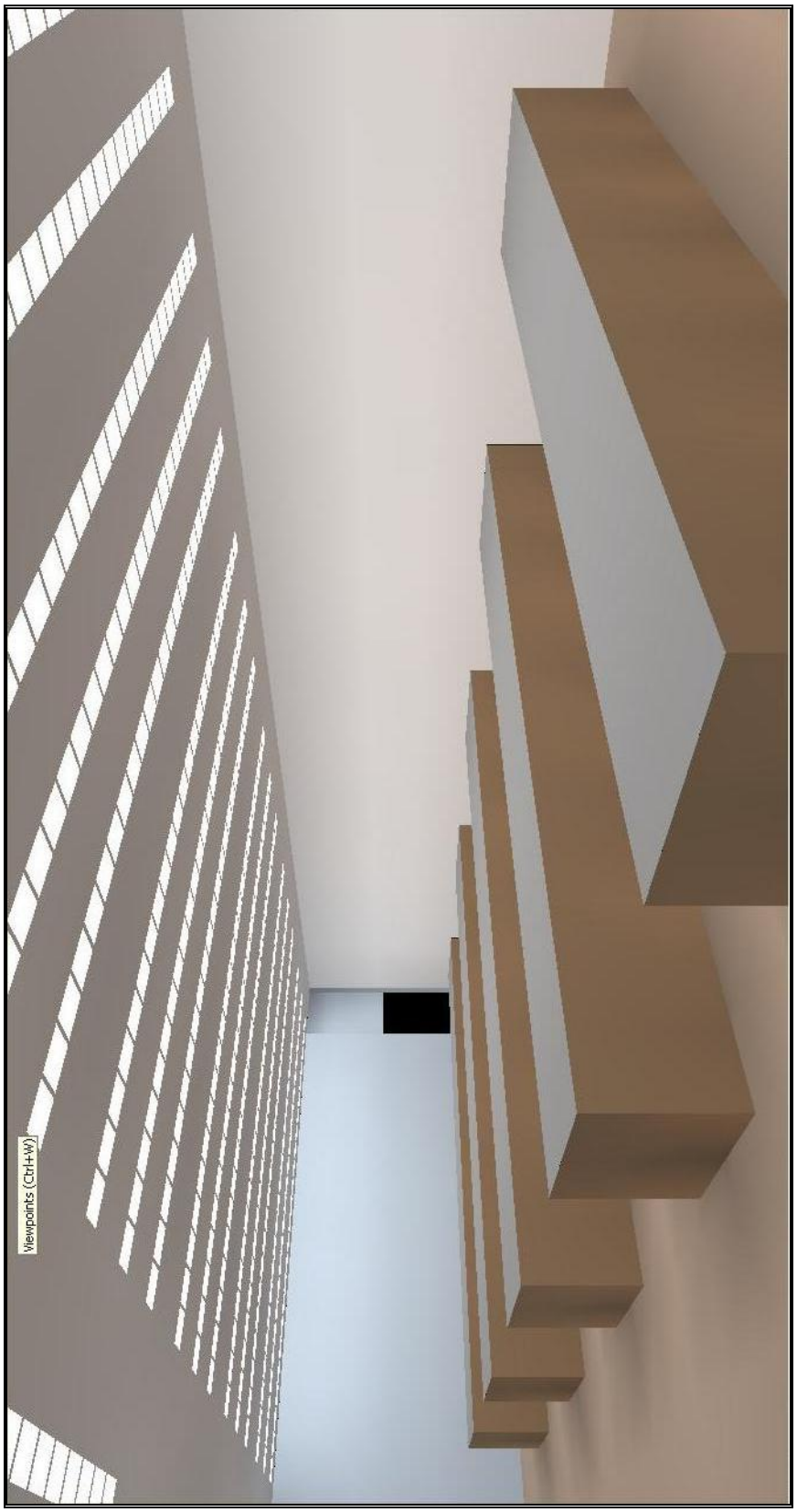


Figure A.15 : New Laboratory 285 Rendering

Figure A.16 : New Laboratory 285 Rendering

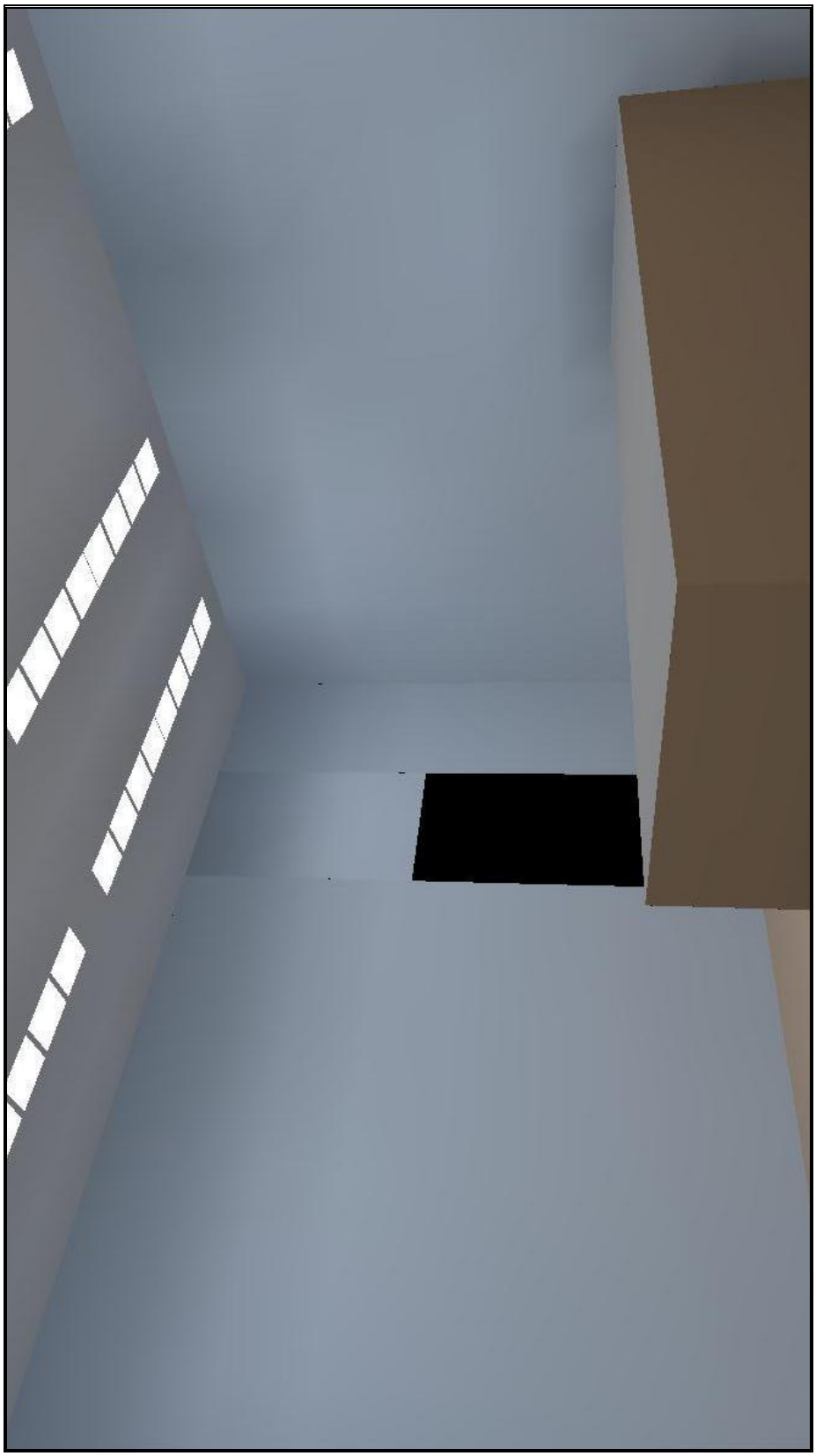


Figure A.17 : Large Support Space Rendering, New Design

Figure A.18 : Hallway Rendering, New Design

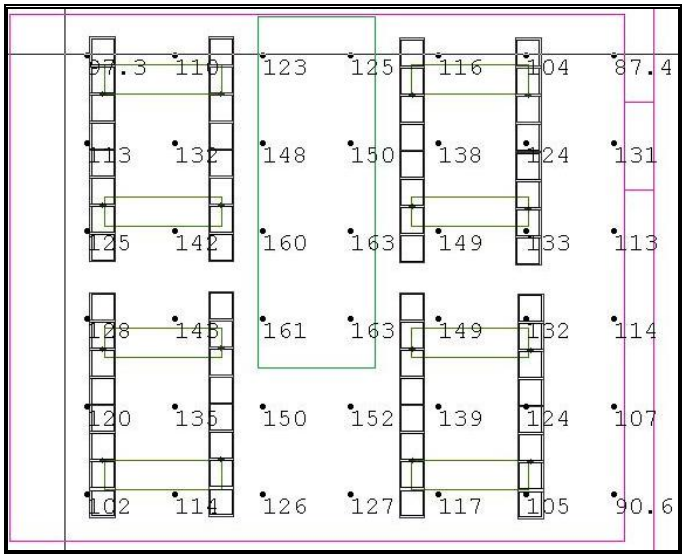


Figure A.19 : Large Support Space, New Design

ORIGINAL LIGHTING SCHEDULE

Table A.24

Fixture						
Tag	**Discription**	**Manufacturer**	**Product No.**	**Power**	**Lamps**	**Voltage**
L1	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	2/32W	T8	277
L1A	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423283	2/32W	T8	277
L8	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	2/32W	T8	277
L8A	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	4/40W	T5	277
L36	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	1/32W	Vert CFL	120/277

Table A.25

Lamp				
Tag	**Discription**	**Manufacturer**	**Product No.**	**Avg Rated Life**
L1	(2) F32/835/XPS/ECO	OSI	21697	30000
L1A	(2) F32/835/XPS/ECO	OSI	21697	30000
L8	(2) F32/835/XPS/ECO	OSI	21697	30000
L8A	(4) FT40DL/835/RS	OSI	20585	20000
L36	(1)CF32DT/E/IN/835	OSI	20885	12000

Table A.26

Lamp						
Tag	**Base**	**Watts**	**Bulb**	**CRI**	**CCT**	**Mean Lumens/Lamp**
L1	Medium Bipin	32	T8	85	3500	2945
L1A	Medium Bipin	32	T8	85	3500	2945
L8	Medium Bipin	32	T8	85	3500	2945
L8A	2G11	40	T5	82	3500	2709
L36	GX24Q-3	32	T4	82	3500	2064

Table A.27

Ballast					
Tag	**Discription**	**Product No.**	**Ballast Factor**	**PF**	**Lamp No.**
L1	QT2X32T8277ISNSC	49,914	0.9	0.97	2
L1A	QT2X32T8277ISNSC	49,914	0.9	0.97	2
L8	QT2X32T8277ISNSC	49,914	0.9	0.97	2
L8A	QT2X40/277DL	49,644	1.0	0.97	2
L36	QTP 1/2CF/UNV TM	51,768	1.0	0.98	1

Table A.28

Layout Summary				
Tag	**Number of Fixtures**	**Total Lumens**	**Total Watts**	**Lumens/Watt**
L1	112	659,680	7,168	92.03
L1A	32	188,480	2,048	92.03
L8	16	94,240	1,024	92.03
L8A	18	195,048	2,880	67.73
L36	8	16,512	256	64.50
Total	**186**	**1,153,960**	**13,376**	

NEW LIGHTING SCHEDULE

Table A.29

Fixture						
Tag	**Discription**	**Manufacturer**	**Product No.**	**Power**	**Lamps**	**Voltage**
L1	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	2/32W	T8	277
L8A_A2	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	2/40W	T8	277
L1_A	Recessed Row 1'X8' 2 Lamp T8	Lithonia Lighting	RR 2 96T8 TUBI	2/40W	T8	277
L36_A	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	1/32W	Vert CFL	120/277

Table A.30

Lamp				
Tag	**Discription**	**Manufacturer**	**Product No.**	**Avg Rated Life**
L1	(2) F32/835/XPS/ECO	OSI	21697	30000
L8A_A2	(2) F40T8 TL835 60 ALTO 1LP	Philips	368340	20000
L1_A	(2) FO96/835/XP/SS/ECO	OSI	22100	18000
L36_A	(1) Mini Dec Twister 27W Med EL/mDT 1CT	Philips	137158	137158

Table A.31

Lamp						
Tag	**Base**	**Watts**	**Bulb**	**CRI**	**CCT**	**Mean Lumens/Lamp**
L1	Medium Bipin	32	T8	85	3500	2945
L8A_A2	Medium Bipin	40	T8	86	3500	3500
L1_A	Single Pin	55	T8	82	3500	5415
L36_A	Med	27	EL	82	3500	1750

Table A.32

Ballast					
Tag	**Discription**	**Product No.**	**Ballast Factor**	**PF**	**Lamp No.**
L1	QT2X32T8277ISNSC	49,914	0.9	0.97	2
L8A_A2	QT2X32T8277ISNSC	49,914	0.9	0.97	2
L1_A	QT2X32T8277ISNSC	49,914	0.9	0.97	2
L36_A	QTP 1/2CF/UNV TM	51,768	1.0	0.98	1

Table A.33

Layout Summary				
Tag	**Number of Fixtures**	**Total Lumens**	**Total Watts**	**Lumens/Watt**
L1	16	94,240	1,024	92.03
L8A_A2	36	252,000	2,880	87.50
L1_A	54	584,820	5,940	98.45
L36_A	8	14,000	256	54.69
Total	**114**	**945,060**	**10,100**	

Table A.34

Layout Comparison			
	Number of Fixtures	**Total Lumens**	**Total Watts**
Original	186	1,153,960	13,376
New	114	945,060	10,100
Difference	**-72**	**-208,900**	**-3,276**

Table A.34 : Linear Fluorescent Lamp Comparison

Discription	Manufacturer	Product No.	Watts	Mean Lumens/Lamp	Lumen/Watt
39W/830 WW Min Bipin HO UNP	Philips	290221	39	NA	--
54W/835 WH Min Bipin HO UNP	Philips	290288	54	NA	--
F17T8 TL735 24 ALTO 1LP	Philips	368084	17	1200	70.59
F32T8 25W ADV835 XEW LL ALTO 1LP	Philips	137828	25	2280	91.20
F32T8 30W ADV835 EW ALTO 1LP	Philips	387811	30	2710	90.33
F32T8 TL835 48 ALTO BLK	Philips	272336	32	2800	87.50
F34T12 34W/836 ADV835 Med Bipin EW ALTO	Philips	142588	34	2790	82.06
F40T12 ADV835 48 ALTO 1LP	Philips	266312	40	3250	81.25
F40T8 TL835 60 ALTO 1LP	Philips	368340	40	3500	87.50
F48T12 60W SPEC35 HO 1LP	Philips	218974	60	3830	63.83
F48T8 44W TL835 HO ALTO 1LP	Philips	388090	44	3600	81.82
F72T12 85W SPEC35 HO 1LP	Philips	300012	85	6000	70.59
F72T8 65W TL835 HO ALTO 1LP	Philips	388215	65	5490	84.46
F96T12 110W SPEC35 HO 1LP	Philips	276816	110	8375	76.14
F96T12 95W SPEC35 HO/EW 1LP	Philips	221176	95	7500	78.95
F96T8 59W TL835 ALTO Plus 1LP	Philips	388017	59	5490	93.05
F96T8 86W TL835 HO ALTO Plus 1LP	Philips	388272	86	7625	88.66
FB32T8/6 TL735 22.44 ALTO 1LP	Philips	378935	32	2370	74.06
PL-L 80W/835 2G11/4P 1CT	Philips	386987	80	6000	75.00
Slimline F72T12 56W 35U ALTO 1LP	Philips	366187	56	4550	81.25
Slimline F96T12 58W SPEC35 EW ALTO 1LP	Philips	134372	58	4900	84.48
Slimline F96T12 75W SPEC35 ALTO 1LP	Philips	366484	75	6050	80.67
FP39/835/HO/ECO	OSI	20933	39	2883	73.92
F32/835/XPS/ECO	OSI	21697	32	2945	92.03
FP54/835/HO/ECO	OSI	20904	54	4138	76.63
FP80/835/HO/ECO	OSI	20936	80	5719	71.49
FP35/835/ECO	OSI	20926	35	3069	87.69
FO96/835/XP/SS/ECO	OSI	22100	55	5415	98.45
FO96/835/XP/ECO	OSI	22034	59	5795	98.22
FO30/835/XP/SS/ECO	OSI	22060	30	2710	90.33
FO96/835/XP	OSI	21740	59	5795	98.22
FO96/835/HO/ECO	OSI	22206	86	7380	85.81
FO40/735/ECO	OSI	22103	40	3150	78.75
FBO30/835XP/6/SS/ECO	OSI	22171	30	2660	88.67

Table A.35 : Compact Fluorescent Lamp Comparison

Discription	Manufacturer	Product No.	Watts	Mean Lumens/Lamp	Lumen/Watt
Mini Dec Twister 27W Med EL/mDT 1CT	Philips	137158	27	1750	64.81
20W Med EL/A G40 ALTO 1CT	Philips	145151	20	1100	55.00
Decorative Twister 23W Med EL/DT 1BC	OSI	381111	23	1400	60.87
Decorative Twister 42W Med EL/DT 1BC	OSI	139477	42	2800	66.67
Universals 25W Med SLS ALTO 1BC	OSI	371153	25	1750	70.00
CF23ELMINITWISTDAYBL1 5/CS 1/SKU	OSI	29417	23	1247	54.22
CF42DT/E/IN/835	OSI	20871	42	2752	65.52
CF57DT/E/IN/835	OSI	20897	57	3698	64.88
CF32DT/E/IN/835	OSI	20885	32	2064	64.50
42W TWIST 2700K CD	Westinghouse	36645	42	2800	66.67

Figure A.20 : L1 & L1A Fixture

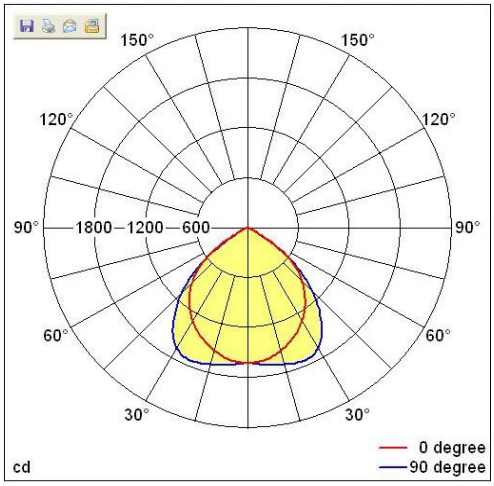


Figure 21 : L1 & L1A Photometric Distribution

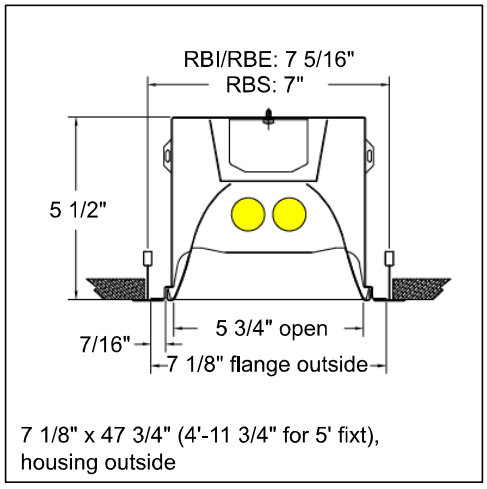
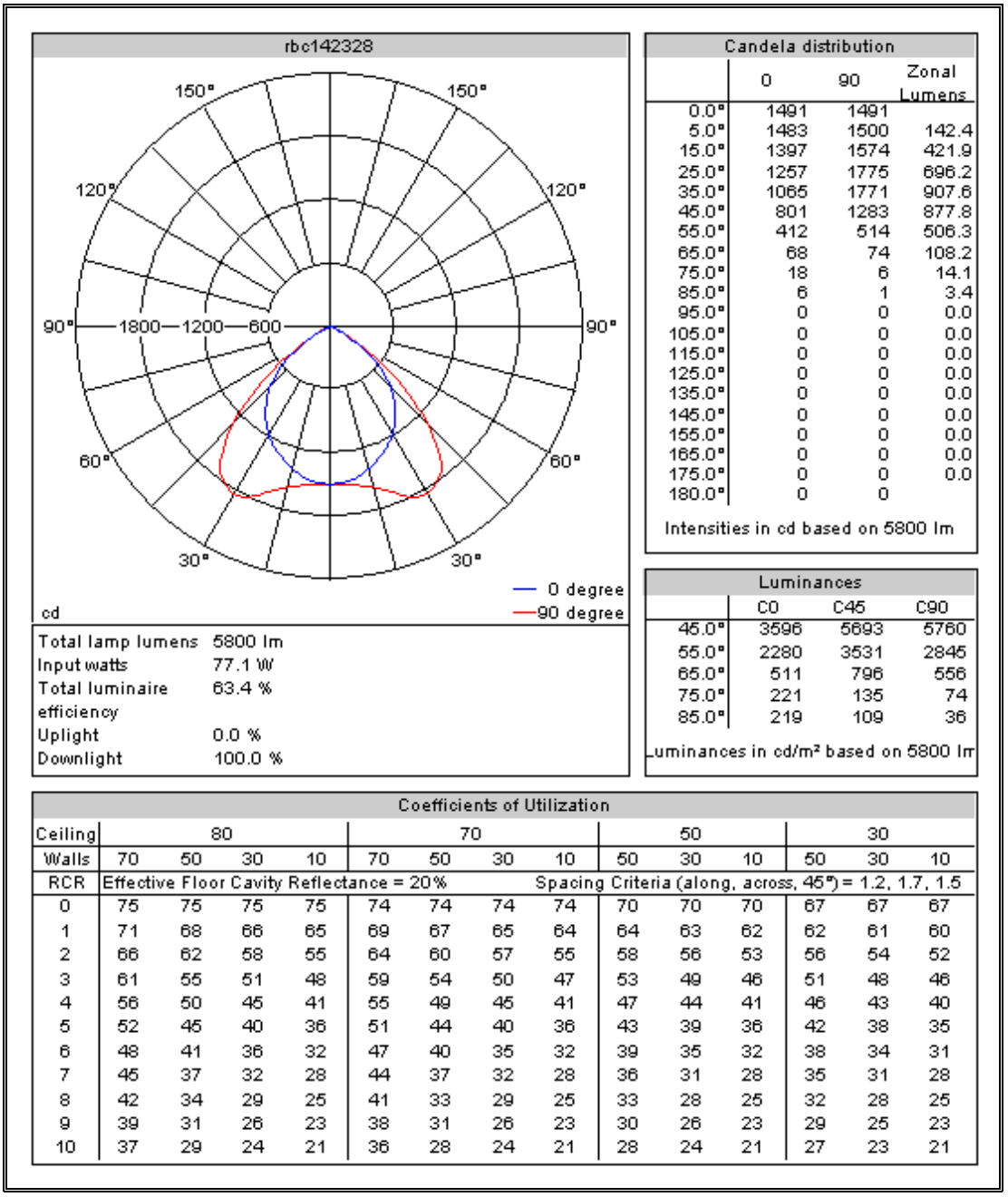


Figure A.22 : L1 & L1A Fixture



Candela distribution

	0	90	Zonal Lumens
0.0°	1491	1491	
5.0°	1483	1500	142.4
15.0°	1397	1574	421.9
25.0°	1257	1775	696.2
35.0°	1065	1771	907.6
45.0°	801	1283	877.8
55.0°	412	514	506.3
65.0°	68	74	108.2
75.0°	18	6	14.1
85.0°	6	1	3.4
95.0°	0	0	0.0
105.0°	0	0	0.0
115.0°	0	0	0.0
125.0°	0	0	0.0
135.0°	0	0	0.0
145.0°	0	0	0.0
155.0°	0	0	0.0
165.0°	0	0	0.0
175.0°	0	0	0.0
180.0°	0	0	

Intensities in cd based on 5800 lm

Luminances

	C0	C45	C90
45.0°	3596	5693	5760
55.0°	2280	3531	2845
65.0°	511	796	556
75.0°	221	135	74
85.0°	219	109	36

Luminances in cd/m² based on 5800 lm

Coefficients of Utilization

Ceiling	80				70				50			30		
Walls	70	50	30	10	70	50	30	10	50	30	10	50	30	10
RCR	Effective Floor Cavity Reflectance = 20%								Spacing Criteria (along, across, 45°) = 1.2, 1.7, 1.5					
0	75	75	75	75	74	74	74	74	70	70	70	67	67	67
1	71	68	66	65	69	67	65	64	64	63	62	62	61	60
2	66	62	58	55	64	60	57	55	58	56	53	56	54	52
3	61	55	51	48	59	54	50	47	53	49	46	51	48	46
4	56	50	45	41	55	49	45	41	47	44	41	46	43	40
5	52	45	40	36	51	44	40	36	43	39	36	42	38	35
6	48	41	36	32	47	40	35	32	39	35	32	38	34	31
7	45	37	32	28	44	37	32	28	36	31	28	35	31	28
8	42	34	29	25	41	33	29	25	33	28	25	32	28	25
9	39	31	26	23	38	31	26	23	30	26	23	29	25	23
10	37	29	24	21	36	28	24	21	28	24	21	27	23	21

Figure A.23 : L8 Photometric Data

Figure A.24 : L8 Fixture

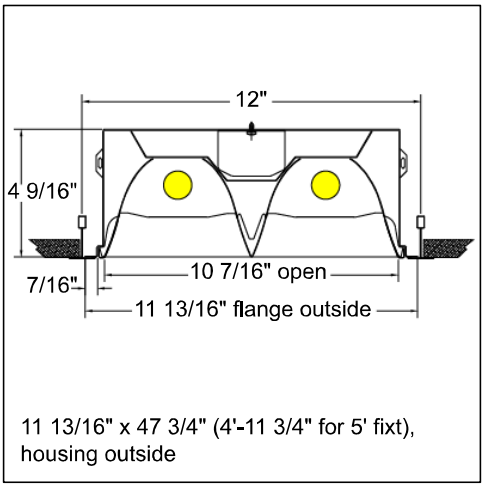
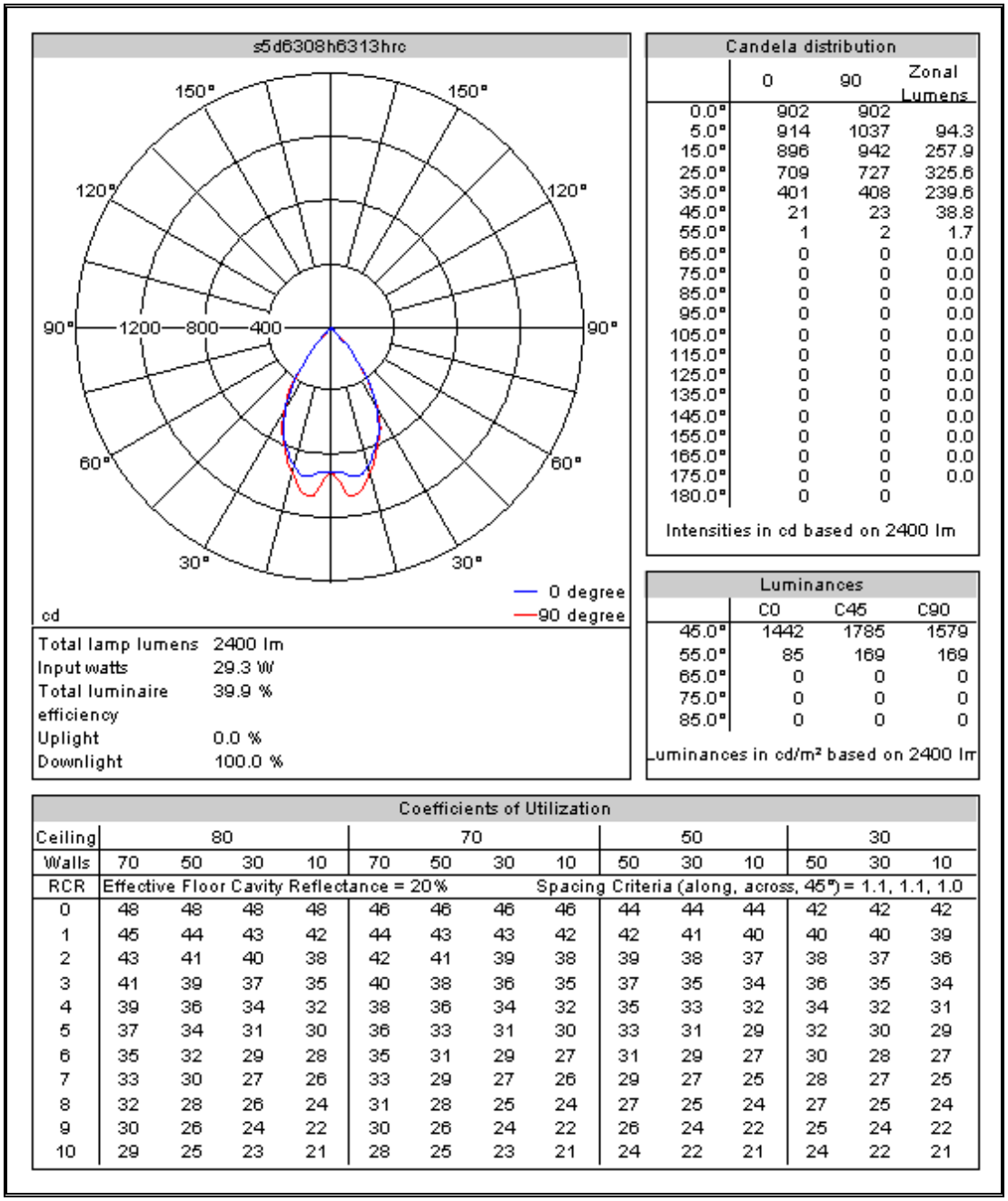


Figure A.25 : L8 Fixture



Candela distribution

	0	90	Zonal Lumens
0.0°	902	902	
5.0°	914	1037	94.3
15.0°	896	942	257.9
25.0°	709	727	325.6
35.0°	401	408	239.6
45.0°	21	23	38.8
55.0°	1	2	1.7
65.0°	0	0	0.0
75.0°	0	0	0.0
85.0°	0	0	0.0
95.0°	0	0	0.0
105.0°	0	0	0.0
115.0°	0	0	0.0
125.0°	0	0	0.0
135.0°	0	0	0.0
145.0°	0	0	0.0
155.0°	0	0	0.0
165.0°	0	0	0.0
175.0°	0	0	0.0
180.0°	0	0	

Intensities in cd based on 2400 lm

Luminances

	C0	C45	C90
45.0°	1442	1785	1579
55.0°	85	169	169
65.0°	0	0	0
75.0°	0	0	0
85.0°	0	0	0

Luminances in cd/m² based on 2400 lm

Coefficients of Utilization

Ceiling	80				70				50			30		
Walls	70	50	30	10	70	50	30	10	50	30	10	50	30	10
RCR	Effective Floor Cavity Reflectance = 20%								Spacing Criteria (along, across, 45°) = 1.1, 1.1, 1.0					
0	48	48	48	48	46	46	46	46	44	44	44	42	42	42
1	45	44	43	42	44	43	43	42	42	41	40	40	40	39
2	43	41	40	38	42	41	39	38	39	38	37	38	37	36
3	41	39	37	35	40	38	36	35	37	35	34	36	35	34
4	39	36	34	32	38	36	34	32	35	33	32	34	32	31
5	37	34	31	30	36	33	31	30	33	31	29	32	30	29
6	35	32	29	28	35	31	29	27	31	29	27	30	28	27
7	33	30	27	26	33	29	27	26	29	27	25	28	27	25
8	32	28	26	24	31	28	25	24	27	25	24	27	25	24
9	30	26	24	22	30	26	24	22	26	24	22	25	24	22
10	29	25	23	21	28	25	23	21	24	22	21	24	22	21

Figure A.26 : L36 Photometric Data

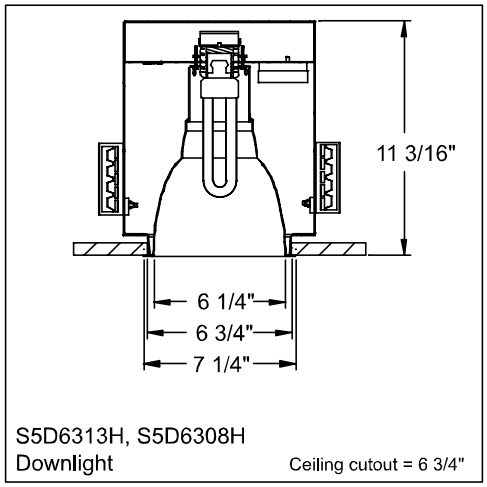


Figure A.27 : L36 Fixture

Figure A.28 : L36 Fixture

K : ACOUSTIC CALCULATION

Table A.36

Surface	Area [SF]	Sound Absorption Coefficients					
		125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Concrete Block, painted	4,600	0.10	0.05	0.06	0.07	0.09	0.08
Concrete Floor	3,450	0.01	0.01	0.02	0.02	0.02	0.02
Concrete Ceiling	3,450	0.01	0.01	0.02	0.02	0.02	0.02
Sides Without Walls	600	1.00	1.00	1.00	1.00	1.00	1.00

Surface	Area [SF]	Sound Absorption [sabins]					
		125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Concrete Block, painted	4,600	460	230	276	322	414	368
Concrete Floor	3,450	34.5	34.5	69	69	69	69
Concrete Ceiling	3,450	34.5	34.5	69	69	69	69
Sides Without Walls	600	600	600	600	600	600	600
a_2 [sabins]		**1129**	**899**	**1014**	**1060**	**1152**	**1106**

	Noise Reduction & Transmission Loss [dB]					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Likely Noise in the Mech Room	86	85	84	83	82	80
Likely Noise in the Corridor	66	72	77	74	68	60
Required NR	20	13	7	9	14	20
Minus 10 log a_2/S	-6	-7	-7	-6	-6	-6
Required TL	**26**	**20**	**14**	**15**	**20**	**26**
Actual Wall Assembly TL, 8" Concrete, painted	**34**	**40**	**44**	**49**	**59**	**64**

L : LIFE CYCLE COST ANAYLSIS

Table A.37

System Cost										
Case	System	Unit	Type	Description	Manufacturer	Product No.	Rated Life	Quantity	Unit Price	Cost [$]
Case 1	Lighting	L1	Original Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	112	135	15,120
		L1A	Original Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	32	135	4,320
		L8	Original Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	16	129	2,064
		L8A	Original Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	18	129	2,322
		L36	Original Fixture	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	--	8	81	648
		Fixture Subtotal						**186**		**24,474**
		L1	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	224	13.56	3,037
		L1A	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	64	13.56	868
		L8	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	32	13.56	434
		L8A	Original Lamp	FT40DL/835/RS	OSI	20585	20,000	72	19.1	1,375
		L36	Original Lamp	CF32DT/E/IN/835	OSI	20885	12,000	8	10.33	83
		Lamp Subtotal						**400**		**5,797**
	HVAC	Cooling Tower	--	NC Class	Marley	NC8311J1	--	2	79,300	158,600
		HVAC Subtotal								**158,600**
		Case 1 Total								**188,871**
Case 4	Lighting	L1	New Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	16	135	2,160
		L8A_A2	New Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	36	129	4,644
		L1_A	New Fixture	Recessed Row 1'X8'	Lithonia Lighting	RR 2 96T8 TUBI	--	54	215	11,610
		L36_A	New Fixture	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	--	8	81	648
		Fixture Subtotal						**516**		**19,062**
		L1	New Lamp	F32/835/XPS/ECO	OSI	21697	30,000	32	13.56	434
		L8A_A2	New Lamp	F40T8 TL835 60 ALTO 1LP	Philips	368340	20,000	72	4.89	352
		L1_A	New Lamp	FO96/835/XP/SS/ECO	OSI	22100	18,000	108	10.33	1,116
		L36_A	New Lamp	Mini 27W Med EL/mDT 1CT	Philips	137158	137,158	8	5.99	48
		Lamp Subtotal						**736**		**1,950**
	HVAC	Cooling Tower	--	NC Class	Marley	NC8311J1	--	2	79,300	158,600
		HVAC Subtotal								**158,600**
		Case 2 Total								**179,612**
Case 5	Lighting	L1	Original Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	112	135	15,120
		L1A	Original Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	32	135	4,320
		L8	Original Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	16	129	2,064
		L8A	Original Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	18	129	2,322
		L36	Original Fixture	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	--	8	81	648
		Fixture Subtotal						**186**		**24,474**
		L1	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	224	13.56	3,037
		L1A	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	64	13.56	868
		L8	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	32	13.56	434
		L8A	Original Lamp	FT40DL/835/RS	OSI	20585	20,000	72	19.1	1,375
		L36	Original Lamp	CF32DT/E/IN/835	OSI	20885	12,000	8	10.33	83
		Lamp Subtotal						**400**		**5,797**
	Ground Loop	Pumps	Split-Coupled	Series 4300, 4x4x10	Armstrong	PT82-1-0	--	7	6,150	43,050
		Heat Exchanges	Plate-Frame	B56Hx200 4*2 1/2"NPT	SWEP	11487-200	--	4	6,636	26,544
		As Calculated by RETStreen GSHP3		Drilling & Backfill	--	--	--	61,185	3.66	223,815
				Ground Loop Pipes	--	--	--	61,185	11	673,035
				Fittings and valves	--	--	--	2,403	12	28,841
				Internal Piping & Insulation	--	--	--	2,403	60	144,203
		Ground Loop Sub Total								**1,139,488**
		Case 5 Total								**1,169,759**
Case 6	Lighting	L1	Original Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	112	135	15,120
		L1A	Original Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	32	135	4,320
		L8	Original Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	16	129	2,064
		L8A	Original Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	18	129	2,322
		L36	Original Fixture	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	--	8	81	648
		Fixture Subtotal						**186**		**24,474**
		L1	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	224	13.56	3,037
		L1A	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	64	13.56	868
		L8	Original Lamp	F32/835/XPS/ECO	OSI	21697	30,000	32	13.56	434
		L8A	Original Lamp	FT40DL/835/RS	OSI	20585	20,000	72	19.1	1,375
		L36	Original Lamp	CF32DT/E/IN/835	OSI	20885	12,000	8	10.33	83
		Lamp Subtotal						**400**		**5,797**
	Ground Loop	Pumps	End Suction	Series 1510 Model 4 BC	Bell & Gossett	--	--	4	3,050	12,200
		Heat Exchanges	Plate-Frame	B56Hx200 4*2 1/2"NPT	SWEP	11487-200	--	4	6,636	26,544
		As Calculated by RETStreen GSHP3		Drilling & Backfill	--	--	--	300	3.66	1,097
				Fittings and valves	--	--	--	2,403	12	28,841
				Internal Piping & Insulation	--	--	--	2,403	60	144,203
		Ground Loop Sub Total								**212,885**
		Case 6 Total								**243,156**

Table A.38

System Cost										
Case	**System**	**Unit**	**Type**	**Description**	**Manufacturer**	**Product No.**	**Rated Life**	**Quantity**	**Unit Price**	**Cost [$]**
Case 7	Lighting	L1	New Fixture	Recessed Bivergence 7"	Zumtovbel Staff	RBNIC7423282	--	16	135	2,160
		L8A_A2	New Fixture	Recessed Bivergence 1'	Zumtovbel Staff	RBIC1423282	--	36	129	4,644
		L1_A	New Fixture	Recessed Row 1'X8'	Lithonia Lighting	RR 2 96T8 TUBI	--	54	215	11,610
		L36_A	New Fixture	6" Recessed DL	Zumtovbel Staff	S5D6308HU6313HRC	--	8	81	648
		Fixture Subtotal						**114**		**19,062**
		L1	New Lamp	F32/835/XPS/ECO	OSI	21697	30,000	32	13.56	434
		L8A_A2	New Lamp	F40T8 TL835 60 ALTO 1LP	Philips	368340	20,000	72	4.89	352
		L1_A	New Lamp	FO96/835/XP/SS/ECO	OSI	22100	18,000	108	10.33	1,116
		L36_A	New Lamp	Mini 27W Med EL/mDT 1CT	Philips	137158	137,158	8	5.99	48
		Lamp Subtotal						**334**		**1,950**
		Lighting Subtotal								**21,012**
	Ground Loop	Pumps	End Suction	Series 1510 Model 4 BC	Bell & Gossett	--	--	4	3,050	12,200
		Heat Exchanges	Plate-Frame	B56Hx200 4*2 1/2"NPT	SWEP	11487-200	--	4	6,636	26,544
		As Calculated by RETStreen GSHP3		Drilling & Backfill	--	--	--	300	3.66	1,097
				Fittings and valves	--	--	--	2,403	12	28,841
				Internal Piping & Insulation	--	--	--	2,403	60	144,203
		Mechanical System Subtotal								**212,885**
		Case 7 Total								**233,897**

Lifecycle Summary

Project: Model 1 4/3/2006
Prepared By: Penn State 12:45:17 PM

Copy (1) of Landscape Building, Laboratory Space

Model 1

Type of Analysis ..... Private Sector Lifecycle Analysis
Type of Design Alternatives ..... Mutually Exclusive
Length of Analysis ..... 20 yrs
Minimum Attractive Rate of Return ..... 10.00 %
Income Taxes ..... Not Considered

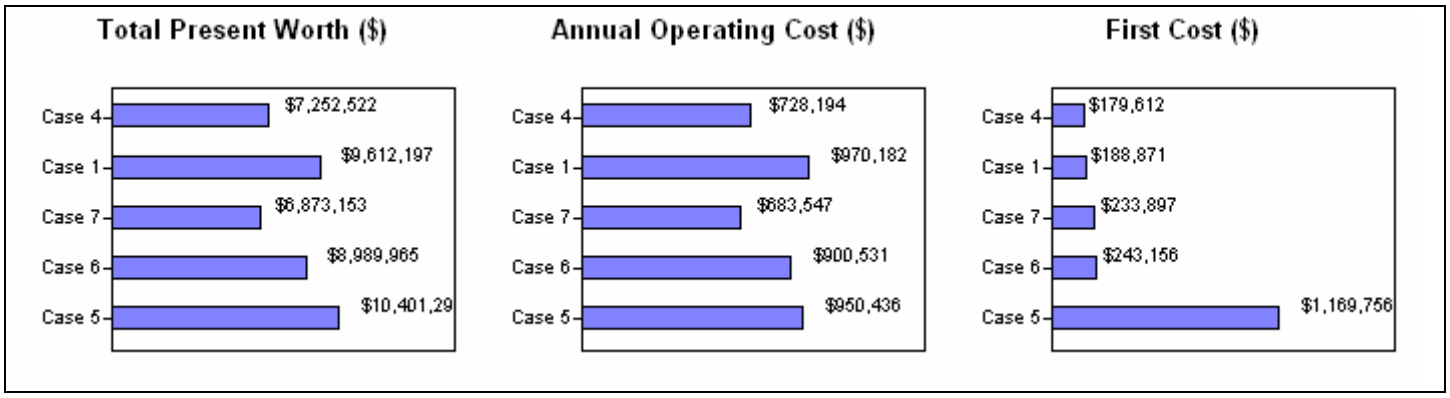


Table 1. Executive Summary

Economic Criteria	Best Design Case for Each Criteria	Value ($)
Incremental NPW Savings Analysis	Case 7	-
Lowest Total Present Worth	Case 7	$6,873,152
Lowest Annual Operating Cost	Case 7	$683,547
Lowest First Cost	Case 4	$179,612

Table 2. Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Case 4	Case 4	$7,252,521	$728,194	$179,612
Case 1	Case 1	$9,612,197	$970,182	$188,871
Case 7	Case 7	$6,873,152	$683,547	$233,897
Case 6	Case 6	$8,989,965	$900,531	$243,156
Case 5	Case 5	$10,401,290	$950,436	$1,169,756

Table 3. Incremental Analysis Data

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
Case 1	Case 4 [Winner]	$9,259	$-2,359,676	n/a	n/a
Case 7 [Winner]	Case 4	$54,285	$379,369	85.89	1.3
Case 6	Case 7 [Winner]	$9,259	$-2,116,813	n/a	n/a
Case 5	Case 7 [Winner]	$935,859	$-3,528,138	n/a	n/a

Analysis Details

Project: Model 1 4/3/2006
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Copy (1) of Landscape Building, Laboratory Space

Model 1

Type of Analysis ..... Private Sector Lifecycle Analysis
Type of Design Alternatives ..... Mutually Exclusive
Length of Analysis ..... 20 yrs
Minimum Attractive Rate of Return ..... 10.00 %
Income Taxes ..... Not Considered

1A. Summary of Results

Base Case **[Winner]**	Case 4 [Case 4]
Challenger	Case 1 [Case 1]
[Case 4] Total Present Worth ($)	$7,252,521
[Case 1] Total Present Worth ($)	$9,612,197
Net Present Worth Savings ($)	$-2,359,676
Internal Rate of Return	n/a
Payback Period (yrs)	n/a

1B. Comparative Analysis Details

		Cash Flow (Present Worth $)			SIR and Payback Calculation (Present Worth $)				
Year	**Date**	**[Case 4] Cash Flow ($)**	**[Case 1] Cash Flow ($)**	**Net Present Worth Savings ($)**	**Operating Cost Savings ($)**	**Cumulative Operating Cost Savings ($)**	**Additional Investment Cost ($)**	**Cumulative Additional Investment Cost ($)**	**Year-End SIR**
0	Initial	179,612	188,871	-9,259	0	0	9,259	9,259	0.000
1	1	675,234	899,623	-224,389	-224,389	-224,389	0	9,259	-24.235
2	2	626,126	834,196	-208,070	-208,070	-432,459	0	9,259	-46.707
3	3	580,590	773,527	-192,937	-192,937	-625,396	0	9,259	-67.545
4	4	538,365	717,271	-178,906	-178,906	-804,301	0	9,259	-86.867
5	5	499,211	665,106	-165,894	-165,894	-970,196	0	9,259	-104.784
6	6	462,905	616,734	-153,829	-153,829	-1,124,025	0	9,259	-121.398
7	7	429,239	571,881	-142,642	-142,642	-1,266,666	0	9,259	-136.804
8	8	398,022	530,290	-132,268	-132,268	-1,398,934	0	9,259	-151.089
9	9	369,075	491,723	-122,648	-122,648	-1,521,582	0	9,259	-164.335
10	10	342,233	455,961	-113,728	-113,728	-1,635,311	0	9,259	-176.618
11	11	317,343	422,801	-105,457	-105,457	-1,740,768	0	9,259	-188.008
12	12	294,264	392,051	-97,788	-97,788	-1,838,555	0	9,259	-198.570
13	13	272,863	363,539	-90,676	-90,676	-1,929,231	0	9,259	-208.363
14	14	253,018	337,099	-84,081	-84,081	-2,013,312	0	9,259	-217.444
15	15	234,617	312,583	-77,966	-77,966	-2,091,278	0	9,259	-225.864
16	16	217,554	289,850	-72,296	-72,296	-2,163,574	0	9,259	-233.673
17	17	201,732	268,770	-67,038	-67,038	-2,230,612	0	9,259	-240.913
18	18	187,060	249,223	-62,163	-62,163	-2,292,775	0	9,259	-247.627
19	19	173,456	231,098	-57,642	-57,642	-2,350,417	0	9,259	-253.852
20	20	0	0	0	0	-2,350,417	0	9,259	-253.852
Totals		7,252,521	9,612,197	-2,359,676	-2,350,417		9,259		

Analysis Details

Project: Model 1 4/3/2006
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2A. Summary of Results

Base Case	Case 4 [Case 4]
Challenger **[Winner]**	Case 7 [Case 7]
[Case 4] Total Present Worth ($)	$7,252,521
[Case 7] Total Present Worth ($)	$6,873,152
Net Present Worth Savings ($)	$379,369
Internal Rate of Return	85.9 %
Payback Period (yrs)	1.3 years

2B. Comparative Analysis Details

		Cash Flow (Present Worth $)			SIR and Payback Calculation (Present Worth $)				
Year	**Date**	**[Case 4] Cash Flow ($)**	**[Case 7] Cash Flow ($)**	**Net Present Worth Savings ($)**	**Operating Cost Savings ($)**	**Cumulative Operating Cost Savings ($)**	**Additional Investment Cost ($)**	**Cumulative Additional Investment Cost ($)**	**Year-End SIR**
0	Initial	179,612	233,897	-54,285	0	0	54,285	54,285	0.000
1	1	675,234	633,834	41,400	41,400	41,400	0	54,285	0.763
2	2	626,126	587,737	38,389	38,389	79,789	0	54,285	1.470
3	3	580,590	544,993	35,597	35,597	115,386	0	54,285	2.126
4	4	538,365	505,357	33,008	33,008	148,394	0	54,285	2.734
5	5	499,211	468,604	30,608	30,608	179,002	0	54,285	3.297
6	6	462,905	434,524	28,382	28,382	207,384	0	54,285	3.820
7	7	429,239	402,922	26,318	26,318	233,701	0	54,285	4.305
8	8	398,022	373,618	24,404	24,404	258,105	0	54,285	4.755
9	9	369,075	346,446	22,629	22,629	280,733	0	54,285	5.171
10	10	342,233	321,250	20,983	20,983	301,716	0	54,285	5.558
11	11	317,343	297,886	19,457	19,457	321,173	0	54,285	5.916
12	12	294,264	276,222	18,042	18,042	339,215	0	54,285	6.249
13	13	272,863	256,133	16,730	16,730	355,945	0	54,285	6.557
14	14	253,018	237,505	15,513	15,513	371,458	0	54,285	6.843
15	15	234,617	220,232	14,385	14,385	385,843	0	54,285	7.108
16	16	217,554	204,215	13,339	13,339	399,181	0	54,285	7.353
17	17	201,732	189,363	12,369	12,369	411,550	0	54,285	7.581
18	18	187,060	175,591	11,469	11,469	423,019	0	54,285	7.793
19	19	173,456	162,821	10,635	10,635	433,654	0	54,285	7.988
20	20	0	0	0	0	433,654	0	54,285	7.988
Totals		7,252,521	6,873,152	379,369	433,654		54,285		

Analysis Details

Project: Model 1 4/3/2006
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3A. Summary of Results

Base Case **[Winner]**	Case 7 [Case 7]
Challenger	Case 6 [Case 6]
[Case 7] Total Present Worth ($)	$6,873,152
[Case 6] Total Present Worth ($)	$8,989,965
Net Present Worth Savings ($)	$-2,116,813
Internal Rate of Return	n/a
Payback Period (yrs)	n/a

3B. Comparative Analysis Details

		Cash Flow (Present Worth $)			SIR and Payback Calculation (Present Worth $)				
Year	**Date**	**[Case 7] Cash Flow ($)**	**[Case 6] Cash Flow ($)**	**Net Present Worth Savings ($)**	**Operating Cost Savings ($)**	**Cumulative Operating Cost Savings ($)**	**Additional Investment Cost ($)**	**Cumulative Additional Investment Cost ($)**	**Year-End SIR**
0	Initial	233,897	243,156	-9,259	0	0	9,259	9,259	0.000
1	1	633,834	835,038	-201,203	-201,203	-201,203	0	9,259	-21.731
2	2	587,737	774,308	-186,570	-186,570	-387,774	0	9,259	-41.881
3	3	544,993	717,995	-173,002	-173,002	-560,775	0	9,259	-60.565
4	4	505,357	665,777	-160,420	-160,420	-721,195	0	9,259	-77.891
5	5	468,604	617,357	-148,753	-148,753	-869,948	0	9,259	-93.957
6	6	434,524	572,458	-137,934	-137,934	-1,007,882	0	9,259	-108.854
7	7	402,922	530,825	-127,903	-127,903	-1,135,785	0	9,259	-122.668
8	8	373,618	492,219	-118,601	-118,601	-1,254,386	0	9,259	-135.477
9	9	346,446	456,421	-109,975	-109,975	-1,364,361	0	9,259	-147.355
10	10	321,250	423,227	-101,977	-101,977	-1,466,338	0	9,259	-158.369
11	11	297,886	392,447	-94,561	-94,561	-1,560,899	0	9,259	-168.582
12	12	276,222	363,905	-87,683	-87,683	-1,648,582	0	9,259	-178.052
13	13	256,133	337,440	-81,306	-81,306	-1,729,889	0	9,259	-186.833
14	14	237,505	312,898	-75,393	-75,393	-1,805,282	0	9,259	-194.976
15	15	220,232	290,142	-69,910	-69,910	-1,875,192	0	9,259	-202.526
16	16	204,215	269,041	-64,826	-64,826	-1,940,018	0	9,259	-209.528
17	17	189,363	249,474	-60,111	-60,111	-2,000,129	0	9,259	-216.020
18	18	175,591	231,331	-55,739	-55,739	-2,055,868	0	9,259	-222.040
19	19	162,821	214,507	-51,686	-51,686	-2,107,554	0	9,259	-227.622
20	20	0	0	0	0	-2,107,554	0	9,259	-227.622
Totals		6,873,152	8,989,965	-2,116,813	-2,107,554		9,259		

Analysis Details

Project: Model 1 4/3/2006
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4A. Summary of Results

Base Case **[Winner]**	Case 7 [Case 7]
Challenger	Case 5 [Case 5]
[Case 7] Total Present Worth ($)	$6,873,152
[Case 5] Total Present Worth ($)	$10,401,290
Net Present Worth Savings ($)	$-3,528,138
Internal Rate of Return	n/a
Payback Period (yrs)	n/a

4B. Comparative Analysis Details

		Cash Flow (Present Worth $)			SIR and Payback Calculation (Present Worth $)				
Year	**Date**	**[Case 7] Cash Flow ($)**	**[Case 5] Cash Flow ($)**	**Net Present Worth Savings ($)**	**Operating Cost Savings ($)**	**Cumulative Operating Cost Savings ($)**	**Additional Investment Cost ($)**	**Cumulative Additional Investment Cost ($)**	**Year-End SIR**
0	Initial	233,897	1,169,756	-935,859	0	0	935,859	935,859	0.000
1	1	633,834	881,313	-247,479	-247,479	-247,479	0	935,859	-0.264
2	2	587,737	817,218	-229,480	-229,480	-476,959	0	935,859	-0.510
3	3	544,993	757,784	-212,791	-212,791	-689,750	0	935,859	-0.737
4	4	505,357	702,672	-197,315	-197,315	-887,065	0	935,859	-0.948
5	5	468,604	651,569	-182,965	-182,965	-1,070,031	0	935,859	-1.143
6	6	434,524	604,182	-169,658	-169,658	-1,239,689	0	935,859	-1.325
7	7	402,922	560,242	-157,320	-157,320	-1,397,009	0	935,859	-1.493
8	8	373,618	519,497	-145,878	-145,878	-1,542,887	0	935,859	-1.649
9	9	346,446	481,715	-135,269	-135,269	-1,678,156	0	935,859	-1.793
10	10	321,250	446,681	-125,431	-125,431	-1,803,587	0	935,859	-1.927
11	11	297,886	414,195	-116,309	-116,309	-1,919,896	0	935,859	-2.051
12	12	276,222	384,072	-107,850	-107,850	-2,027,746	0	935,859	-2.167
13	13	256,133	356,140	-100,006	-100,006	-2,127,753	0	935,859	-2.274
14	14	237,505	330,238	-92,733	-92,733	-2,220,486	0	935,859	-2.373
15	15	220,232	306,221	-85,989	-85,989	-2,306,475	0	935,859	-2.465
16	16	204,215	283,951	-79,735	-79,735	-2,386,210	0	935,859	-2.550
17	17	189,363	263,300	-73,936	-73,936	-2,460,146	0	935,859	-2.629
18	18	175,591	244,151	-68,559	-68,559	-2,528,706	0	935,859	-2.702
19	19	162,821	226,394	-63,573	-63,573	-2,592,279	0	935,859	-2.770
20	20	0	0	0	0	-2,592,279	0	935,859	-2.770
Totals		6,873,152	10,401,290	-3,528,138	-2,592,279		935,859		

Total Present Worth Profiles

Project: Model 1 4/3/2006
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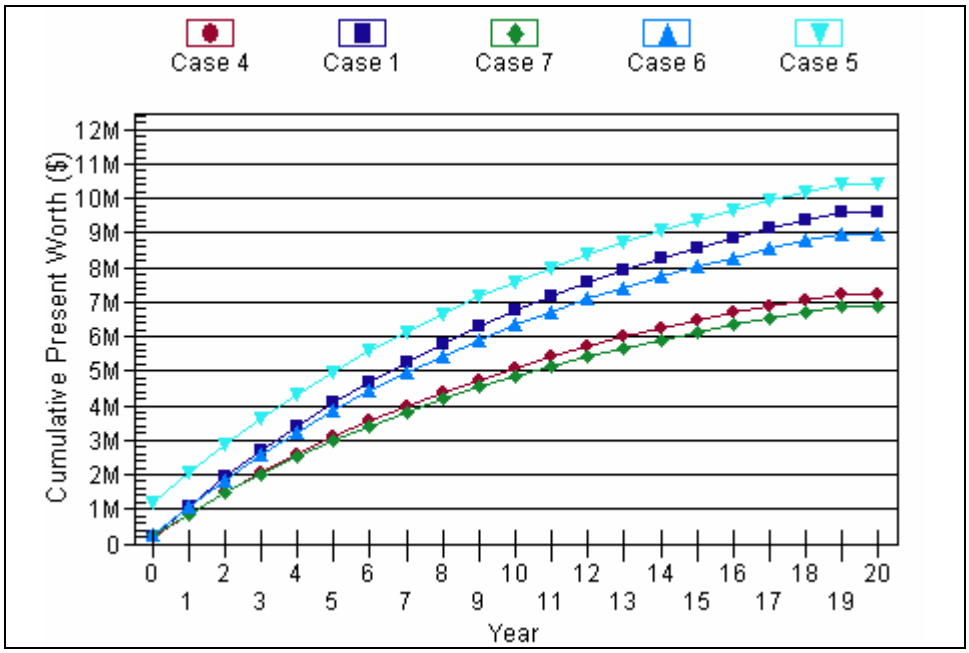
Copy (1) of Landscape Building, Laboratory Space

Model 1

Type of Analysis	Private Sector Lifecycle Analysis	
Type of Design Alternatives	Mutually Exclusive	
Length of Analysis	20	yrs
Minimum Attractive Rate of Return	10.00	%
Income Taxes	Not Considered	



Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Case 4	Case 4	$7,252,521	$728,194	$179,612
Case 1	Case 1	$9,612,197	$970,182	$188,871
Case 7	Case 7	$6,873,152	$683,547	$233,897
Case 6	Case 6	$8,989,965	$900,531	$243,156
Case 5	Case 5	$10,401,290	$950,436	$1,169,756

Cash Flow Details

Project: Model 1
Prepared By: Penn State

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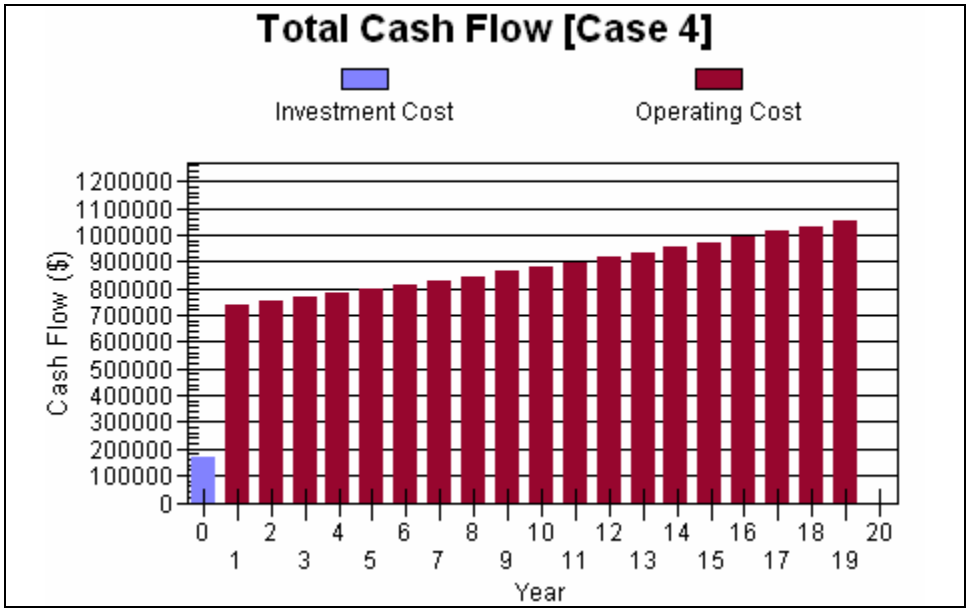
Copy (1) of Landscape Building, Laboratory Space

Model 1

Type of Analysis	Private Sector Lifecycle Analysis	
Type of Design Alternatives	Mutually Exclusive	
Length of Analysis	20	yrs
Minimum Attractive Rate of Return	10.00	%
Income Taxes	Not Considered	



1A. Component Cash Flows [Case 4], Actual Value

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
0	Initial	179,612	0	0	179,612	0	0	0	179,612
1	1	0	0	0	0	742,758	0	742,758	742,758
2	2	0	0	0	0	757,613	0	757,613	757,613
3	3	0	0	0	0	772,765	0	772,765	772,765
4	4	0	0	0	0	788,221	0	788,221	788,221
5	5	0	0	0	0	803,985	0	803,985	803,985

Cash Flow Details

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
6	6	0	0	0	0	820,065	0	820,065	820,065
7	7	0	0	0	0	836,466	0	836,466	836,466
8	8	0	0	0	0	853,195	0	853,195	853,195
9	9	0	0	0	0	870,259	0	870,259	870,259
10	10	0	0	0	0	887,664	0	887,664	887,664
11	11	0	0	0	0	905,418	0	905,418	905,418
12	12	0	0	0	0	923,526	0	923,526	923,526
13	13	0	0	0	0	941,997	0	941,997	941,997
14	14	0	0	0	0	960,837	0	960,837	960,837
15	15	0	0	0	0	980,053	0	980,053	980,053
16	16	0	0	0	0	999,654	0	999,654	999,654
17	17	0	0	0	0	1,019,647	0	1,019,647	1,019,647
18	18	0	0	0	0	1,040,040	0	1,040,040	1,040,040
19	19	0	0	0	0	1,060,841	0	1,060,841	1,060,841
20	20	0	0	0	0	0	0	0	0
Totals		179,612	0	0	179,612	16,965,004	0	16,965,004	17,144,616

1B. Present Worth Cash Flows [Case 4]

Year	Date	Total Investment Cost ($)	Total Operating Cost ($)	Total Present Worth ($)
0	Initial	179,612	0	179,612
1	1	0	675,234	675,234
2	2	0	626,126	626,126
3	3	0	580,590	580,590
4	4	0	538,365	538,365
5	5	0	499,211	499,211
6	6	0	462,905	462,905
7	7	0	429,239	429,239
8	8	0	398,022	398,022
9	9	0	369,075	369,075
10	10	0	342,233	342,233
11	11	0	317,343	317,343
12	12	0	294,264	294,264
13	13	0	272,863	272,863
14	14	0	253,018	253,018
15	15	0	234,617	234,617
16	16	0	217,554	217,554

Cash Flow Details

Project: Model 1 4/3/2006
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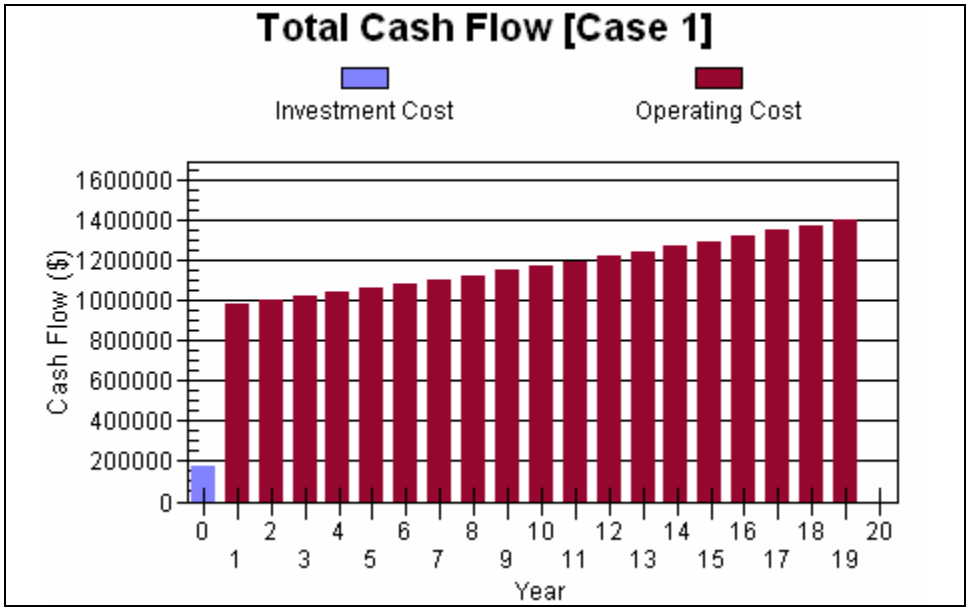
Year	Date	Total Investment Cost ($)	Total Operating Cost ($)	Total Present Worth ($)
17	17	0	201,732	201,732
18	18	0	187,060	187,060
19	19	0	173,456	173,456
20	20	0	0	0
Totals		179,612	7,072,907	7,252,519



2A. Component Cash Flows [Case 1], Actual Value

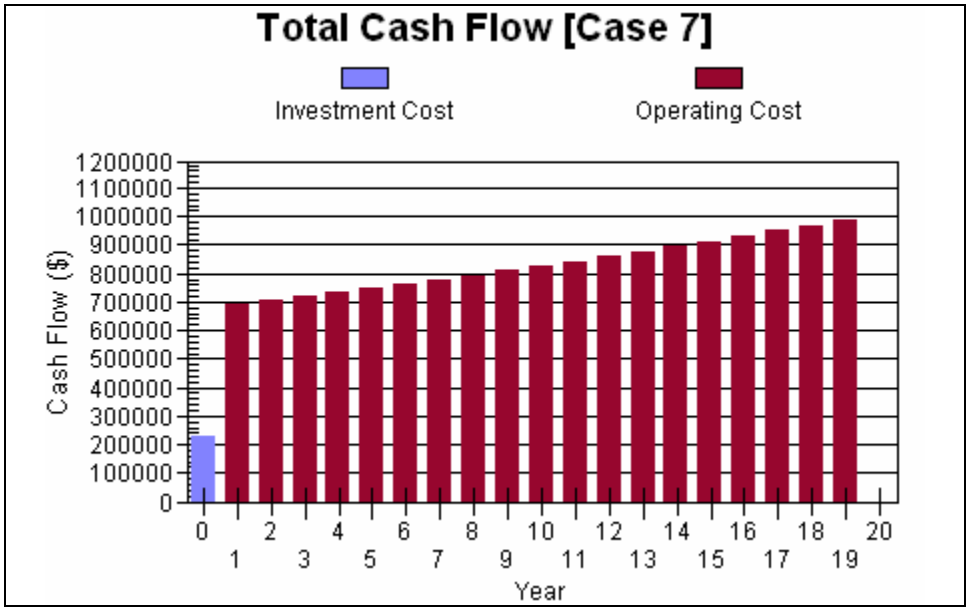
Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
0	Initial	188,871	0	0	188,871	0	0	0	188,871
1	1	0	0	0	0	989,586	0	989,586	989,586
2	2	0	0	0	0	1,009,377	0	1,009,377	1,009,377
3	3	0	0	0	0	1,029,565	0	1,029,565	1,029,565
4	4	0	0	0	0	1,050,156	0	1,050,156	1,050,156
5	5	0	0	0	0	1,071,159	0	1,071,159	1,071,159
6	6	0	0	0	0	1,092,583	0	1,092,583	1,092,583
7	7	0	0	0	0	1,114,434	0	1,114,434	1,114,434
8	8	0	0	0	0	1,136,723	0	1,136,723	1,136,723
9	9	0	0	0	0	1,159,457	0	1,159,457	1,159,457
10	10	0	0	0	0	1,182,646	0	1,182,646	1,182,646
11	11	0	0	0	0	1,206,299	0	1,206,299	1,206,299
12	12	0	0	0	0	1,230,425	0	1,230,425	1,230,425
13	13	0	0	0	0	1,255,034	0	1,255,034	1,255,034
14	14	0	0	0	0	1,280,135	0	1,280,135	1,280,135

Cash Flow Details

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
15	15	0	0	0	0	1,305,737	0	1,305,737	1,305,737
16	16	0	0	0	0	1,331,852	0	1,331,852	1,331,852
17	17	0	0	0	0	1,358,489	0	1,358,489	1,358,489
18	18	0	0	0	0	1,385,659	0	1,385,659	1,385,659
19	19	0	0	0	0	1,413,372	0	1,413,372	1,413,372
20	20	0	0	0	0	0	0	0	0
Totals		188,871	0	0	188,871	22,602,688	0	22,602,688	22,791,559

2B. Present Worth Cash Flows [Case 1]

Year	Date	Total Investment Cost ($)	Total Operating Cost ($)	Total Present Worth ($)
0	Initial	188,871	0	188,871
1	1	0	899,623	899,623
2	2	0	834,196	834,196
3	3	0	773,527	773,527
4	4	0	717,271	717,271
5	5	0	665,106	665,106
6	6	0	616,734	616,734
7	7	0	571,881	571,881
8	8	0	530,290	530,290
9	9	0	491,723	491,723
10	10	0	455,961	455,961
11	11	0	422,801	422,801
12	12	0	392,051	392,051
13	13	0	363,539	363,539
14	14	0	337,099	337,099
15	15	0	312,583	312,583
16	16	0	289,850	289,850
17	17	0	268,770	268,770
18	18	0	249,223	249,223
19	19	0	231,098	231,098
20	20	0	0	0
Totals		188,871	9,423,326	9,612,197



3A. Component Cash Flows [Case 7], Actual Value

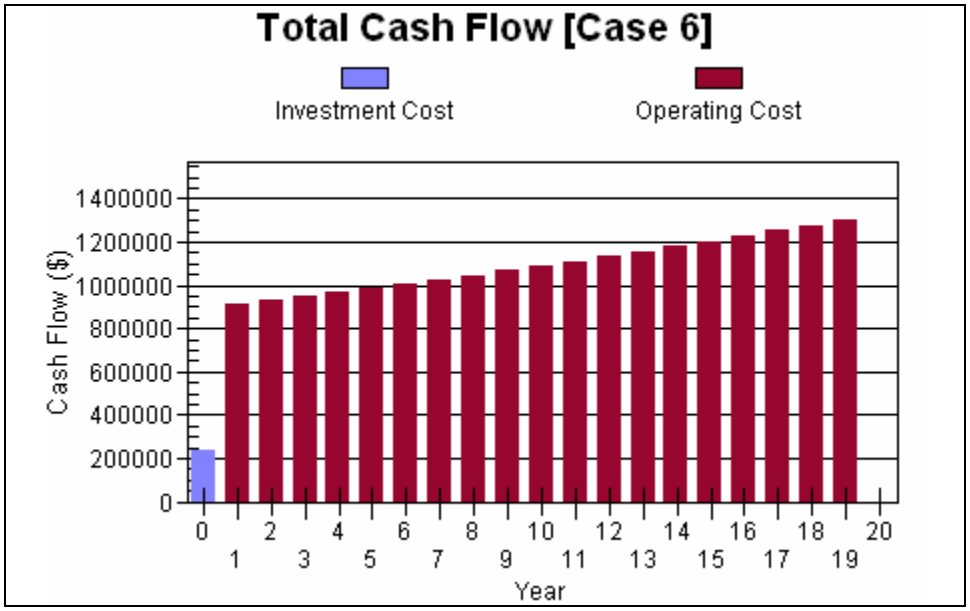
Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
0	Initial	233,897	0	0	233,897	0	0	0	233,897
1	1	0	0	0	0	697,218	0	697,218	697,218
2	2	0	0	0	0	711,162	0	711,162	711,162
3	3	0	0	0	0	725,386	0	725,386	725,386
4	4	0	0	0	0	739,893	0	739,893	739,893
5	5	0	0	0	0	754,691	0	754,691	754,691
6	6	0	0	0	0	769,785	0	769,785	769,785
7	7	0	0	0	0	785,181	0	785,181	785,181
8	8	0	0	0	0	800,884	0	800,884	800,884
9	9	0	0	0	0	816,902	0	816,902	816,902
10	10	0	0	0	0	833,240	0	833,240	833,240
11	11	0	0	0	0	849,905	0	849,905	849,905
12	12	0	0	0	0	866,903	0	866,903	866,903
13	13	0	0	0	0	884,241	0	884,241	884,241
14	14	0	0	0	0	901,926	0	901,926	901,926

Cash Flow Details

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
15	15	0	0	0	0	919,964	0	919,964	919,964
16	16	0	0	0	0	938,364	0	938,364	938,364
17	17	0	0	0	0	957,131	0	957,131	957,131
18	18	0	0	0	0	976,273	0	976,273	976,273
19	19	0	0	0	0	995,799	0	995,799	995,799
20	20	0	0	0	0	0	0	0	0
Totals		233,897	0	0	233,897	15,924,848	0	15,924,848	16,158,745

3B. Present Worth Cash Flows [Case 7]

Year	Date	Total Investment Cost ($)	Total Operating Cost ($)	Total Present Worth ($)
0	Initial	233,897	0	233,897
1	1	0	633,834	633,834
2	2	0	587,737	587,737
3	3	0	544,993	544,993
4	4	0	505,357	505,357
5	5	0	468,604	468,604
6	6	0	434,524	434,524
7	7	0	402,922	402,922
8	8	0	373,618	373,618
9	9	0	346,446	346,446
10	10	0	321,250	321,250
11	11	0	297,886	297,886
12	12	0	276,222	276,222
13	13	0	256,133	256,133
14	14	0	237,505	237,505
15	15	0	220,232	220,232
16	16	0	204,215	204,215
17	17	0	189,363	189,363
18	18	0	175,591	175,591
19	19	0	162,821	162,821
20	20	0	0	0
Totals		233,897	6,639,253	6,873,150



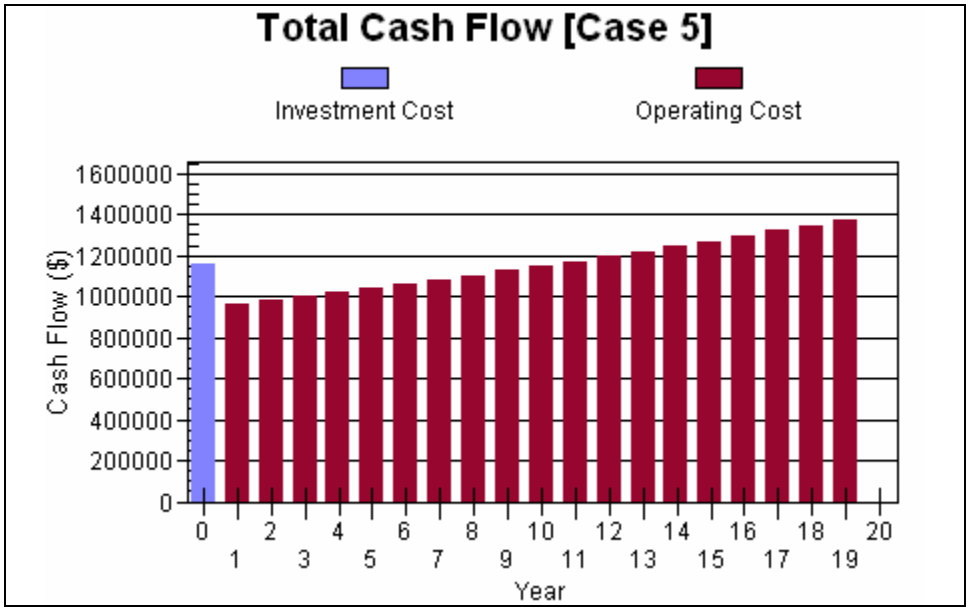
4A. Component Cash Flows [Case 6], Actual Value

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
0	Initial	243,156	0	0	243,156	0	0	0	243,156
1	1	0	0	0	0	918,542	0	918,542	918,542
2	2	0	0	0	0	936,912	0	936,912	936,912
3	3	0	0	0	0	955,651	0	955,651	955,651
4	4	0	0	0	0	974,764	0	974,764	974,764
5	5	0	0	0	0	994,259	0	994,259	994,259
6	6	0	0	0	0	1,014,144	0	1,014,144	1,014,144
7	7	0	0	0	0	1,034,427	0	1,034,427	1,034,427
8	8	0	0	0	0	1,055,116	0	1,055,116	1,055,116
9	9	0	0	0	0	1,076,218	0	1,076,218	1,076,218
10	10	0	0	0	0	1,097,742	0	1,097,742	1,097,742
11	11	0	0	0	0	1,119,697	0	1,119,697	1,119,697
12	12	0	0	0	0	1,142,091	0	1,142,091	1,142,091
13	13	0	0	0	0	1,164,933	0	1,164,933	1,164,933
14	14	0	0	0	0	1,188,232	0	1,188,232	1,188,232

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
15	15	0	0	0	0	1,211,996	0	1,211,996	1,211,996
16	16	0	0	0	0	1,236,236	0	1,236,236	1,236,236
17	17	0	0	0	0	1,260,961	0	1,260,961	1,260,961
18	18	0	0	0	0	1,286,180	0	1,286,180	1,286,180
19	19	0	0	0	0	1,311,904	0	1,311,904	1,311,904
20	20	0	0	0	0	0	0	0	0
Totals		243,156	0	0	243,156	20,980,005	0	20,980,005	21,223,161

4B. Present Worth Cash Flows [Case 6]

Year	Date	Total Investment Cost ($)	Total Operating Cost ($)	Total Present Worth ($)
0	Initial	243,156	0	243,156
1	1	0	835,038	835,038
2	2	0	774,308	774,308
3	3	0	717,995	717,995
4	4	0	665,777	665,777
5	5	0	617,357	617,357
6	6	0	572,458	572,458
7	7	0	530,825	530,825
8	8	0	492,219	492,219
9	9	0	456,421	456,421
10	10	0	423,227	423,227
11	11	0	392,447	392,447
12	12	0	363,905	363,905
13	13	0	337,440	337,440
14	14	0	312,898	312,898
15	15	0	290,142	290,142
16	16	0	269,041	269,041
17	17	0	249,474	249,474
18	18	0	231,331	231,331
19	19	0	214,507	214,507
20	20	0	0	0
Totals		243,156	8,746,810	8,989,966



5A. Component Cash Flows [Case 5], Actual Value

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
0	Initial	1,169,756	0	0	1,169,756	0	0	0	1,169,756
1	1	0	0	0	0	969,445	0	969,445	969,445
2	2	0	0	0	0	988,834	0	988,834	988,834
3	3	0	0	0	0	1,008,610	0	1,008,610	1,008,610
4	4	0	0	0	0	1,028,782	0	1,028,782	1,028,782
5	5	0	0	0	0	1,049,358	0	1,049,358	1,049,358
6	6	0	0	0	0	1,070,345	0	1,070,345	1,070,345
7	7	0	0	0	0	1,091,752	0	1,091,752	1,091,752
8	8	0	0	0	0	1,113,587	0	1,113,587	1,113,587
9	9	0	0	0	0	1,135,859	0	1,135,859	1,135,859
10	10	0	0	0	0	1,158,576	0	1,158,576	1,158,576
11	11	0	0	0	0	1,181,748	0	1,181,748	1,181,748
12	12	0	0	0	0	1,205,383	0	1,205,383	1,205,383
13	13	0	0	0	0	1,229,490	0	1,229,490	1,229,490
14	14	0	0	0	0	1,254,080	0	1,254,080	1,254,080

Year	Date	Cash Investment ($)	Loan Principal ($)	Loan Interest ($)	Total Investment Cost ($)	Annual Operating Cost ($)	Non-Annual Operating Cost ($)	Total Operating Cost ($)	Total Cash Flow ($)
15	15	0	0	0	0	1,279,162	0	1,279,162	1,279,162
16	16	0	0	0	0	1,304,745	0	1,304,745	1,304,745
17	17	0	0	0	0	1,330,840	0	1,330,840	1,330,840
18	18	0	0	0	0	1,357,457	0	1,357,457	1,357,457
19	19	0	0	0	0	1,384,606	0	1,384,606	1,384,606
20	20	0	0	0	0	0	0	0	0
Totals		1,169,756	0	0	1,169,756	22,142,659	0	22,142,659	23,312,415

5B. Present Worth Cash Flows [Case 5]

Year	Date	Total Investment Cost ($)	Total Operating Cost ($)	Total Present Worth ($)
0	Initial	1,169,756	0	1,169,756
1	1	0	881,313	881,313
2	2	0	817,218	817,218
3	3	0	757,784	757,784
4	4	0	702,672	702,672
5	5	0	651,569	651,569
6	6	0	604,182	604,182
7	7	0	560,242	560,242
8	8	0	519,497	519,497
9	9	0	481,715	481,715
10	10	0	446,681	446,681
11	11	0	414,195	414,195
12	12	0	384,072	384,072
13	13	0	356,140	356,140
14	14	0	330,238	330,238
15	15	0	306,221	306,221
16	16	0	283,951	283,951
17	17	0	263,300	263,300
18	18	0	244,151	244,151
19	19	0	226,394	226,394
20	20	0	0	0
Totals		1,169,756	9,231,535	10,401,291