



APPENDIX

มหาวิทยาลัยนครสวรรค์



APPENDIX A

COOLING AND HEAT GAIN LOAD

มหาวิทยาลัยสุรินทร์

APPENDIX A

COOLING AND HEAT GAIN LOAD

Table 24 Profile Angle for Testing Building at SERT (Latitude 16.78°)

Month	Time	Solar Position		Profile (Shadow Line) Angles, Ω								
		ALT	AZ	N	NE	E	SE	S	SW	W	NW	
Jan	6	-3.7736	69.2792									
	7	9.4499	64.6459		10.0224	10.4360	10.0224	21.2408				
	8	22.0842	58.3478		22.6362	25.4842	22.6362	37.7106				
	9	33.7182	49.4926		33.7997	41.2752	33.7997	45.7757				
	10	43.5822	36.7033		43.8833	57.8709	43.8833	49.8880	81.3783			
	11	50.3247	18.6314		53.3809	75.1576	53.3809	51.8321	69.7756			
	12	52.2304	3.5425		62.8898		62.8898	52.2304	59.8182	27.1818		
	13	48.6242	24.9800		73.2186		73.2186	51.3938	50.3875	69.5952		
	14	40.7031	41.2996		85.7094		85.7094	48.8681	40.7622	52.5034		
	15	30.1603	52.6634					43.7743	30.3841	36.1612	77.0751	
	16	18.1461	60.5782					33.7104	18.7904	20.6198	50.6685	
	17	5.2909	66.2709					12.9598	5.6752	5.7763	14.3201	
	18	-8.0666	70.4954									
Feb	6	-2.6268	77.2580									
	7	11.2428	72.6222		12.6451	11.7659	12.6451	33.6460				
	8	24.7127	66.6387		26.3404	26.6253	26.3404	49.2515				
	9	37.4644	58.2591		38.2144	42.0225	38.2144	55.5312				
	10	48.8166	45.5538		48.8179	58.0105	48.8179	58.5061				
	11	57.2716	25.5428		58.7848	74.5110	58.7848	59.8917	77.9164			
	12	60.2493	2.2782		68.8905		68.8905	60.2493	67.2174	28.6991		
	13	56.2496	29.2229		79.7029		79.7029	59.7515	57.2583	71.9329		
	14	47.1989	47.9152					58.1736	47.2359	55.5005	87.3036	
	15	35.5600	59.7756					54.8482	36.4764	39.6024	70.3660	
	16	22.6656	67.6868					47.7241	24.3527	24.2946	47.2748	
	17	9.1185	73.4086					29.3404	10.3415	9.5075	18.6427	
	18	-4.7960	77.8969									
Mar	6	1.5856	86.9949		2.1330	1.5877	2.1330	27.8342				
	7	15.8831	82.4374		19.7153	16.0153	19.7153	65.1778				
	8	30.0132	76.9930		34.2592	30.6624	34.2592	68.7129				
	9	43.7733	69.5180		46.4794	45.6437	46.4794	69.9365				
	10	56.6615	57.4152		57.2811	61.0008	57.2811	70.4919				
	11	67.1178	34.1293		67.4872	76.6780	67.4872	70.7426	85.4491			
	12	70.6581	7.2191		77.8635		77.8635	70.6581	74.4944	27.4743		
	13	64.2475	43.4069		89.2316		89.2316	70.6866	64.2562	71.6601		
	14	52.7110	62.0494					70.3576	53.9444	56.0727	77.4142	

*Green numeric is profile angle as the shadow of roof over height the bottom window frame

Table 24 (Cont.)

Month	Time	Solar Position		N	NE	E	Profile (Shadow Line) Angles, Ω				
		ALT	AZ				SE	S	SW	W	NW
	15	39.4536	72.2285					69.6514	42.7854	40.8341	60.9278
	16	25.5425	78.8759					68.0149	29.9245	25.9678	40.6083
	17	11.3437	83.9480					62.2761	14.4642	11.4056	17.6997
	18	-2.9823	88.3719								
Apr	6	7.1686	101.9477	31.2805	8.5339	7.3256	12.9857				
	7	21.3068	98.2362	69.8319	25.9592	21.5087	33.0900				
	8	35.5737	94.7681	83.3709	43.1330	35.6677	47.9169				
	9	49.9132	91.0973	89.0765	58.7653	49.9184	59.7299				
	10	64.2673	86.2225		72.3796	64.3160	70.0736	88.1813			
	11	78.4577	74.8154		84.2020	78.8504	79.9521	86.9381			
	12	85.2271	46.3223					86.6928	85.2284	88.5443	89.8856
	13	71.7966	82.0110					87.3832	75.2867	71.9617	78.8026
	14	57.4811	88.8029					89.2369	65.2917	57.4868	66.1887
	15	43.1248	92.8981	86.9101					54.4034	43.1614	51.6144
	16	28.8133	96.4021	78.5404					41.4030	28.9649	35.1382
	17	14.5993	99.9389	56.4698					24.3905	14.8120	17.6516
	18	0.5477	103.8958	2.2795					1.0601	0.5642	0.6397
May	6	10.5503	106.6236	33.0652	21.3995	10.9995	21.3995				
	7	24.4222	103.4501	62.8770	40.9526	25.0275	40.9526				
	8	38.4606	100.9627	76.5360	54.8286	38.9755	54.8286				
	9	52.6029	99.1811	83.0456	65.8967	52.9588	65.8967				
	10	66.7968	98.6582	86.3077	75.7467	67.0337	75.7467				
	11	80.9249	104.2015	87.7559	85.3245	81.1979	85.3245				
	12	84.2076	111.1724	87.9012					87.6538	84.5964	84.6981
	13	70.1936	98.9577	86.7904					78.0357	70.4167	73.7639
	14	55.9975	98.8960	84.0446					68.3225	56.3182	61.4087
	15	41.8378	100.4651	78.5315					57.6576	42.3159	47.3820
	16	27.7696	102.7957	67.1881					44.6551	28.3678	31.8941
	17	13.8509	105.7944	42.1725					26.8081	14.3722	15.7737
	18	0.1661	109.6082	0.4948					0.3872	0.1763	0.1838
Jun	6	10.8814	111.0439	28.1622	25.3346	11.6385	25.3346				
	7	24.4133	108.2339	55.4195	45.2249	25.5429	45.2249				
	8	38.1266	106.4970	70.1095	58.6995	39.3019	58.6995				
	9	51.9179	106.2118	77.6597	69.3256	53.0408	69.3256				
	10	65.6337	109.0811	81.5780	78.8021	66.8277	78.8021				
	11	78.6262	125.2912	83.3710	88.0571	80.6757	88.0571				
	12	82.1863	144.5571	83.8175						85.4444	82.2371
	13	70.2610	111.8559	82.3915					81.9724	71.5807	71.7401
	14	56.6524	106.6666	79.3120					72.6554	57.7718	59.9192

*Green numeric is profile angle as the shadow of roof over height the bottom window frame

Table 24 (Cont.)

Month	Time	Solar Position			Profile (Shadow Line) Angles, Ω						
		ALT	AZ	N	NE	E	SE	S	SW	W	NW
	15	42.8630	106.1946	73.2733					62.5621	44.0211	46.6442
	16	29.1109	107.5090	61.6181					50.3420	30.2804	32.1174
	17	15.5046	109.9602	39.0989					33.2421	16.4434	17.0239
	18	2.1563	113.4836	5.3978					5.8615	2.3508	2.3177
Jul	6	8.8837	109.5653	25.0206	9.8195	9.4186	19.9983				
	7	22.5452	106.4681	55.6723	25.2919	23.4076	40.9948				
	8	36.3969	104.2772	71.5030	40.6142	37.2593	55.2770				
	9	50.3548	103.1584	79.3180	54.8581	51.1018	66.3875				
	10	64.3268	104.1160	83.3135	67.5822	65.0061	76.1397				
	11	78.0249	113.4158	85.1820	78.8428	78.9860	85.5385				
	12	84.6481	145.8693	85.5658	82.9879					86.9911	84.7435
	13	72.2323	107.2075	84.5847					81.5021	72.9806	74.1731
	14	58.3396	103.3023	81.9244					72.0469	59.0315	62.3152
	15	44.3588	103.4755	76.5962					61.8667	45.1585	48.9210
	16	30.4389	105.1049	66.0825					49.6930	31.3243	34.1272
	17	16.6554	107.6829	44.5646					33.1003	17.4324	18.6093
	18	3.1080	111.1993	8.5394					7.6630	3.3331	3.3962
Aug	6	7.1686	101.9477	31.2805	8.5339	7.3256	12.9857				
	7	21.3068	98.2362	69.8319	25.9592	21.5087	33.0900				
	8	35.5737	94.7681	83.3709	43.1330	35.6677	47.9169				
	9	49.9132	91.0973	89.0765	58.7653	49.9184	59.7299				
	10	64.2673	86.2225		72.3796	64.3160	70.0736	88.1813			
	11	78.4577	74.8154		84.2020	78.8504	79.9521	86.9381			
	12	85.2271	46.3223					86.6998	85.2284	86.5443	80.8856
	13	71.7966	82.0110					87.3832	75.2867	71.9617	78.8026
	14	57.4811	88.8029					89.2369	65.2917	57.4868	66.1887
	15	43.1248	92.8981	86.9101				54.4034	43.1614		51.6144
	16	28.8133	96.4021	78.5404				41.4030	28.9649		35.1382
	17	14.5993	99.9389	56.4698				24.3905	14.8120		17.6516
	18	0.5477	103.8958	2.2795				1.0601	0.5642		0.6397
Sep	6	6.2176	90.4464		8.6925	6.2178	8.5268				
	7	20.5686	85.9861		29.7754	20.6149	26.4323	79.4336			
	8	34.8319	80.7582		49.9767	35.1837	40.6128	77.0037			
	9	48.8379	73.5297		67.3364	50.0237	52.4720	76.0786			
	10	62.1268	61.0708		81.6708	65.1615	63.0600	75.6497			
	11	72.8698	32.7377			80.5368	73.2384	75.4656	86.2547		
	12	74.3493	22.0924				83.7767	75.4484	75.5303	83.9853	
	13	64.8712	56.7886					75.5917	65.3376	68.5734	84.5262
	14	51.8918	71.3985					75.9535	54.9103	53.3744	70.7752

*Green numeric is profile angle as the shadow of roof over height the bottom window frame

Table 24 (Cont.)

Month	Time	Solar Position		N	NE	E	Profile (Shadow Line) Angles, Ω				
		ALT	AZ				SE	S	SW	W	NW
	15	37.9865	79.3849					76.7270	43.4182	38.4673	54.1257
	16	23.7611	84.9167					78.6205	29.8556	23.8444	34.4534
	17	9.4202	89.4801					86.8698	13.0905	9.4205	13.3218
	18	-4.9318	93.8171					52.3499			
Oct	6	5.0772	78.3665		9.1764	5.1831	6.0724	23.7781			
	7	19.0018	73.2587		36.0300	19.7788	21.3534	50.0884			
	8	32.4952	66.5112		60.0717	34.7800	34.3971	57.9639			
	9	45.1509	56.6261		78.6644	50.2832	45.7447	61.3120			
	10	56.0073	40.6500			66.2851	56.0839	62.9052	87.0720		
	11	62.8064	14.5297			82.6551	66.1148	63.5563	75.3969		
	12	62.3662	17.9298				76.5950	63.5204	65.9078	80.6486	
	13	54.9586	42.8338				88.4816	62.7845	54.9778	64.5088	
	14	43.8258	57.9373					61.0546	44.5620	48.5576	76.8703
	15	31.0460	67.3682					57.4107	33.0614	33.1114	57.6988
	16	17.4912	73.8805					48.6187	19.7933	18.1608	33.1230
	17	3.5333	78.8648					17.7300	4.2527	3.6009	6.3230
	18	-10.6485	83.0772								
Nov	6	-5.3691	71.8394								
	7	8.0971	67.3663		20.4994	8.7626	8.7460	20.2886			
	8	21.0570	61.3899		53.7622	23.6801	21.8663	38.8003			
	9	33.1533	53.0352		77.9214	39.2674	33.4127	47.3687			
	10	43.6950	40.8595			55.6003	43.7698	51.6357	85.6784		
	11	51.3801	23.0970			72.5999	53.4543	53.8906	73.4057		
	12	54.3080	0.0000			90.0000	63.0714	54.3080	63.0714	90.0000	
	13	51.3801	23.0970				73.4057	53.8906	53.4543	72.5999	
	14	43.6950	40.8595				85.6784	51.6357	43.7698	55.6003	
	15	33.1533	53.0352					47.3687	33.4127	39.2674	77.9214
	16	21.0570	61.3899					38.8003	21.8663	23.6801	53.7622
	17	8.0971	67.3663					20.2886	8.7460	8.7626	20.4994
	18	-5.3691	71.8394								
Dec	6	-0.7578	66.1096								
	7	12.1177	61.1184		37.7172	13.7773	12.5980	23.9662			
	8	24.2714	54.2281		70.4225	29.0635	24.5523	37.6457			
	9	35.2034	44.5033			45.1858	35.2044	44.6891	89.2960		
	10	44.0204	30.6735			62.1707	44.9252	48.3305	75.6376		
	11	49.3134	12.0348			79.8372	54.1966	49.9418	64.9297		
	12	43.6657	9.2684				63.6250	50.0368	55.4230	82.2128	
	13	44.9608	28.4709				74.0982	48.6437	46.1695	64.4819	
	14	36.5203	42.9333				87.2118	45.3253	36.5381	47.3911	
	15	25.8065	53.1263					38.8639	26.0338	31.1521	73.7052
	16	13.7796	60.3296					26.3556	14.2676	15.7619	42.8509

Table 24 (Cont.)

Month	Time	Solar Position		Profile (Shadow Line) Angles, Ω							
		ALT	AZ	N	NE	E	SE	S	SW	W	NW
	17	0.9803	65.5335					2.3658	1.0468	1.0770	2.7929
	18	-12.2888	69.3385								

*Green numeric is profile angle as the shadow of roof over height the bottom window frame

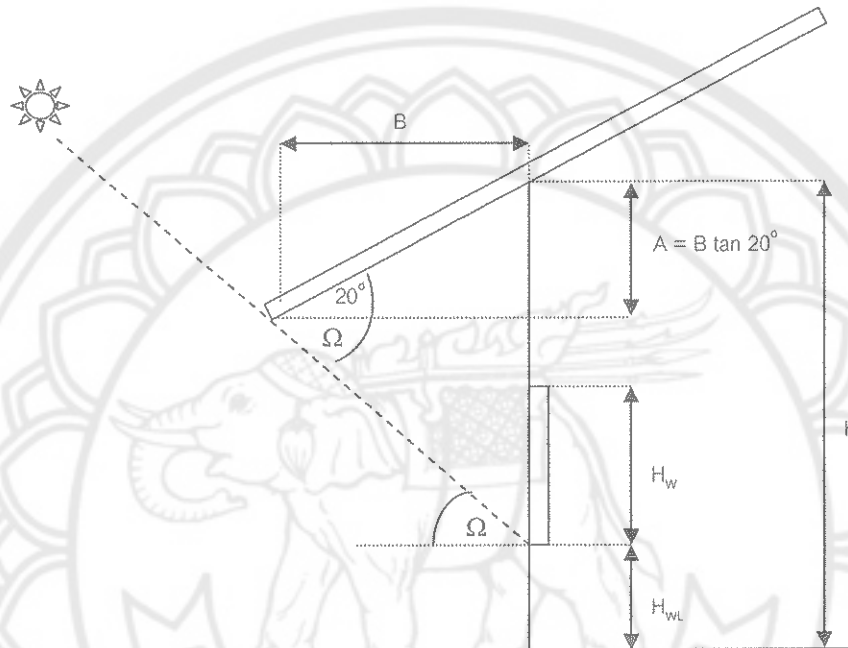


Figure 37 Profile angle at the shadow of roof project the bottom frame of window for external wall in 30° to 150° from south

The profile angle (Ω), that calculated from trigonometrics in figure A-1 is the minimum angle as shading to still project the bottom frame of window. For -30° to 150° from south;

At -30° to 82.5 and 128.5° to 150° from south H , H_w , H_{wL} and B are equal 4.6, 1.55, 1.0 and 3.0 m. The minimum profile angle is 39.8967°

At 128.5° to 150° from south H , H_w and H_{wL} are equal 4.3, 1.85, 0.3 and 4.0 m. The minimum profile angle is 32.4576°

This the profile angle can use finding shadow line project to the window at any time from table 24



APPENDIX B

SOLAR COOLING SYSTEM

มหาวิทยาลัยนครสวรรค์

APPENDIX B

SOLAR COOLING SYSTEM

Collector Size	10 tubes	18 tubes	20 tubes	22 tubes	30 tubes
Overall Length ¹	1980mm / 80"				
Overall Height ²	156mm / 6.14" (manifold + standard frame)				
Overall Width ³	796mm / 31.3"	1356mm / 53.4"	1496mm / 58.8"	1636mm / 64.4"	2196mm / 86.4"
Absorber Area ⁴	0.8m ² / 0.86ft ²	1.44m ² / 15.5ft ²	1.6m ² / 17.2ft ²	1.76m ² / 18.9ft ²	2.4m ² / 25.8ft ²
Aperture Area ⁵	0.94m ² / 10.1ft ²	1.69m ² / 18.2ft ²	1.85m ² / 20.2ft ²	2.07m ² / 22.3ft ²	2.82m ² / 30.3ft ²
Gross Area	1.57m ² / 16.95ft ²	2.68m ² / 28.8ft ²	2.96m ² / 31.8ft ²	3.24m ² / 34.8ft ²	4.35m ² / 46.8ft ²
Gross Dry Weight (Standard Frame)	34.8kg / 76.5p	58.2kg / 128p	63.5kg / 139.7p	71.3kg / 156.8p	94.8kg / 208.5p
Fluid Capacity	290ml / 9.8oz	490ml / 16.57oz	520ml / 17.58oz	550ml / 18.6oz	710ml / 24oz

Figure 38 General specification of solar collector

Stagnation SPF Report No. C632LPEN	245°C, when G = 1000W/m ² , Ambient Temp = 30°C 477°F, when G = 317Btu/ft ² , Ambient Temp = 86°F									
Efficiency SPF Report No. C632LPEN	$\eta_0 (-) = 0.717$, $a_1 (W/m^2K) = 1.52$, $a_2 (W/m^2K^2) = 0.0085$ G = 800W/m ² / 253Btu/ft ² based on Absorber area.									
Quality Certifications	SPF Solar Collector Quality Test Certificate No. C632QPEN (SPF Quality Test According to: EN 12975.2: 2001, Section 5)									
	SRCC OG100 Award of Collector Certification Certification No. 100-2894993A,B,C,D Testing conducted by Bodycote Materials Testing Canada Inc.									
	Australian Standards Mark Plumbing AS2712 (License No. SMK20405)									
Incidence Angle Modifier	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
K _θ (longitudinal)						0.93				
K _θ (transversal)	1.0	1.02	1.08	1.18	1.37	1.4	1.34	1.24	0.95	0.0

Figure 39 Performance and quality specification of solar collector

Model	WFC	SC10	SH10	SC20	SH20	SC30	SH30
Cooling	Capacity (Btu/hr x 1000)	120.0		240.0		360.0	
	Chilled Water Temp. (°F)	44.6 Outlet, 54.5 Inlet					
Heating	Capacity (Btu/hr x 1000)	—	185.3	—	332.6	—	498.9
	Hot Water Temp. (°F)	131.0 Outlet, 117.3 Inlet					
Chilled/Hot Water	Rated Water Flow (gpm)	24.2		48.4		72.6	
	Evap. Press Drop (psi)	8.1		9.6		10.1	
	Water Retention Volume (gal)	4.5		12.4		19.3	
Cooling Water	Heat Rejection (Btu/hr x 1000)	291.4		662.8		874.2	
	Inlet Temperature (°F)	67.8 (Standard)					
	*Rated Water Flow (gpm)	80.8		161.7		242.5	
	Cond./Abs. Press. Drop (psi)	12.3		6.6		6.7	
	Water Retention Volume (gal)	17.4		33.0		51.3	
Heat Medium	Input (Btu/hr x 1000)	171.4		342.8		514.2	
	Inlet Temperature (°F)	190.4 (Standard)					
		Temperature Range 168 (min.) - 203 (max.)					
	Rated Water Flow (gpm)	38.0		76.1		114.1	
	Generator Press. Drop (psi)	13.1		6.7		8.8	
Electrical	Water Retention Volume (gal)	5.5		14.3		22.2	
	Power Supply	208V, 60Hz, 3 ph					
Capacity Control	Consumption (W)	210		260		310	
		On - Off					
Noise Level	Sound Pressure dB(A)	49		49		46	
	Chilled/Hot Water (in)	1-1/2 NPT		2 NPT		2 NPT	
	Cooling Water (in)	2 NPT		2 NPT		2-1/2 NPT	
Piping	Heat Medium (in)	1-1/2 NPT		2 NPT		2-1/2 NPT	
	Dry (lb)	1,100		2,050		3,200	
Weight	Operating (lb)	1,325		2,548		3,975	

Figure 40 Specification of Absorption chiller

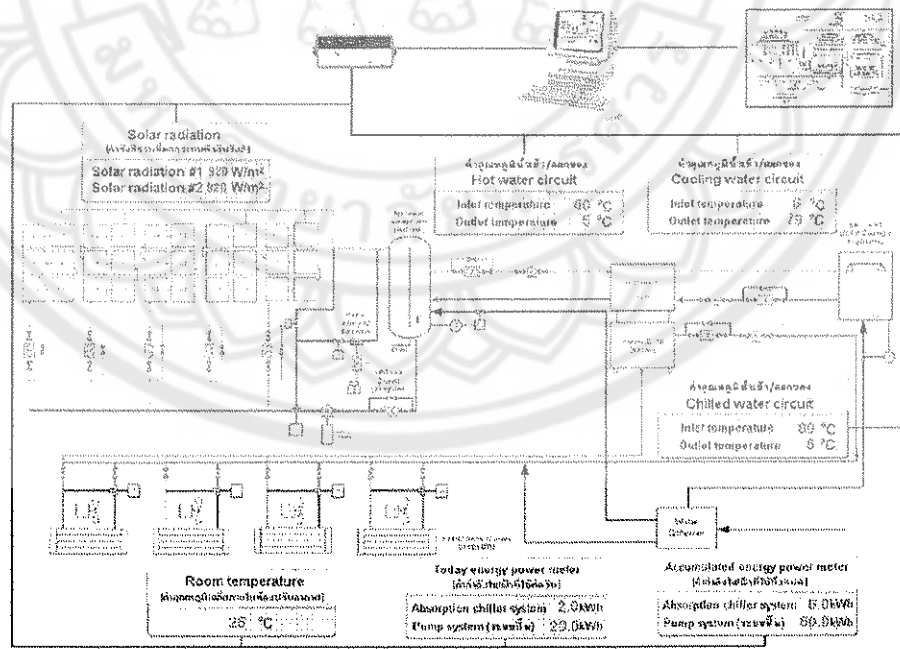


Figure 41 Control and Monitoring of Solar Cooling System

(Nipon Ketjoy, May 1st 2005.)

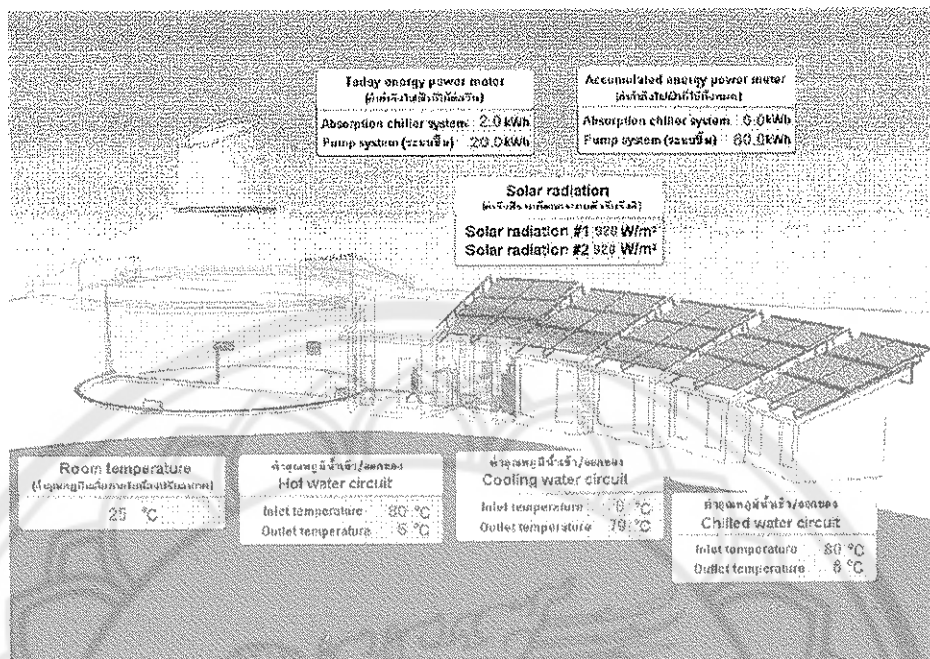


Figure 42 Solar Cooling System (Nipon Ketjoy, May 1st 2005.)

Part Heat backup simulation for design system:

MONTH	Energy from Heater backup (w)									
	7:00-8:00	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00
JAN	-12,232.69	-6,607.97	1,765.01	8,991.67	14,216.52	14,852.36	11,206.90	3,647.97	-5,283.33	-16,532.16
FEB	-12,475.91	-7,019.09	124.83	7,153.70	11,742.38	12,909.59	10,464.07	4,443.65	-2,991.74	-13,431.35
MAR	-10,417.04	-6,956.42	1,737.79	8,181.20	12,844.23	13,104.16	10,924.81	5,126.48	-2,345.23	-14,883.61
APR	-9,522.40	-6,258.30	558.65	5,546.32	9,512.98	9,743.62	7,457.97	1,936.31	-4,865.69	-16,325.82
MAY	-10,007.66	-8,189.53	-3,048.99	735.82	4,022.40	4,299.96	2,729.54	-1,478.02	-6,523.71	-16,965.59
JUN	-11,472.29	-10,556.66	-6,061.49	-2,898.64	360.80	942.60	-359.98	-3,546.37	-7,558.85	-16,373.23
JUL	-11,637.96	-10,611.08	-5,997.75	-2,549.82	644.87	1,476.62	391.32	-2,791.55	-6,639.69	-15,314.72
AUG	-12,337.39	-11,414.60	-6,755.16	-3,322.96	-64.16	898.82	-162.79	-3,213.19	-6,954.38	-16,132.46
SEP	-11,931.21	-10,234.25	-4,931.69	-1,042.93	2,328.14	2,725.52	1,150.79	-2,743.52	-7,381.09	-18,559.89
OCT	-11,989.13	-9,924.45	-4,430.40	-428.58	2,608.90	2,499.85	236.37	-4,065.11	-9,002.23	-19,568.57
NOV	-10,771.87	-8,115.43	-2,205.33	2,659.71	5,851.44	5,388.56	2,535.44	-3,992.78	-7,964.51	-17,842.66
DEC	-10,504.21	-6,892.24	1,104.17	7,120.05	10,991.23	10,523.89	6,513.99	-318.19	-8,138.32	-17,721.43

Auxiliary Energy Need = Absorption Chiller Energy Demand - Energy Supply by Collector

Figure 43 Energy Heat backup (Nipon Ketjoy, May 1st 2005.)

MONTH	Energy from Heater backup (w)	Daily energy input to Absorption chiller (w)	%
JAN	-46,655.548	208,122.857	-19.534
FEB	-38,968.979	231,817.143	-16.767
MAR	-33,682.304	243,780.000	-13.817
APR	-37,472.714	263,192.857	-14.238
MAY	-46,213.414	264,670.000	-17.461
JUN	-59,237.422	263,708.571	-22.463
JUL	-55,562.379	250,512.857	-22.180
AUG	-60,357.086	246,751.429	-24.461
SEP	-58,844.514	245,005.714	-23.201
OCT	-59,338.467	236,362.857	-25.105
NOV	-49,702.769	215,027.143	-23.115
DEC	-42,794.393	209,354.286	-20.441
	-42,394.182	239,858.810	-20.176

Figure 44 Energy supply ratio: Solar collector/Auxiliary energy
between 7.00am – 17.00pm (Nipon Ketjoy, May 1st 2005.)

Month	Energy (kW/day)	(MJ/day)	(litre/day)	(litre/ 2 weeks)*	(kg/ 2 weeks)	(48 kg)/ 2 weeks
Jan	40,655.548	146,360	5,695	56,949	30,183	0.629
Feb	38,868.970	139,928	5,445	54,447	28,857	0.601
Mar	33,682.304	121,256	4,718	47,181	25,006	0.521
Apr	37,472.714	134,902	5,249	52,491	27,820	0.580
May	46,213.414	166,368	6,473	64,735	34,309	0.715
Jun	59,273.402	213,384	8,303	83,029	44,005	0.917
Jul	55,562.579	200,025	7,783	77,831	41,250	0.859
Aug	60,357.086	217,286	8,455	84,547	44,810	0.934
Sep	56,844.514	204,640	7,963	79,627	42,202	0.879
Oct	59,338.467	213,618	8,312	83,120	44,054	0.918
Nov	49,702.769	178,930	6,962	69,623	36,900	0.769
Dec	42,794.393	154,060	5,995	59,945	31,771	0.662

2 LPG Tanks Sufficient for 2 Weeks peration
 *Operation Day : Monday - Friday

Figure 45 LPG tank calculation between 7.00am – 17.00pm
 (Nipon Ketjoy, May 1st 2005.)