

CHAPTER IV

DESCRIPTION OF SOLAR HOUSE

The typical solar house⁽³⁵⁾ studied is shown in FIGURE 4.1. Its inside look is shown in FIGURE 4.2. The construction features are as follows:

a) Location: In Bangkok, latitude $13^{\circ} 44' 00''$ north, longitude $100^{\circ} 30' 00''$ east.

b) House floor area: 86.25 m^2

c) Orientation and tilt of the solar collector on south roof: South, 13° tilt from horizon.

d) Wall structure: 4" concrete block with thermal insulation

e) Sectional views of the various portions of the house are shown in TABLE 4.1

There are four occupants in the family.⁽³⁵⁾

The solar thermal system installed on the house is illustrated in FIGURE 4.3. The whole system consists of the 19 components listed in TABLE 4.2. In MOSTPROSIT, specifications of system components are done via the parametric values chosen for the corresponding modules. TABLE 4.3 lists the complete set of parametric values for the solar system. It should be noted that not all modules represent actual devices

and that not all parametric values are specifications for the devices. For example, component 19 is nonexistent but is used to help plot certain histograms. For this reason, it is not shown in FIGURE 4.3. FIGURE 4.4 presents the material, energy, and signal flow chart for the house.

Certain time-dependent diurnal inputs have been used in the simulation to represent the daily activities and demands of the occupants in the house. Their values are computed via functions HWATER, QPEPL and QLIGHT. Details of the functions, as well as the estimations of certain parametric values, are shown in Appendix C.

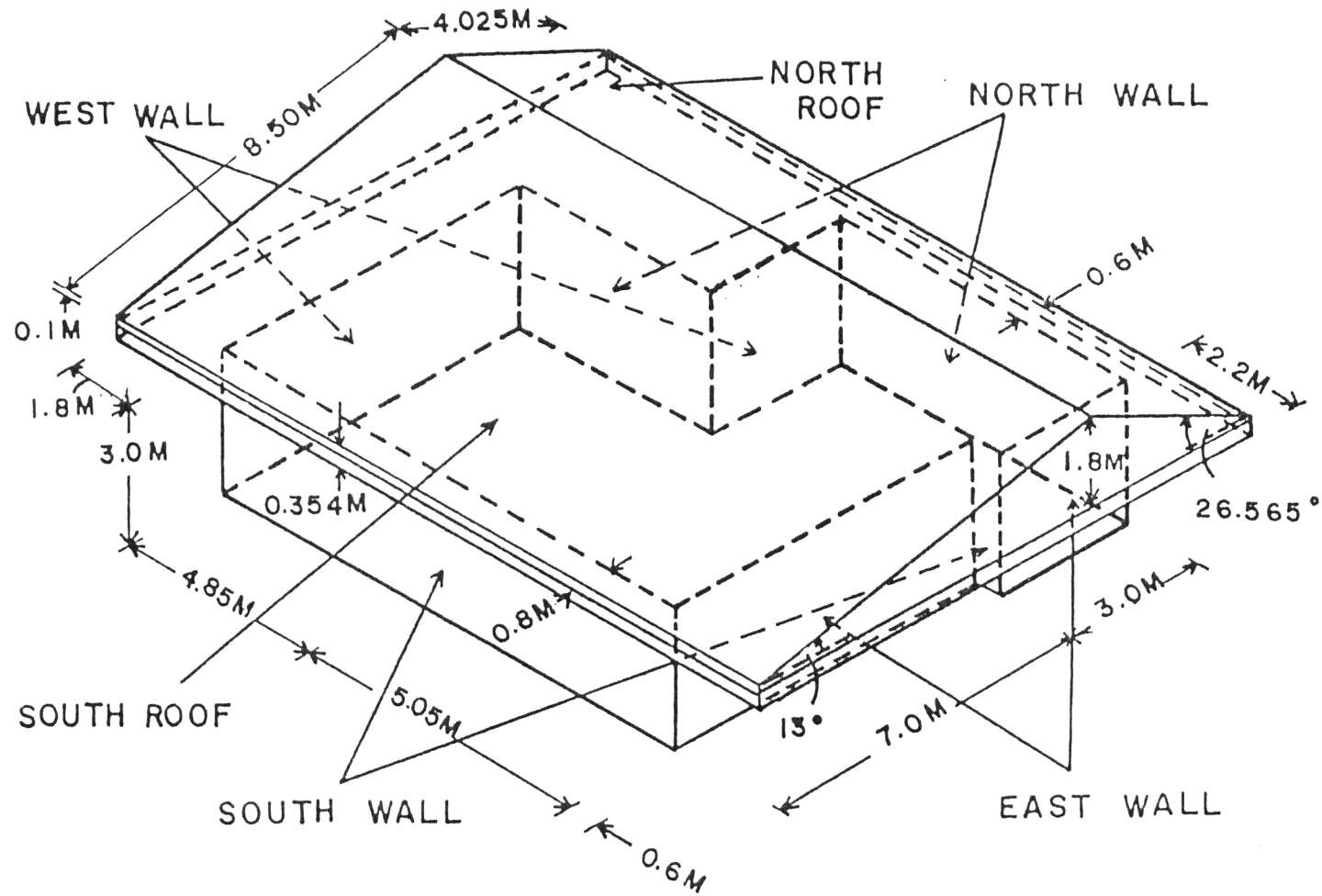


FIGURE 4.1 DIMENSIONS OF THE SOLAR HOUSE

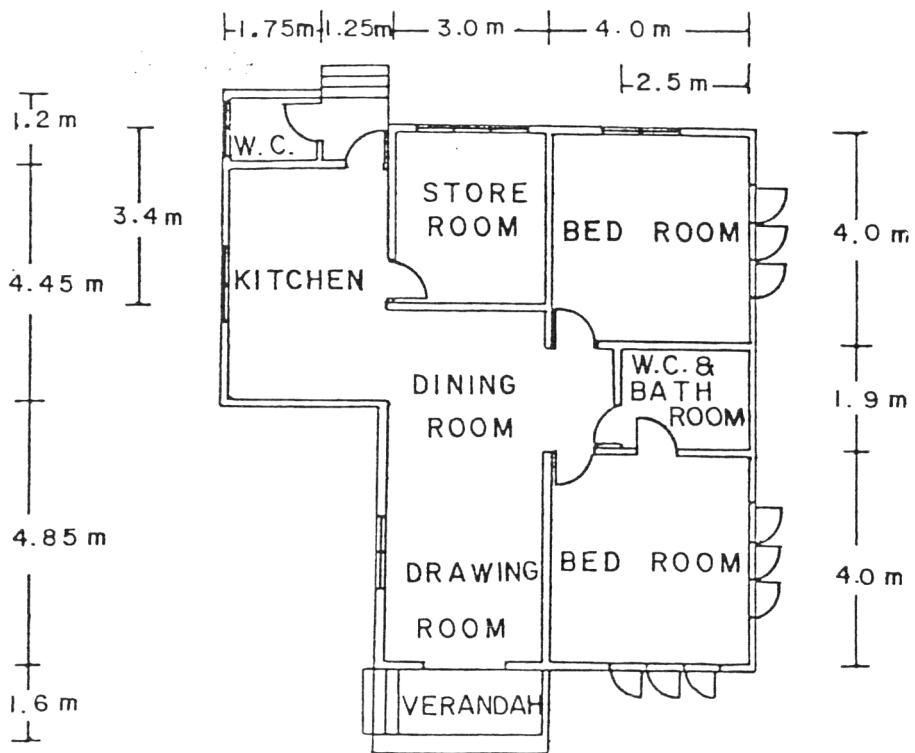
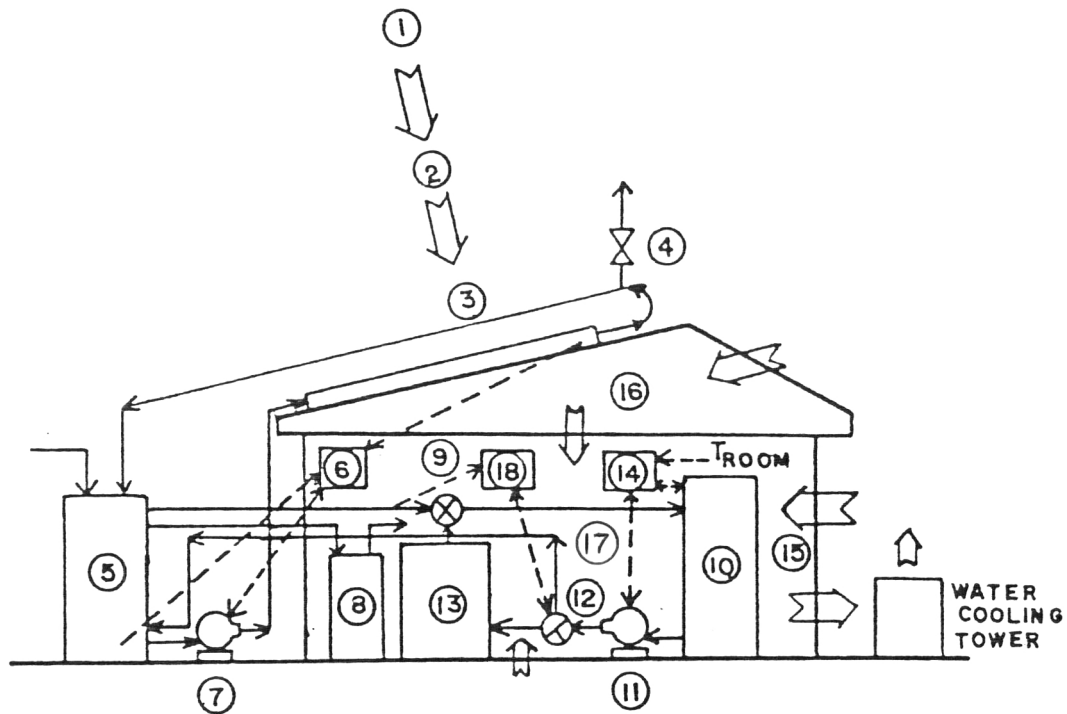


FIGURE 4.2 INSIDE VIEW OF THE SOLAR HOUSE



- | | |
|--|--|
| ① DATA READER | ⑩ HOT WATER FIRED ABSORPTION CHILLER |
| ② SOLAR RADIATION PROCESSOR | ⑪ CIRCULATION PUMP |
| ③ FLAT PLATE COLLECTOR | ⑫ FLOW DIVERTER |
| ④ PRESSURE RELIEF VALVE | ⑬ MAIN AUXILIARY HEATER |
| ⑤ HEAT STORAGE TANK | ⑭ ON/OFF CONTROLLER FOR ABSORPTION CHILLER |
| ⑥ ON/OFF CONTROLLER FOR COLLECTOR PUMP | ⑮ WALLS |
| ⑦ COLLECTOR PUMP | ⑯ PITCHED ROOF |
| ⑧ HOT WATER AUXILIARY HEATER | ⑰ ROOM |
| ⑨ FLOW MIXER | ⑱ ON/OFF CONTROLLER FOR FLOW DIVERTER |

FIGURE 4.3 DIAGRAM OF THE SOLAR HOUSE

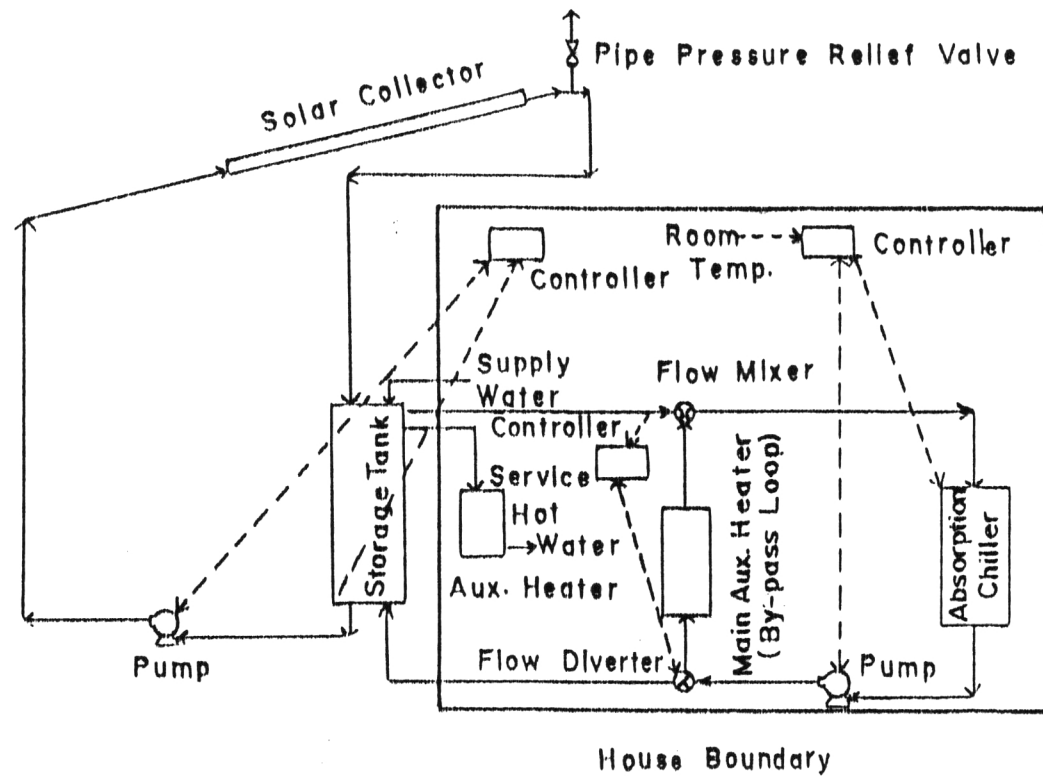


FIGURE 4.4 FLOW CHART AND SIGNAL FLOW CHART OF THE SOLAR HOUSE

TABLE 4.1 Sectional Views of Various Portions of the House

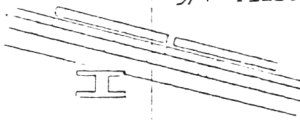
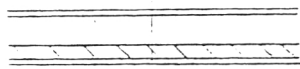
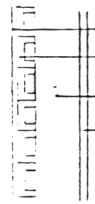
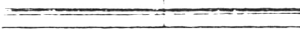
Name of Portion	Details of Sectional Structure
Roof	<ul style="list-style-type: none"> - Solar Collector - 1" Tile - 3" Purlin - 6" Rafter - 3/4" Plywood - 9" Air Space - 3" Insulation - 3/4" Plaster 
Ceiling	
Wall	 <ul style="list-style-type: none"> 3/4" Plaster 4" Low Weight Concrete Block 7" Air Layer 1" Wood Siding Plaster
Floor	<ul style="list-style-type: none"> 1/2" Carpet 1/2" Water-Proof Board 3 1/6" Reinforced Concrete 

TABLE 4.2 List of Solar System Components

Unit No.	Name of System Component	Module Code No.	Number of			
			Inputs	Outputs	Parameters	Derivatives
1.	Data Reader	13	0	4	10	0
2.	Solar Radiation Processor	9	1	12	19	0
3.	Flat-Plate Solar Collector (Unsteady-State Model)	11	10	1	28	31
4.	Pipe Pressure Relief Valve	1	2	2	2	1
5.	Stratified Liquid Storage Tank	3	7	3	8	4
6.	On/off Differential Controller (for Collector Pump)	14	3	1	2	0
7.	Pump (for Solar Collector)	6	2	2	1	0
8.	On/off Auxiliary Heater (for Service Hot Water)	2	2	2	3	1
9.	Flow Mixer (from Storage Tank and Main Auxiliary Heater)	5	4	2	0	0
10.	Lithium Bromide-Water Absorption Air-Conditioner	7	3	2	4	3
11.	Pump (for Circulation)	6	2	2	1	0

TABLE 4.2 List of Solar System Components (Contd.)

Unit No.	Name of System Component	Module Code No.	Number of			
			Inputs	Outputs	Parameters	Derivatives
12.	Flow Diverter (to Storage Tank or Main Auxiliary Heater)	4	3	4	0	0
13.	On/off Main Auxiliary Heater	2	2	2	3	1
14.	On/off Differential Controller (for Air-Conditioner and Circulation Pump)	14	3	1	2	0
15.	House Walls	17	7	3	30	0
16.	Pitched Roof and Attic	18	8	2	15	0
17.	Room	19	9	5	18	1
18.	On/off Differential Controller (for Flow Diverter)	14	3	1	2	0
19.	Absolute Value Taking	20	1	1	0	0

TABLE 4.3 List of System Parametric Values

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
1	N_{Data}	Number of data	4.0	-	1	
2	Δtime	Time interval between data points	1.0	hr	1	
3	ITAPE	Magnetic tape is used?	1.0 (No)	-	1	
4	NCONV	Number of items of which units are to be converted	2.0	-	1	
5	ID_1	No. of first data item requiring unit conversion	1.0	-	1	
6	A_1	Conversion multiplier for the first data item	41.868	$\frac{\text{kJ/m}^2}{\text{cal/cm}^2}$	1	13
7	B_1	Conversion factor to add to the first data item	0.0	-	1	
8	ID_2	No. of second data item requiring unit conversion	2.0	-	1	
9	A_2	Conversion multiplier for the second data item	0.2778	$\frac{\text{m/s}}{\text{km/hr}}$	1	13

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
10	B_2	Conversion factor to add to the second data item	0.0	-	1	
11	ϕ	Latitude of Solar House Location	13.7	degrees (North)	2	14
12	S_c	Solar Constant	4871.0	$\text{kJ/m}^2/\text{hr}$	2	15
13	N_{day}	Starting day of simulation	60.0, 91.0, 121.0, 152.0 (for the first of March, April, May, June, respectively)	-	2	
14	IOPT	Specifies which relationship to estimate beam and diffuse radiation	3.0 (for Orgill's relationship)	-	2	16
15	ρ_{ground}	Ground reflectance of diffuse solar radiation	0.2	-	2	17
16	M	Number of surfaces	6.0	-	2	
17	SHFT	Time shift factor to correct solar radiation reporting hour	-0.5	hr	2	
18	S_1	Slope of the first surface (south roof)	13.0	degrees	2	18

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
19	γ_1	Orientation of the first surface (south roof)	0.0	degree	2	18
20	S_2	Slope of the second surface (north roof)	26.57	degrees	2	19
21	γ_2	Orientation of the second surface (north roof)	180.0	degrees	2	19
22	S_3	Slope of the third surface (south wall)	90.0	degrees	2	19
23	γ_3	Orientation of the third surface (south wall)	0.0	degree	2	19
24	S_4	Slope of the fourth surface (north wall)	90.0	degrees	2	19
25	γ_4	Orientation of the fourth surface (north wall)	180.0	degrees	2	19
26	S_5	Slope of the fifth surface (east wall)	90.0	degrees	2	19
27	γ_5	Orientation of the fifth surface (east wall)	90.0	degrees	2	19
28	S_6	Slope of the sixth surface (west wall)	90.0	degrees	2	19
29	γ_6	Orientation of the sixth surface (west wall)	-90.0	degrees	2	19

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
30	c_{pd}	Specific heat of thermal insulation	0.6573 (glass wool)	$\text{kJ/kg}^\circ\text{C}$	3	13
31	c_{pf}	Specific heat of collector fluid	4.18 (water)	$\text{kJ/kg}^\circ\text{C}$	3	13
32	c_{pg}	Specific heat of glass cover	0.96	$\text{kJ/kg}^\circ\text{C}$	3	20
33	c_{pp}	Specific heat of absorber plate	0.883 (aluminium)	$\text{kJ/kg}^\circ\text{C}$	3	20
34	ρ_d	Insulation density	96.108 (glass wool)	kg/m^3	3	20
35	ρ_f	Collector fluid density	1000.0 (water)	kg/m^3	3	20
36	ρ_g	Glass cover density	2707.0	kg/m^3	3	20
37	ρ_p	Absorber plate density	2707.0 (aluminium)	kg/m^3	3	20
38	B_d	Insulation thickness	0.05	m	3	21
39	B_g	Glass cover thickness	0.003	m	3	21
40	B_p	Absorber plate thickness	0.0005	m	3	21
41	R	Tube inner radius	0.00523	m	3	22
42	W_{total}	Total width of collector	20.0, 24.0, 28.0 (3 separate cases)	m	3	
43	L_{total}	Total length of collector	3.82	m	3	

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
44	N_{cover}	Number of glass covers	2.0	-	3	19,21
45	N_{tube}	Number of tubes across the total width	120.0, 144.0, 168.0 (3 separate cases)	-	3	
46	N_{point}	Number of points along a tube at which temperatures are estimated	10.0	-	3	
47	Slope	Slope of collector plate relative to the horizontal	13.0	degrees	3	18
48	Spacing	Spacing between tubes	0.155	m	3	22
49	ϵ_p	Absorber plate emissivity	0.11	-	3	21
50	ϵ_g	Glass cover emissivity	0.88	-	3	21
51	k_d	Insulation Thermal conductivity	0.1794 (glass wool)	$\frac{kJ}{m \cdot hr}$ $^{\circ}C$	3	20

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
52	k_f	Collector fluid thermal conductivity	2.4 (water)	$\text{kJ/m/hr}/^\circ\text{C}$	3	20
53	k_p	Absorber plate thermal conductivity	822.5 (alumin- ium)	$\text{kJ/m/hr}/^\circ\text{C}$	3	20
54	EXTK	Glass extinction coefficient	4.0	m^{-1}	3	19
55	Δd_{tube}	Tube wall thickness	0.000559	m	3	22
56	k_{tube}	Tube thermal conductivity	822.5 (alumin- ium)	$\text{kJ/m/hr}/^\circ\text{C}$	3	20
57	REFLCO	Absorber plate reflectivity	0.07	-	3	19
58	c_{p_f}	Specific heat of fluid	4.18 (water)	$\text{kJ/kg}/^\circ\text{C}$	4	13
59	T_{max}	Maximum allowable temperature	100.0 (boiling point)	$^\circ\text{C}$	4	
60	c_{p_f}	Specific heat of fluid	4.18 (water)	$\text{kJ/kg}/^\circ\text{C}$	5	13
61	N_{tank}	Number of tank segments	3.0	-	5	6,23
62	UA_1	Product of overall heat transfer coefficient and tank surface area for first segment	4.14, 5.00, 5.27 (3 separate cases)	$\text{kJ/hr}/^\circ\text{C}$	5	Appendix C

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TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
63	UA_2	Product of overall heat transfer coefficient and tank surface area for second segment	2.76, 4.01, 3.89 (3 separate cases)	$\text{kJ/hr/}^\circ\text{C}$	5	Appendix C
64	UA_3	Product of overall heat transfer coefficient and tank surface area for third segment	4.14, 5.00, 5.27 (3 separate cases)	$\text{kJ/hr/}^\circ\text{C}$	5	Appendix C
65	M_1	Mass of liquid in first segment	1333.0, 1608.0, 1880.0 (3 separate cases)	kg	5	
66	M_2	Mass of liquid in second segment	1333.0, 1608.0, 1880.0 (3 separate cases)	kg	5	
67	M_3	Mass of liquid in third segment	1333.0, 1608.0, 1880.0 (3 separate cases)	kg	5	

TABLE 4.3 List of System Parametric Values (Contd.)

No.	Symbol	Parameter			Reference	
		Description	Value	Unit	No.	No.
68	T_A	Reference temperature	0.0	$^{\circ}\text{C}$	6	
69	T_B	Reference temperature	5.0	$^{\circ}\text{C}$	6	
70	\dot{M}_{\max}	Maximum mass flow rate	6610.0	kg/hr	7	19
71	c_{p_f}	Specific heat of fluid	4.18 (water)	$\text{kJ/kg}^{\circ}\text{C}$	8	13
72	T_{set}	Minimum temperature desired of service hot water	60.0	$^{\circ}\text{C}$	8	
73	\dot{Q}_{\max}	Maximum heat delivery capacity of auxiliary heater for service hot water	50000.0	kJ/hr	8	
74	c_{p_f}	Specific heat of fluid	4.18 (water)	$\text{kJ/kg}^{\circ}\text{C}$	10	13
75	$\dot{M}_{f_{\max}}$	Maximum mass flow rate of hot water pump	2498.0	kg/hr	10	24
76	$\dot{Q}_{I_{\text{ref}}}$	Nominal energy input requirement	52750.0	kJ/hr	10	24
77	$\dot{Q}_{c_{\text{ref}}}$	Nominal cooling capacity	37980.0	kJ/hr	10	24
78	\dot{M}_{\max}	Maximum mass flow rate of circulation pump	2498.0	kg/hr	11	24
79	c_{p_f}	Specific heat of fluid	4.18 (water)	$\text{kJ/kg}^{\circ}\text{C}$	13	13
80	T_{set}	Minimum temperature desired of hot water for absorption chiller	85.0	$^{\circ}\text{C}$	13	24

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
81	\dot{Q}_{max}	Maximum heat delivery capacity of the main auxiliary heater	200000.0	KJ/hr	13	
82	T_A	Reference temperature	0.0	$^{\circ}C$	14	
83	T_B	Reference temperature	1.0	$^{\circ}C$	14	
84	IU	Module's given unique number	1.0	-	15	
85	MODE	Mode identifier	2.0 (4 walls required)	-	15	
86	α	Surface absorptance	0.88 (block concrete)	-	15	25
87	ϵ	Surface infrared emittance	0.88 (block concrete)	-	15	25
88	N_B	Number of b_n coefficients used	5.0	-	15	12
89	N_D	Number of d_n coefficients used	4.0	-	15	12
90	A_S	South wall area	36.63	m^2	15	26
91	A_E	East wall area	37.0	m^2	15	26
92	A_N	North wall area	37.37	m^2	15	26
93	A_W	West wall area	37.0	m^2	15	26

TABLE 4.3 List of System Parametric Values (Contd.)

		Parameter			Unit	Reference	
No.	Symbol	Description	Value	Unit	No.	No.	
94	\bar{C}	Effective transmittance of window glazings	0.9	-	15	19	
95	N_G	Number of window glazings	1.0	-	15		
96	F_{sw}	Fraction of south wall occupied by windows	0.13	-	15	26	
97	F_{ew}	Fraction of east wall occupied by windows	0.16	-	15	26	
98	F_{nw}	Fraction of north wall occupied by windows	0.14	-	15	26	
99	F_{ww}	Fraction of west wall occupied by windows	0.41	-	15	26	
100	F_{ss}	Fraction of south windows shaded	0.70	-	15		
101	F_{es}	Fraction of east windows shaded	0.50	-	15		
102	F_{ns}	Fraction of north windows shaded	0.45	-	15		
103	F_{ws}	Fraction of west windows shaded	0.50	-	15		
104	b_0	Transfer function coefficient	0.00021	Btu/hr/ft ² / $^{\circ}$ F	15	12	
105	b_1	Transfer function coefficient	0.00593	Btu/hr/ft ² / $^{\circ}$ F	15	12	

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
106	b_2	Transfer function coefficient	0.00918	$\frac{\text{Btu/hr/ft}^2}{^\circ\text{F}}$	15	12
107	b_3	Transfer function coefficient	0.00168	$\frac{\text{Btu/hr/ft}^2}{^\circ\text{F}}$	15	12
108	b_4	Transfer function coefficient	0.00003	$\frac{\text{Btu/hr/ft}^2}{^\circ\text{F}}$	15	12
109	d_1	Transfer function coefficient	-1.15325	-	15	12
110	d_2	Transfer function coefficient	0.34519	-	15	12
111	d_3	Transfer function coefficient	-0.02937	-	15	12
112	d_4	Transfer function coefficient	0.00004	-	15	12
113	IU	Module's given unique number	1.0 (only one unit required)	-	16	
114	N_{roof}	Is solar collector attached to the roof?	-1.0 (No)	-	16	
115	N_{ins}	Class of insulation thickness	1.0 (3" ceiling insulation)	-	16	

TABLE 4.3 List of Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
116	α	Solar absorptance of exterior roof surface	0.92	-	16	25
117	ϵ	Infrared emittance of exterior roof surface	0.92	-	16	25
118	A_s	Area of south roof surface	123.25 (modified value)	m^2	16	26
119	A_e	Area of east roof surface	10.26	m^2	16	26
120	A_n	Area of north roof surface	58.3625 (modified value)	m^2	16	26
121	A_w	Area of west roof surface	10.26	m^2	16	26
122	A_c	Total ceiling area	86.25	m^2	16	26
123	V	Rate of outside air infiltration into attic	8.0	m^3/hr	16	
124	U_{BE}	Collector back & edge heat loss coefficient	3.70	$\frac{kJ}{hr/m^2 \cdot ^\circ C}$	16	Appendix C
125	S_s	Slope of south roof	13.00	degrees	16	18
126	S_n	Slope of north roof	26.57	degrees	16	
127	FRC	Fraction of south roof occupied by collector	0.62, 0.744, 0.8678 (3 separate cases)	-	16	

TABLE 4.3 List of Parametric Values (Contd.)

Parameter					Unit	Reference
No.	Symbol	Description	Value	Unit	No.	No.
128	IU	Module's given unique number	1.0 (only one unit is required)	-	17	
129	N	Number of inputs	9.0	-	17	
130	VOL	Volume of room	319.125	m ³	17	26
131	RATE	Rate of air change	0.397	hr ⁻¹	17	13
132	AREA	Floor area	86.25	m ²	17	26
133	IC	Construction weight	2.0 (medium)	-	17	
134	CAPAC	Room capacitance	23000.0	kJ/°C	17	Appendix C
135	UA	Product of overall transfer coefficient and house walls	3700.0	kJ/°C/hr	17	Appendix C
136	IBASE	Type of basement	-1.0 (no basement)	-	17	
137	DEPTH	Height of basement walls	0.0	m	17	
138	PERIM	Exposed perimeter of house	40.5	m	17	26
139	T _{GRD}	Ground water temperature	15.0	°C	17	
140	Q _{gen}	Internal heat generation rate	0.0	kJ/hr	17	
141	PEPL	Number of house occupants	0.0 (activity prediction)	-	17	

TABLE 4.3 List of System Parametric Values (Contd.)

Parameter					Unit Reference	
No.	Symbol	Description	Value	Unit	No.	No.
142	C_{min}	Smaller capacitance of load heat exchanger	0.0 (not used here)	$\text{kJ}/^{\circ}\text{C}/\text{hr}$	17	
143	EFF	Constant effectiveness of load heat exchanger	0.0 (not used here)	-	17	
144	c_p	Specific heat of fluid in load heat exchanger	0.0 (not used here)	-	17	
145	IFC	Factor for various room transfer function	0.0	-	17	12
146	T_A	Reference temperature	0.0	$^{\circ}\text{C}$	18	
147	T_B	Reference temperature	3.0	$^{\circ}\text{C}$	18	