APPENDIX A

Material Properties of Solar Water Heater

Table A-1 Specification of evacuated tube (Apricus Solar, 2015)

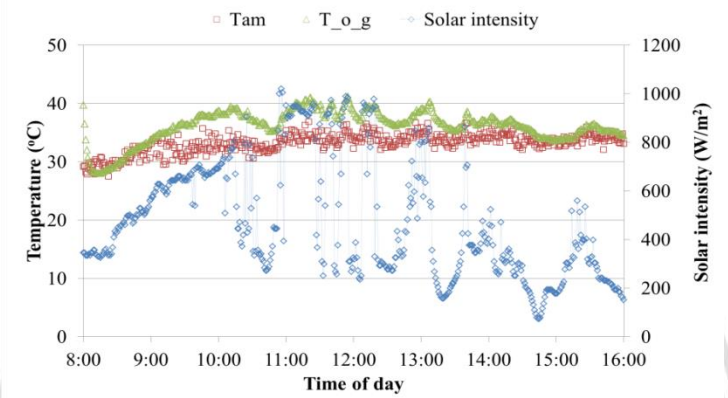
Evacuated tube length	1800 mm
Outer tube diameter	58 mm
Inner tube diameter	47 mm
Glass thickness	1.6 mm
Thermal expansion	$3.3x10^{-6}$ ^{o}C
Material	Borosilicate Glass 3.3
Absorptive coating	Graded Al-N/Al
Absorptance	> 92 % (AM 1.5)
Inner emittance	< 4.4 % (80 ^{o}C)
Outer emisstance	< 6 %
Vacuum	$P < 5x10^{-3}$ Pa
Heat loss	0.8 W/(m^2-^{o}C)
Maximum strength	0.8 MPa

Table A-2 Specification of copper tube

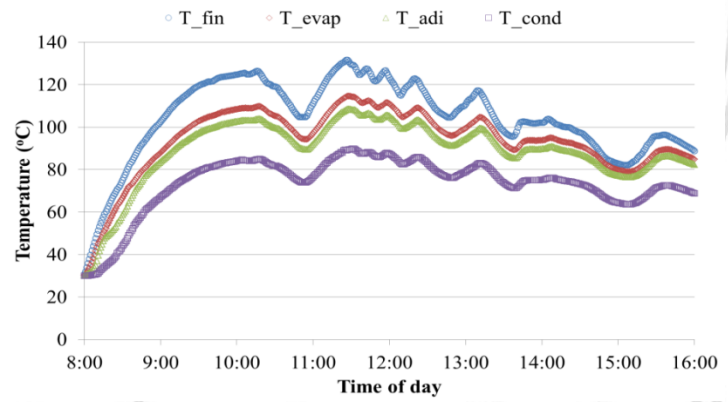
Nominal Size (Inch)	**Outside Diameter**		**TYPE – K (Wall Thickness)**		**TYPE – L (Wall Thickness)**	
	Inch	**mm**	**Inch**	**mm**	**Inch**	**mm**
1/4	1/4	9.52	0.035	0.89	0.030	0.76
3/8	3/8	12.70	0.049	1.24	0.035	0.89
1/2	1/2	15.88	0.049	1.24	0.040	1.02
5/8	5/8	19.05	0.049	1.24	0.042	1.07
3/4	3/4	22.22	0.065	1.65	0.045	1.14
1	1	28.58	0.065	1.65	0.050	1.27
1 ¼	1 ¼	34.92	0.065	1.65	0.055	1.40
1 ½	1 ½	41.27	0.072	1.83	0.060	1.52
2”	2	53.98	0.083	2.11	0.070	1.78

APPENDIX B

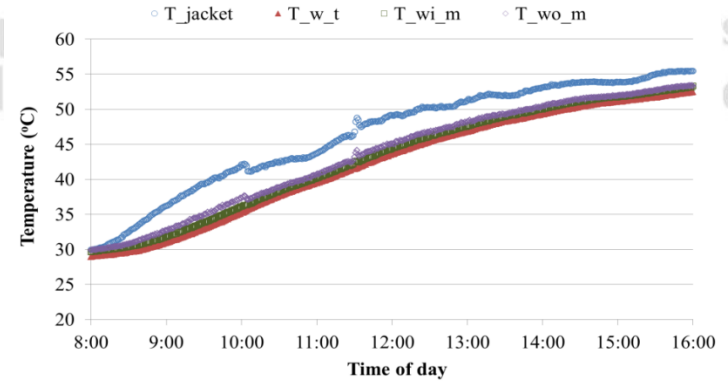
Experimental Data of Solar Water Heater



(a)

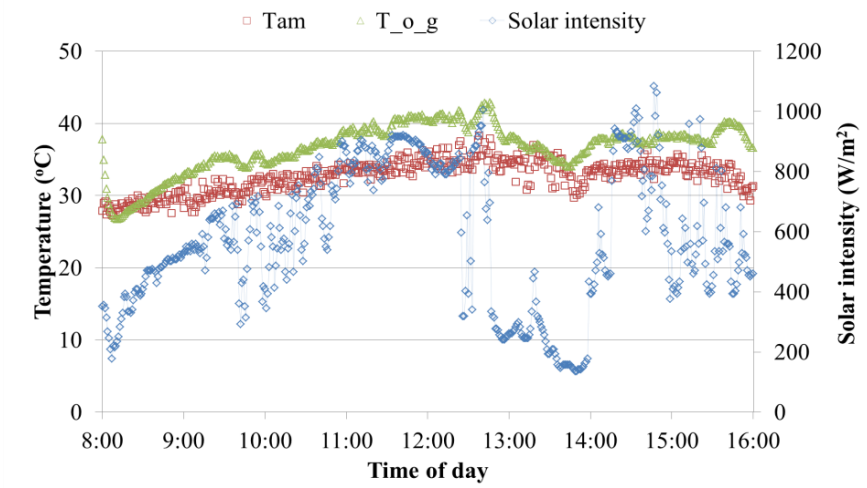


(b)

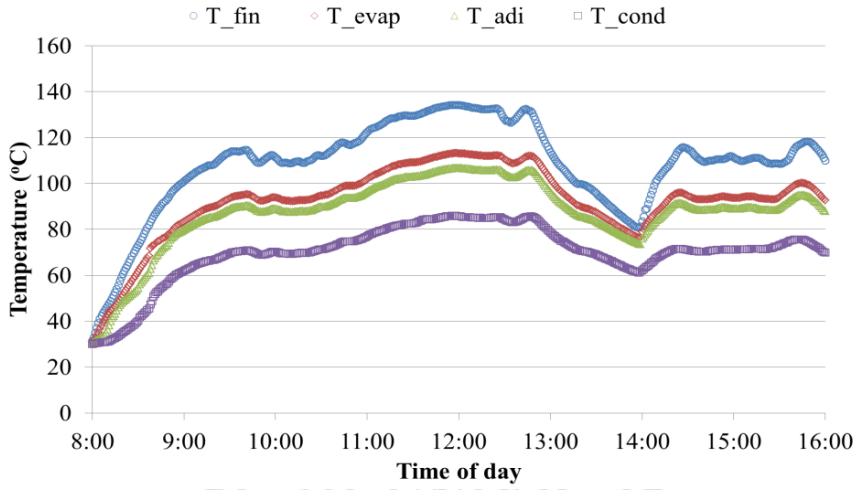


(c)

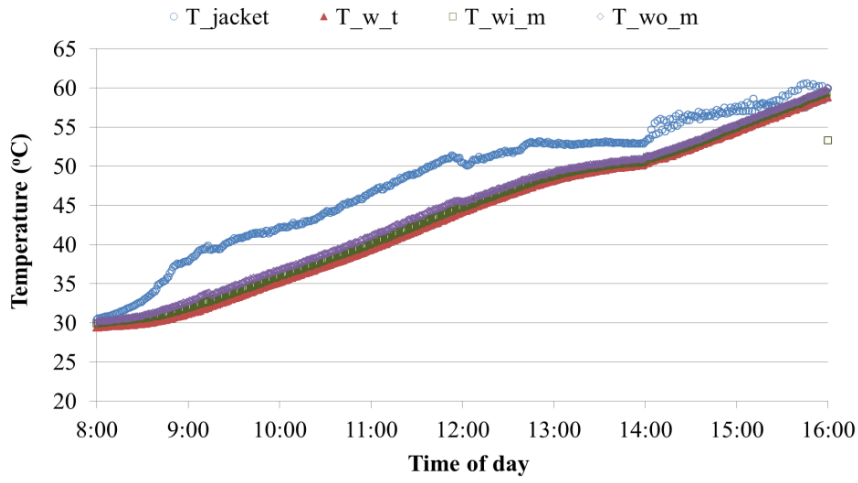
Figure B-1 Experimental data on 18 August 2016



(a)

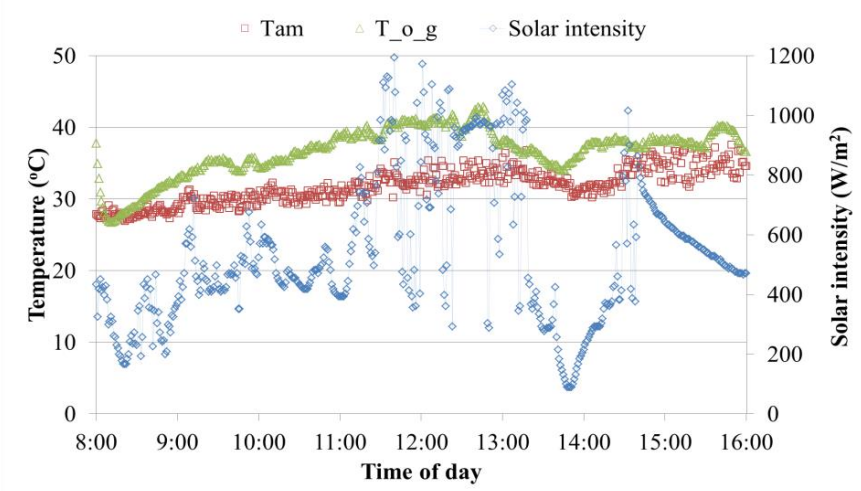


(b)

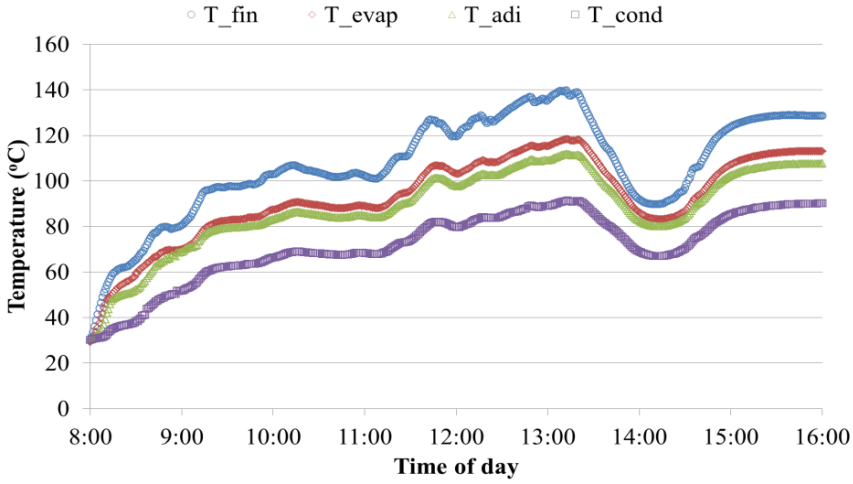


(c)

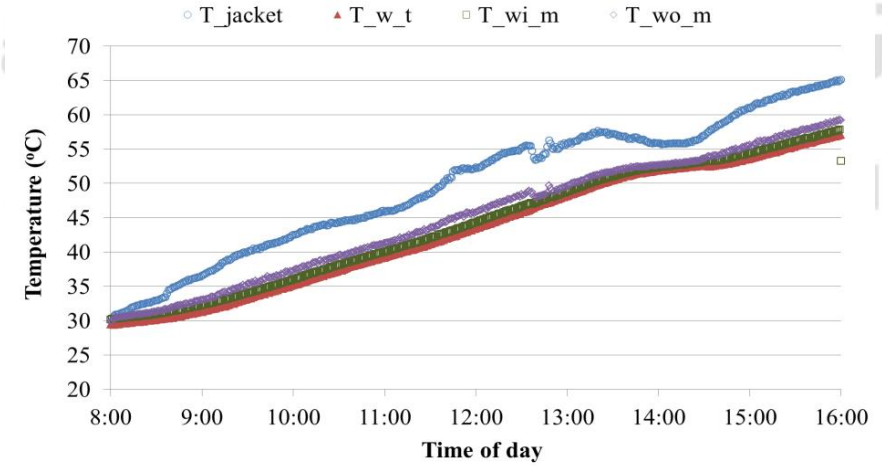
Figure B-2 Experimental data on 22 August 2016



(a)

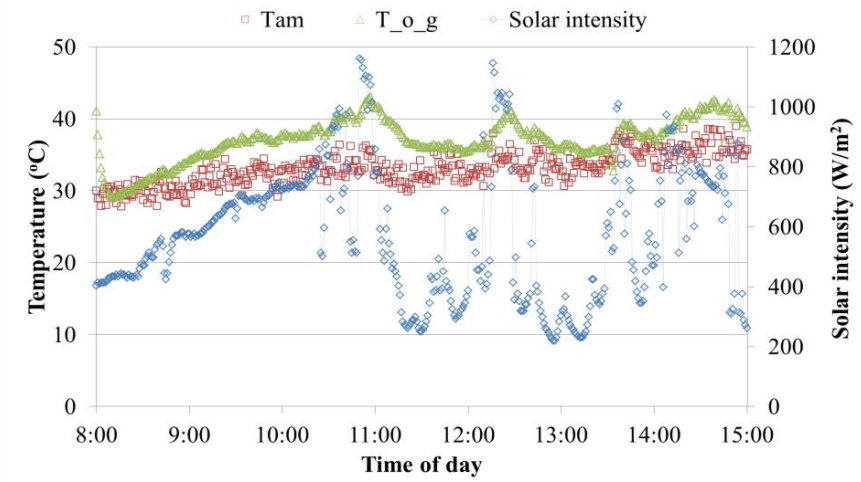


(b)

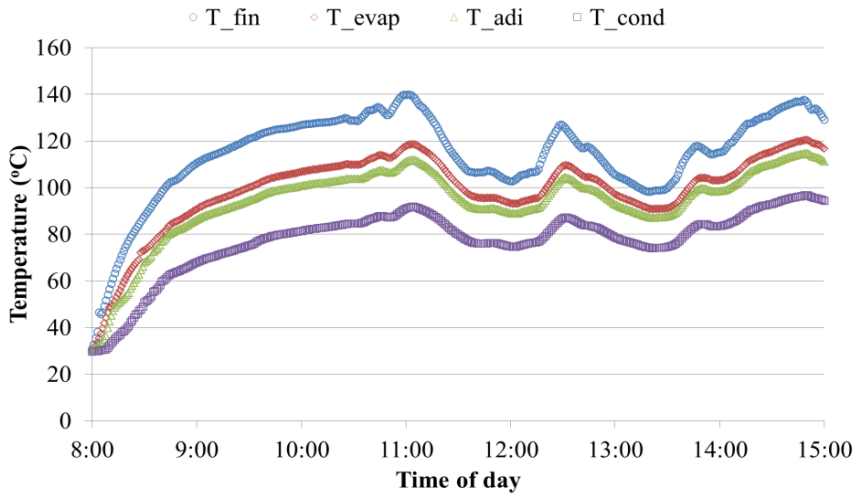


(c)

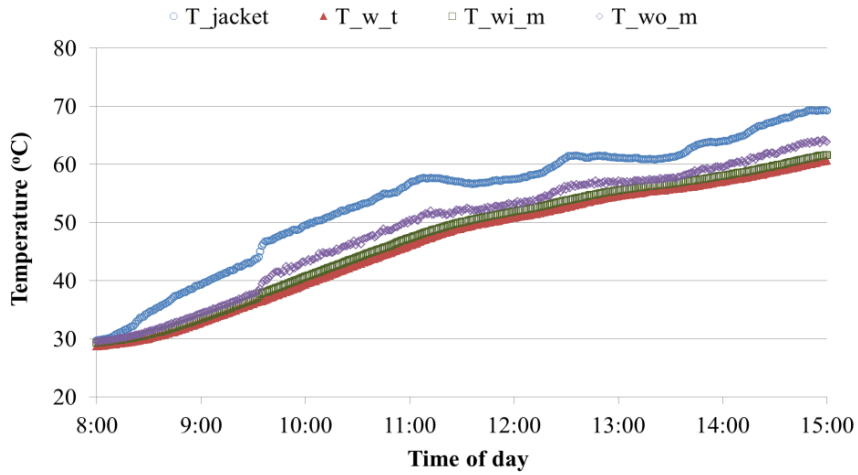
Figure B-3 Experimental data on 30 August 2016



(a)

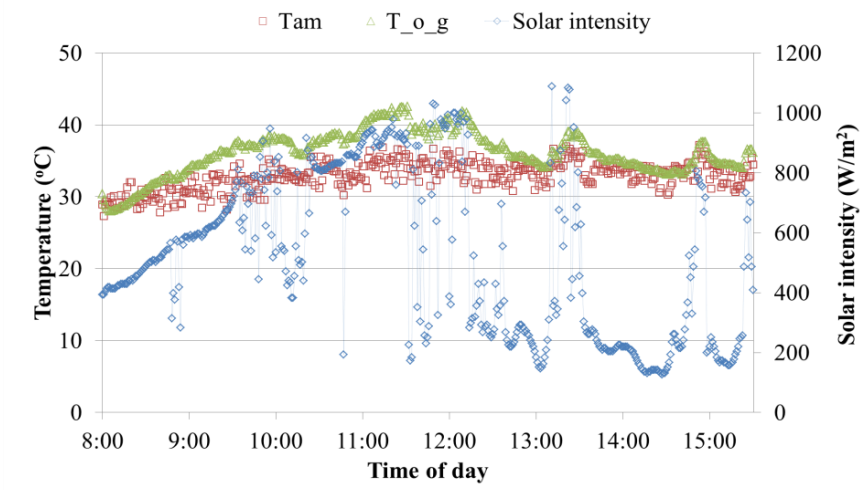


(b)

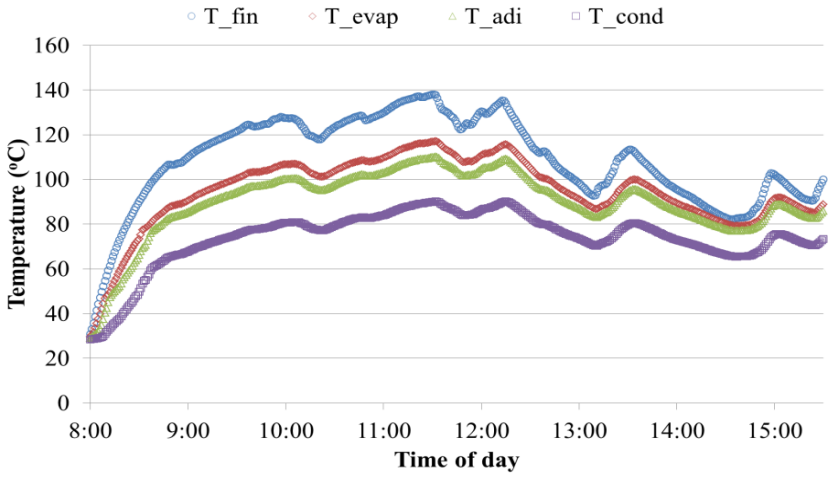


(c)

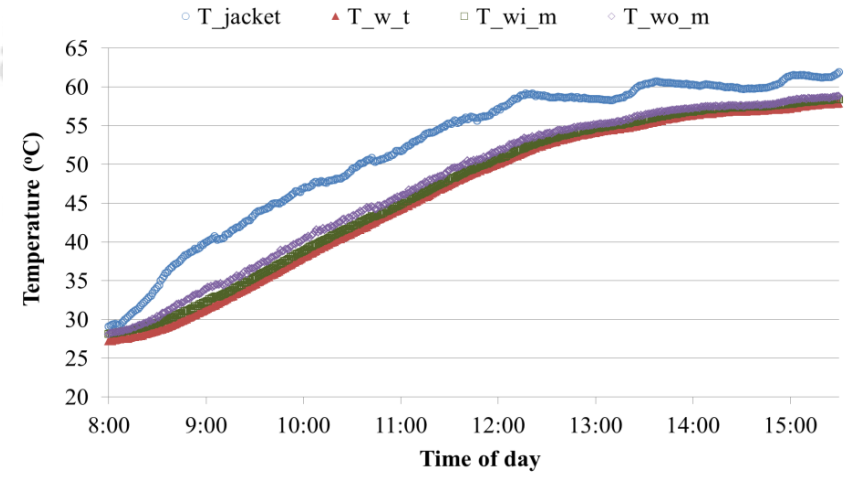
Figure B-4 Experimental data on 31 August 2016



(a)

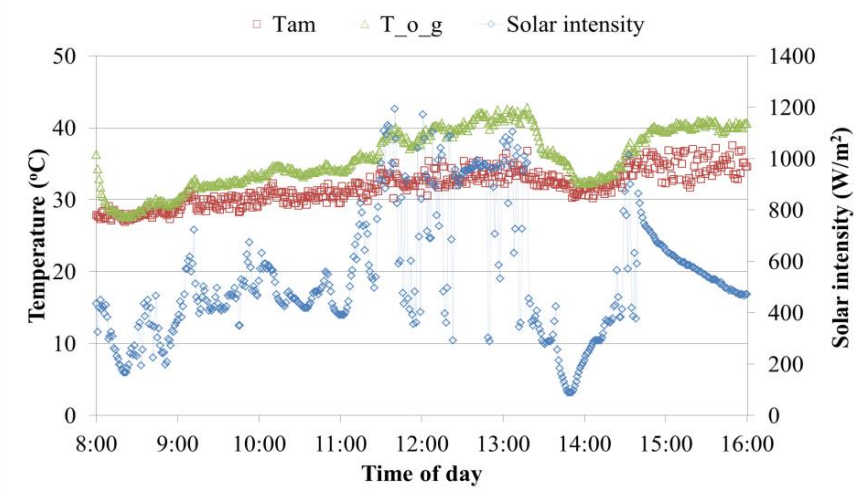


(b)

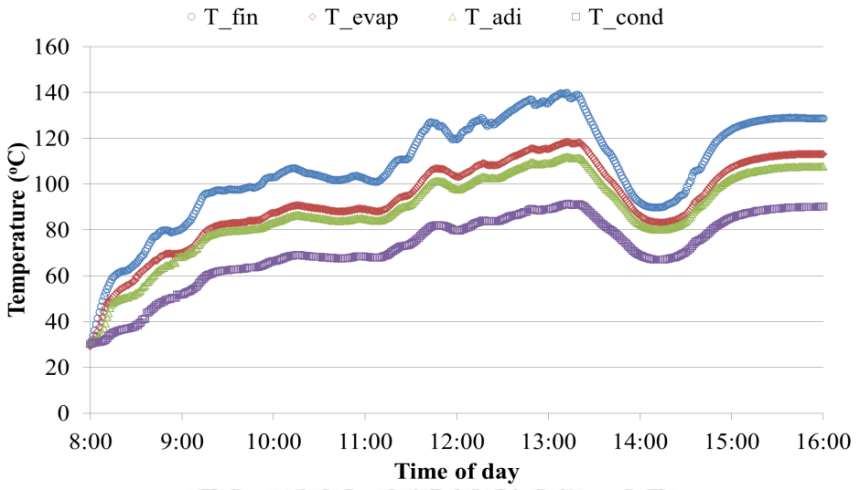


(c)

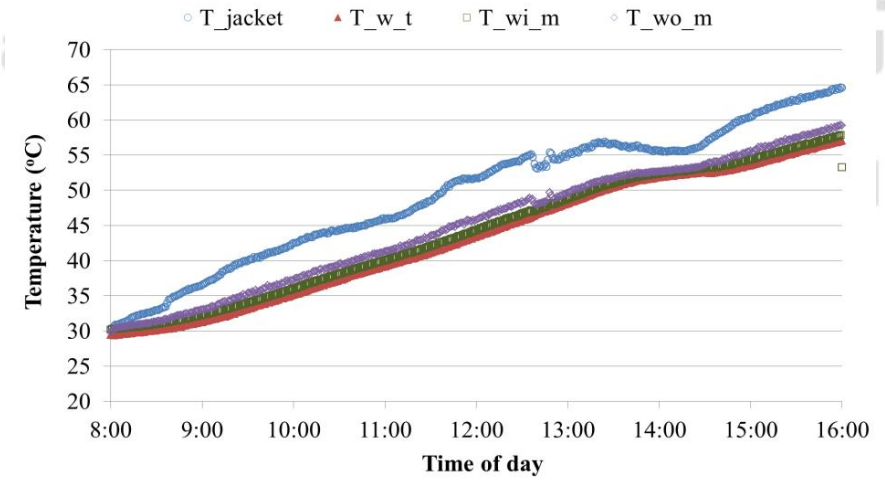
Figure B-5 Experimental data on 3 September 2016



(a)

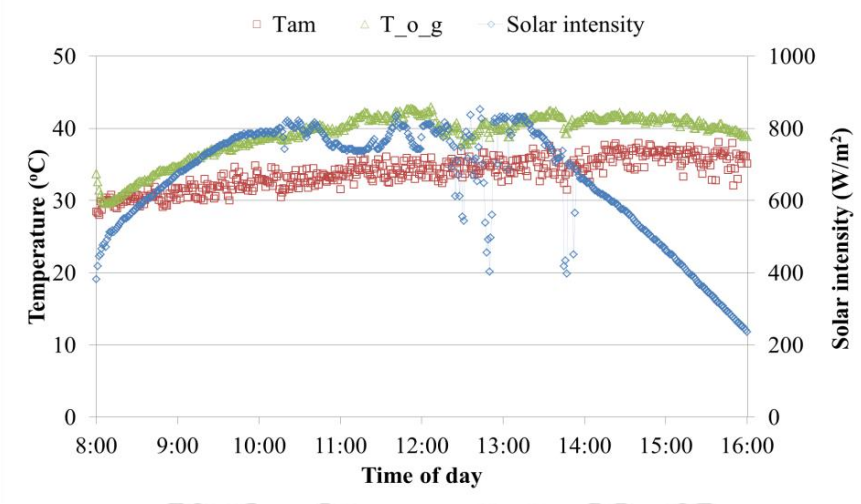


(b)

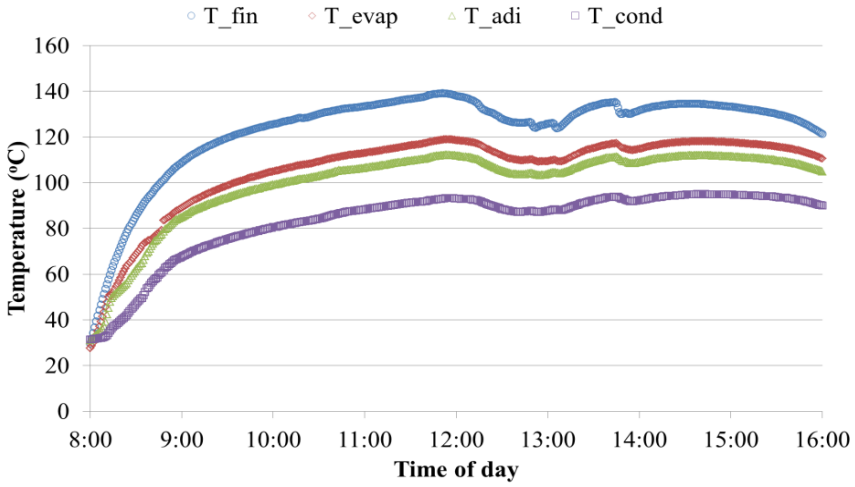


(c)

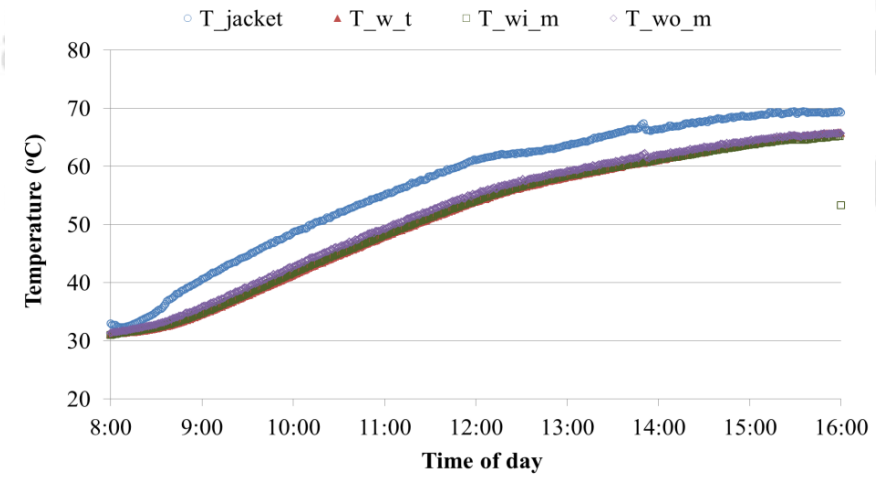
Figure B-6 Experimental data on 4 September 2016



(a)

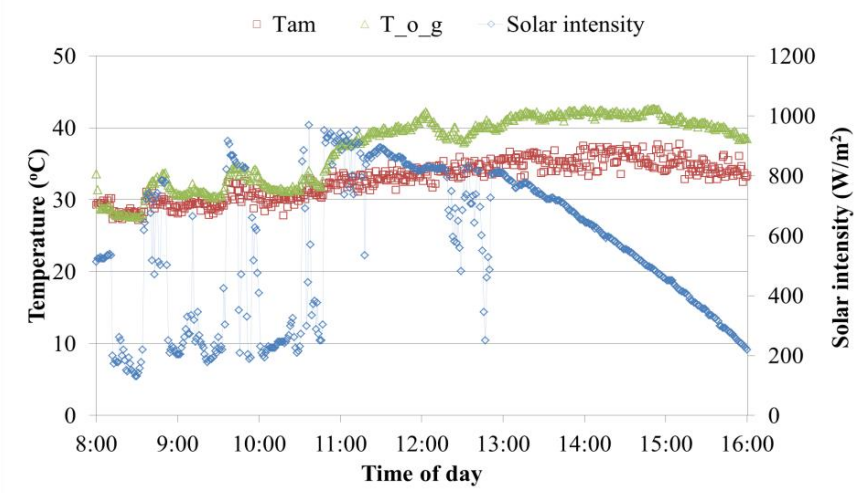


(b)

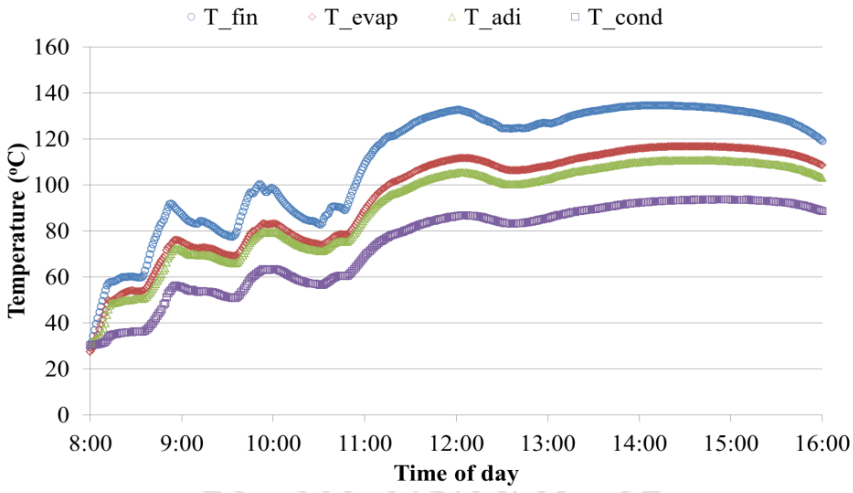


(c)

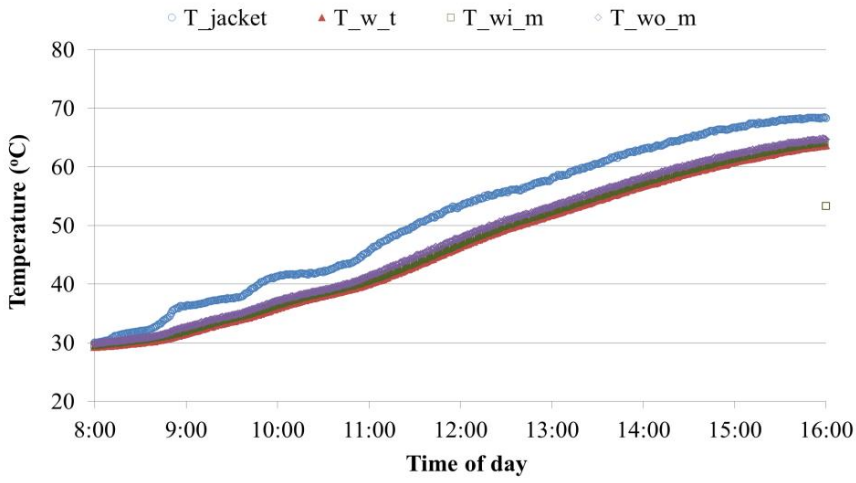
Figure B-7 Experimental data on 10 October 2016



(a)

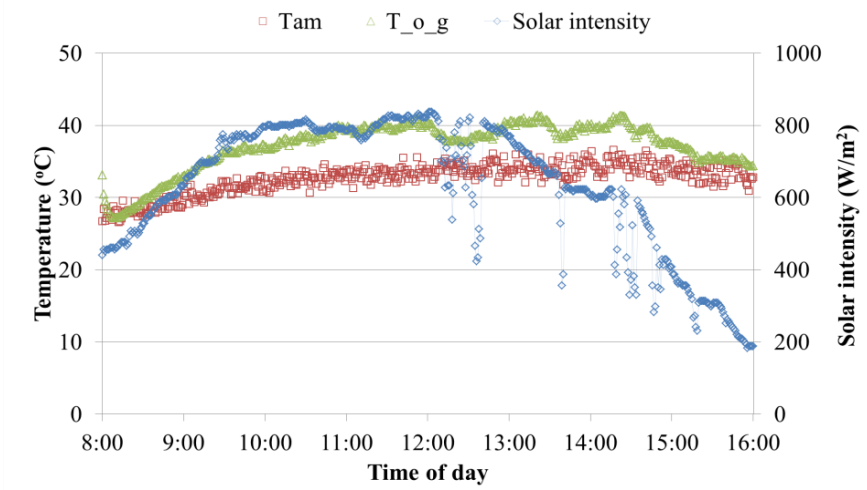


(b)

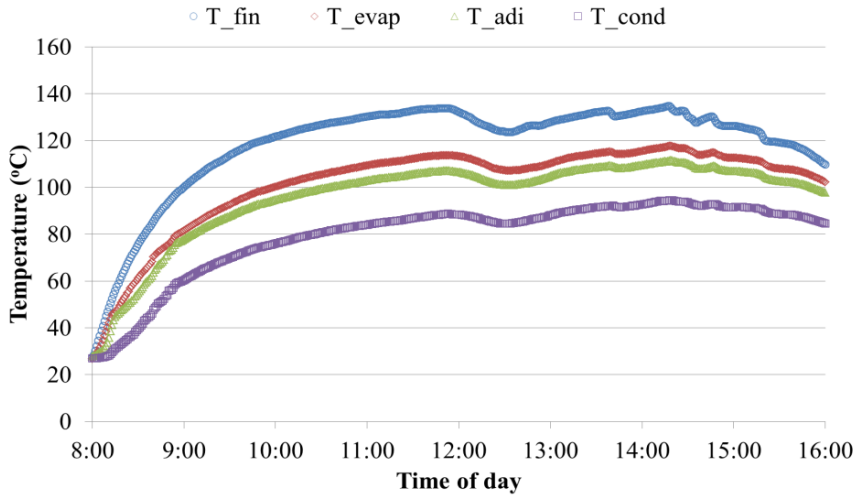


(c)

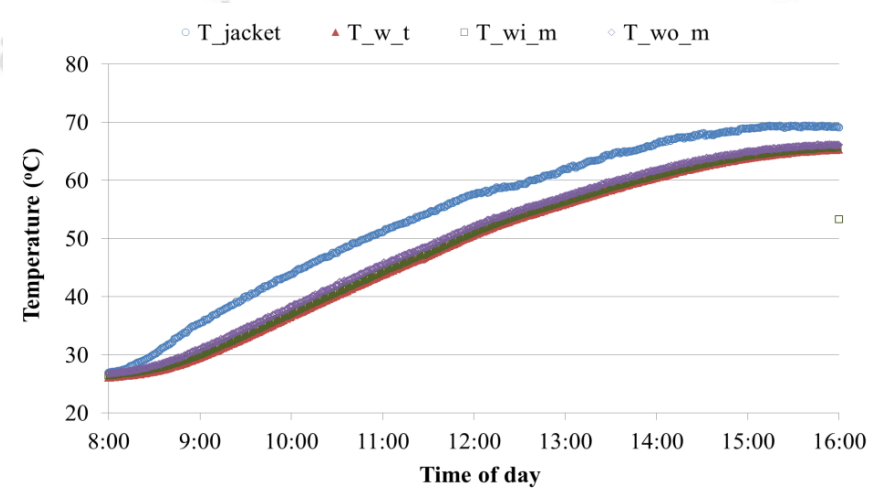
Figure B-8 Experimental data on 11 October 2016



(a)

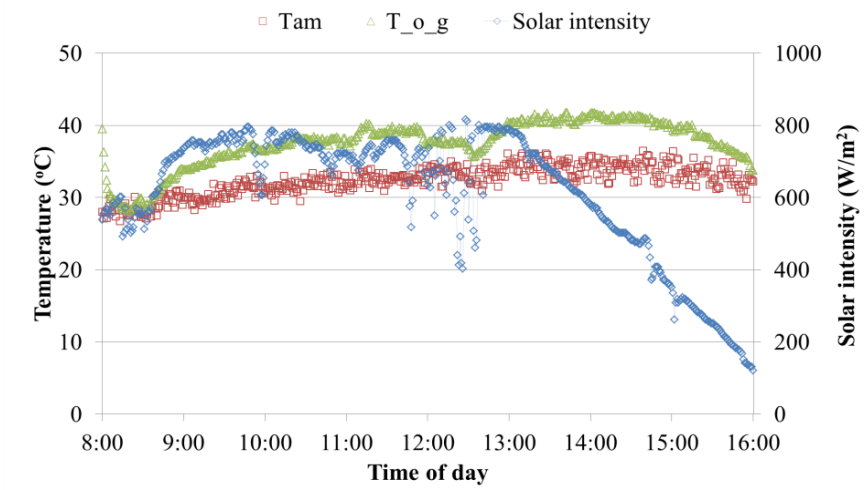


(b)

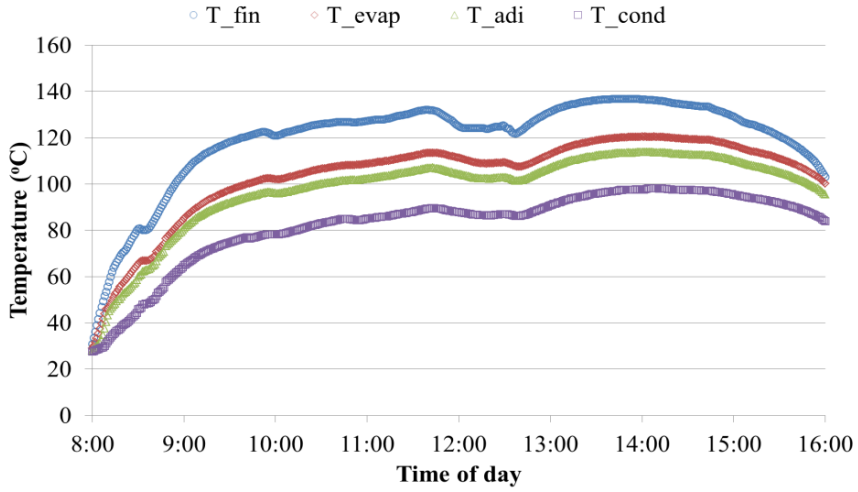


(c)

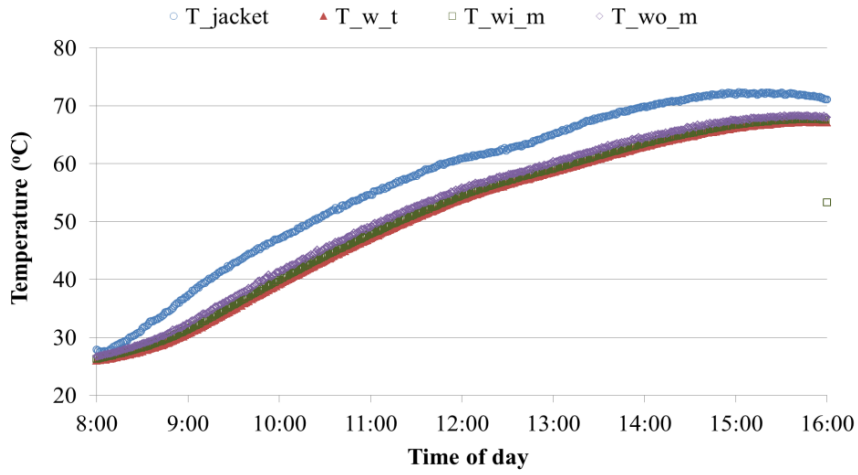
Figure B-9 Experimental data on 14 October 2016



(a)

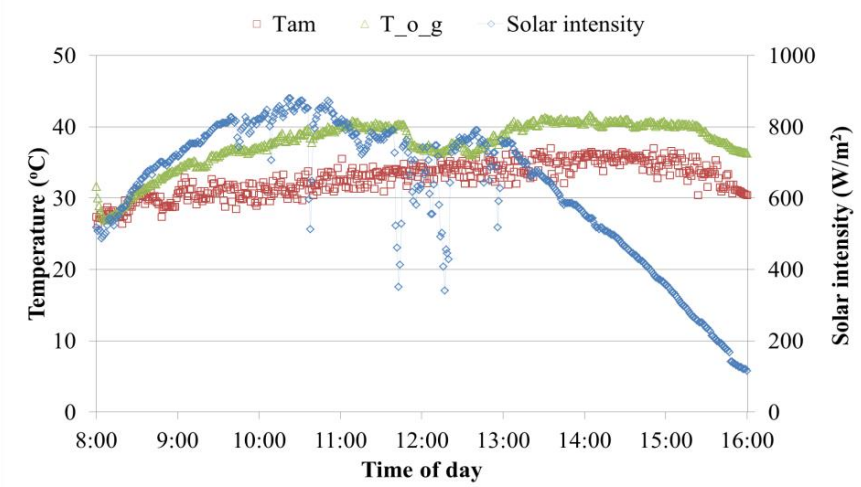


(b)

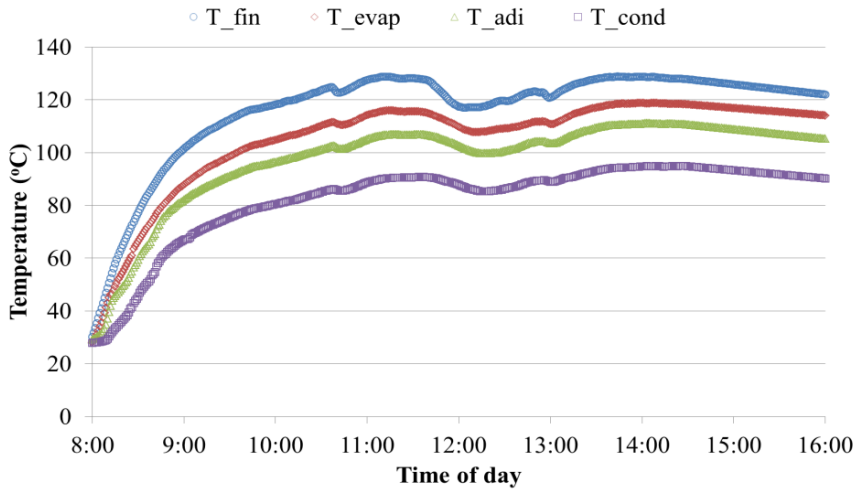


(c)

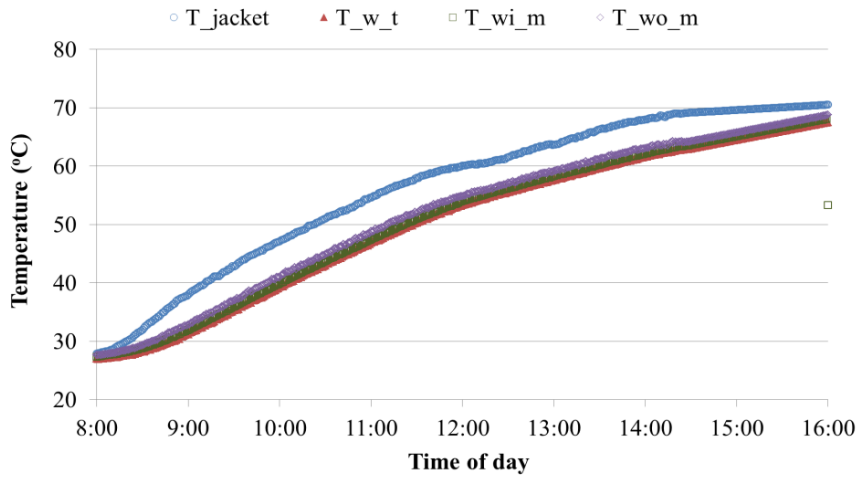
Figure B-10 Experimental data on 18 October 2016



(a)

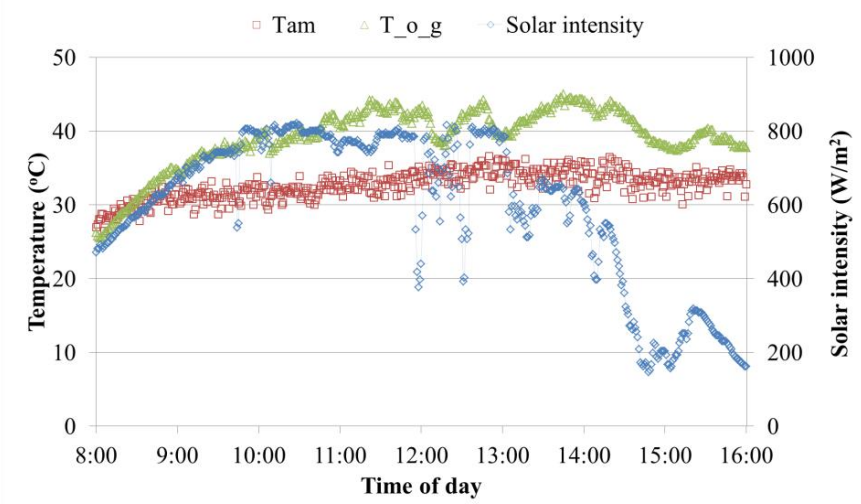


(b)

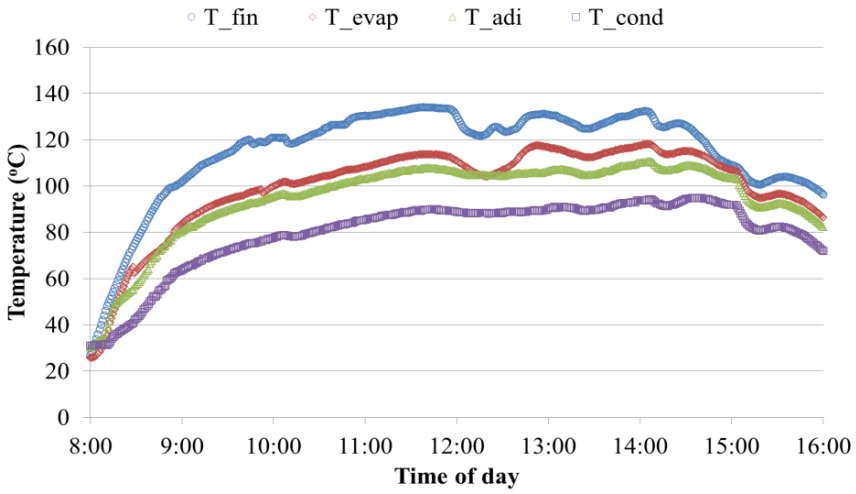


(c)

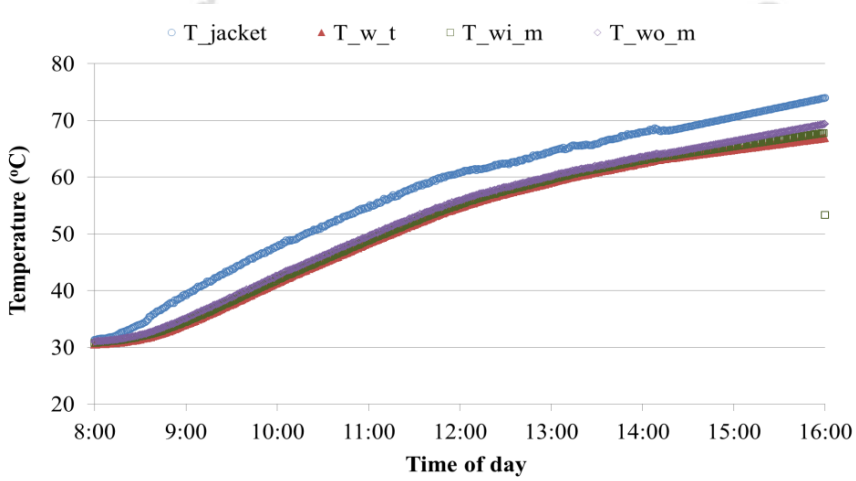
Figure B-11 Experimental data on 19 October 2016



(a)



(b)



(c)

Figure B-12 Experimental data on 20 October 2016

APPENDIX C

Physical Properties of Working Fluid

Table C-1 Thermo physical properties of R141b

Temp.,* °C	Pressure, MPa	Density, kg/m³ Liquid	Volume, m³/kg Vapor	Enthalpy, kJ/kg Liquid	Enthalpy, kJ/kg Vapor	Entropy, kJ/(kg·K) Liquid	Entropy, kJ/(kg·K) Vapor	Specific Heat c_p, kJ/(kg·K) Liquid	Specific Heat c_p, kJ/(kg·K) Vapor	Velocity of Sound, m/s Liquid	Velocity of Sound, m/s Vapor	Viscosity, μPa·s Liquid	Viscosity, μPa·s Vapor	Thermal Cond., mW/(m·K) Liquid	Thermal Cond., mW/(m·K) Vapor
–80	0.00013	1709.6	83.6670	123.92	335.98	0.6712	1.7691	0.924	0.520	1133	108.3	2093.0	6.68	107.4	3.22
–70	0.00034	1687.4	32.8420	133.17	341.25	0.7179	1.7422	0.927	0.537	1091	110.8	1680.0	7.09	104.8	3.79
–60	0.00081	1665.1	14.3330	142.46	346.66	0.7625	1.7206	0.932	0.553	1049	113.3	1383.0	7.50	102.0	4.35
–50	0.00177	1642.6	6.84600	151.81	352.21	0.8054	1.7034	0.939	0.569	1006	115.6	1160.0	7.91	99.1	4.92
–40	0.00358	1620.0	3.53190	161.25	357.88	0.8468	1.6901	0.948	0.585	964	117.9	986.4	8.31	96.1	5.49
–30	0.00675	1597.0	1.94700	170.78	363.65	0.8868	1.6800	0.958	0.601	923	120.0	848.0	8.70	93.0	6.05
–20	0.01200	1573.8	1.13640	180.41	369.52	0.9256	1.6726	0.968	0.617	881	122.0	735.4	9.09	89.8	6.61
–10	0.02025	1550.1	0.69690	190.15	375.45	0.9633	1.6675	0.979	0.634	841	123.8	642.4	9.47	86.7	7.18
0	0.03265	1526.1	0.44609	200.00	381.44	1.0000	1.6642	0.990	0.651	801	125.4	564.6	9.84	83.7	7.74
2	0.03574	1521.3	0.40991	201.98	382.64	1.0072	1.6638	0.993	0.654	793	125.7	550.6	9.91	83.1	7.86
4	0.03907	1516.4	0.37720	203.97	383.84	1.0144	1.6634	0.995	0.658	785	126.0	537.0	9.99	82.5	7.97
6	0.04264	1511.5	0.34759	205.97	385.05	1.0216	1.6631	0.997	0.661	777	126.3	523.8	10.06	81.9	8.08
8	0.04647	1506.6	0.32075	207.96	386.25	1.0287	1.6628	0.999	0.665	769	126.6	511.1	10.13	81.3	8.20
10	0.05057	1501.6	0.29637	209.97	387.46	1.0358	1.6626	1.002	0.668	761	126.8	498.8	10.20	80.7	8.31
12	0.05495	1496.7	0.27420	211.97	388.66	1.0428	1.6625	1.004	0.672	754	127.1	486.8	10.28	80.1	8.43
14	0.05963	1491.7	0.25401	213.99	389.87	1.0499	1.6624	1.006	0.675	746	127.3	475.3	10.35	79.5	8.54
16	0.06463	1486.7	0.23559	216.00	391.08	1.0569	1.6623	1.009	0.679	738	127.6	464.0	10.42	79.0	8.66
18	0.06995	1481.7	0.21877	218.02	392.29	1.0638	1.6623	1.011	0.682	730	127.8	453.2	10.49	78.4	8.77
20	0.07561	1476.6	0.20338	220.05	393.49	1.0707	1.6624	1.014	0.686	723	128.0	442.6	10.56	77.8	8.89
22	0.08163	1471.5	0.18929	222.08	394.70	1.0776	1.6625	1.016	0.690	715	128.2	432.4	10.63	77.3	9.01
24	0.08802	1466.4	0.17637	224.12	395.91	1.0845	1.6626	1.018	0.693	707	128.4	422.4	10.70	76.7	9.12
26	0.09480	1461.3	0.16451	226.16	397.12	1.0913	1.6628	1.021	0.697	700	128.6	412.8	10.77	76.1	9.24
27	0.10133	1456.6	0.15453	228.03	398.22	1.0975	1.6630	1.023	0.701	693	128.7	404.2	10.84	75.6	9.35
28	0.10198	1456.2	0.15360	228.21	398.32	1.0981	1.6630	1.023	0.701	692	128.7	403.4	10.84	75.6	9.36
30	0.10958	1451.0	0.14356	230.26	399.53	1.1049	1.6633	1.026	0.705	684	128.9	394.3	10.91	75.0	9.48
32[b]	0.11762	1445.8	0.13431	232.31	400.73	1.1116	1.6635	1.028	0.709	677	129.0	385.4	10.98	74.5	9.60
34	0.12611	1440.6	0.12577	234.38	401.93	1.1183	1.6639	1.031	0.712	669	129.1	376.8	11.05	74.0	9.72
36	0.13507	1435.4	0.11789	236.44	403.14	1.1250	1.6642	1.033	0.716	662	129.3	368.4	11.12	73.4	9.84
38	0.14452	1430.1	0.11060	238.51	404.34	1.1317	1.6646	1.036	0.720	654	129.4	360.3	11.19	72.9	9.96
40	0.15447	1424.8	0.10385	240.59	405.54	1.1383	1.6651	1.038	0.724	647	129.5	352.4	11.26	72.4	10.08
42	0.16495	1419.4	0.09759	242.67	406.73	1.1449	1.6655	1.041	0.728	639	129.5	344.7	11.33	71.8	10.20
44	0.17597	1414.1	0.09179	244.76	407.93	1.1515	1.6660	1.044	0.732	632	129.6	337.2	11.40	71.3	10.32
46	0.18755	1408.7	0.08641	246.86	409.12	1.1581	1.6665	1.046	0.736	624	129.7	329.9	11.46	70.8	10.45
48	0.19971	1403.3	0.08140	248.95	410.31	1.1646	1.6670	1.049	0.741	617	129.7	322.8	11.53	70.3	10.57
50	0.21246	1397.8	0.07674	251.06	411.50	1.1711	1.6676	1.052	0.745	610	129.7	315.9	11.60	69.8	10.70
52	0.22584	1392.3	0.07240	253.17	412.69	1.1776	1.6682	1.055	0.749	602	129.7	309.1	11.67	69.3	10.82
54	0.23985	1386.8	0.06836	255.28	413.87	1.1840	1.6688	1.058	0.753	595	129.7	302.6	11.74	68.8	10.95
56	0.25451	1381.2	0.06458	257.41	415.05	1.1905	1.6694	1.060	0.758	588	129.7	296.2	11.80	68.3	11.08
58	0.26985	1375.6	0.06106	259.53	416.23	1.1969	1.6701	1.063	0.762	580	129.7	289.9	11.87	67.8	11.21
60	0.28589	1370.0	0.05777	261.67	417.40	1.2033	1.6707	1.066	0.767	573	129.6	283.9	11.94	67.3	11.34
62	0.30264	1364.3	0.05469	263.81	418.57	1.2096	1.6714	1.069	0.771	566	129.6	277.9	12.01	66.8	11.47
64	0.32013	1358.6	0.05180	265.95	419.73	1.2160	1.6721	1.072	0.776	558	129.5	272.1	12.07	66.3	11.61
66	0.33838	1352.8	0.04910	268.10	420.89	1.2223	1.6728	1.076	0.781	551	129.4	266.5	12.14	65.9	11.74
68	0.35740	1347.0	0.04656	270.26	422.05	1.2286	1.6735	1.079	0.785	544	129.3	261.0	12.21	65.4	11.88
70	0.37722	1341.2	0.04418	272.42	423.20	1.2349	1.6743	1.082	0.790	536	129.2	255.6	12.28	64.9	12.01
72	0.39787	1335.3	0.04195	274.60	424.35	1.2411	1.6750	1.085	0.795	529	129.0	250.4	12.35	64.5	12.15
74	0.41936	1329.3	0.03985	276.77	425.50	1.2474	1.6758	1.089	0.800	522	128.9	245.2	12.42	64.0	12.29
76	0.44171	1323.4	0.03787	278.96	426.63	1.2536	1.6766	1.092	0.806	515	128.7	240.2	12.49	63.5	12.44
78	0.46494	1317.3	0.03601	281.15	427.77	1.2598	1.6774	1.096	0.811	507	128.5	235.3	12.55	63.1	12.58
80	0.48909	1311.2	0.03426	283.35	428.89	1.2660	1.6781	1.100	0.816	500	128.3	230.5	12.63	62.6	12.73
82	0.51416	1305.1	0.03261	285.55	430.01	1.2722	1.6789	1.103	0.822	493	128.1	225.9	12.70	62.2	12.87
84	0.54019	1298.9	0.03105	287.77	431.13	1.2783	1.6797	1.107	0.827	486	127.8	221.3	12.77	61.7	13.02
86	0.56720	1292.6	0.02958	289.99	432.23	1.2845	1.6806	1.111	0.833	478	127.6	216.8	12.84	61.3	13.17
88	0.59520	1286.3	0.02819	292.22	433.33	1.2906	1.6814	1.115	0.839	471	127.3	212.5	12.91	60.8	13.33
90	0.62423	1279.9	0.02687	294.45	434.43	1.2967	1.6822	1.120	0.845	464	127.0	208.2	12.98	60.4	13.48
92	0.65430	1273.5	0.02563	296.70	435.51	1.3028	1.6830	1.124	0.851	457	126.6	204.0	13.06	59.9	13.64
94	0.68544	1266.9	0.02445	298.95	436.59	1.3089	1.6838	1.129	0.858	449	126.3	199.9	13.14	59.5	13.80
96	0.71768	1260.3	0.02334	301.21	437.66	1.3150	1.6846	1.133	0.864	442	125.9	195.9	13.21	59.1	13.96
98	0.75103	1253.7	0.02228	303.49	438.72	1.3211	1.6854	1.138	0.871	435	125.5	191.9	13.29	58.6	14.13
100	0.78553	1246.9	0.02128	305.77	439.77	1.3271	1.6862	1.143	0.878	427	125.1	188.1	13.37	58.2	14.29
110	0.97603	1211.9	0.01697	317.32	444.88	1.3572	1.6902	1.172	0.917	391	122.8	169.9	13.80	56.0	15.17
120	1.19900	1174.4	0.01361	329.15	449.67	1.3872	1.6938	1.207	0.964	354	119.8	153.4	14.29	53.9	16.14
130	1.45780	1133.6	0.01094	341.32	454.07	1.4173	1.6969	1.254	1.026	317	116.0	138.1	14.89	51.7	17.22
140	1.75630	1088.3	0.00879	353.92	457.94	1.4475	1.6992	1.318	1.111	279	111.5	123.8	15.65	49.5	18.44
150	2.09870	1036.8	0.00703	367.10	461.05	1.4782	1.7003	1.415	1.240	239	106.0	110.2	16.68	47.2	19.87
160	2.49010	975.7	0.00555	381.13	463.01	1.5101	1.6991	1.584	1.473	198	99.3	96.8	18.19	44.8	21.63
170	2.93720	896.9	0.00425	396.61	462.89	1.5443	1.6939	1.979	2.033	154	91.1	82.7	20.71	42.3	24.05
180	3.45060	765.9	0.00292	416.22	456.82	1.5867	1.6763	4.549	5.661	102	80.6	64.3	26.59	39.7	28.82

Table C-2 Thermo physical properties of water

Temp.,* °C	Pressure, MPa	Density, kg/m³ Liquid	Volume, m³/kg Vapor	Enthalpy, kJ/kg Liquid	Enthalpy, kJ/kg Vapor	Entropy, kJ/(kg·K) Liquid	Entropy, kJ/(kg·K) Vapor	Specific Heat c_p, kJ/(kg·K) Liquid	Specific Heat c_p, kJ/(kg·K) Vapor	Velocity of Sound, m/s Liquid	Velocity of Sound, m/s Vapor	Viscosity, μPa·s Liquid	Viscosity, μPa·s Vapor	Thermal Cond., mW/(m·K) Liquid	Thermal Cond., mW/(m·K) Vapor
0.01[a]	0.00061	999.8	205.990	0.00	2500.92	0.0000	9.1555	4.220	1.884	1402	409.0	1791.2	9.22	561.0	17.07
5	0.00087	999.9	147.010	21.02	2510.06	0.0763	9.0248	4.205	1.889	1426	412.6	1518.3	9.34	570.5	17.34
10	0.00123	999.7	106.300	42.02	2519.21	0.1511	8.8998	4.196	1.895	1447	416.2	1306.0	9.46	580.0	17.62
15	0.00171	999.1	77.8750	62.98	2528.33	0.2245	8.7803	4.189	1.900	1466	419.7	1137.6	9.59	589.3	17.92
20	0.00234	998.2	57.7570	83.91	2537.43	0.2965	8.6660	4.184	1.906	1482	423.2	1001.6	9.73	598.4	18.23
25	0.00317	997.0	43.3370	104.83	2546.51	0.3672	8.5566	4.182	1.912	1497	426.6	890.1	9.87	607.2	18.55
30	0.00425	995.6	32.8780	125.73	2555.55	0.4368	8.4520	4.180	1.918	1509	430.0	797.4	10.01	615.5	18.89
35	0.00563	994.0	25.2050	146.63	2564.55	0.5051	8.3517	4.180	1.925	1520	433.4	719.3	10.16	623.3	19.24
40	0.00738	992.2	19.5150	167.53	2573.51	0.5724	8.2555	4.180	1.931	1529	436.7	653.0	10.31	630.6	19.60
45	0.00959	990.2	15.2520	188.43	2582.43	0.6386	8.1633	4.180	1.939	1536	440.0	596.1	10.46	637.3	19.97
50	0.01235	988.0	12.0270	209.34	2591.29	0.7038	8.0748	4.182	1.947	1542	443.2	546.8	10.62	643.6	20.36
55	0.01576	985.7	9.5643	230.26	2600.09	0.7680	7.9898	4.183	1.955	1547	446.4	504.0	10.77	649.2	20.77
60	0.01995	983.2	7.6672	251.18	2608.83	0.8313	7.9081	4.185	1.965	1551	449.5	466.4	10.93	654.3	21.19
65	0.02504	980.5	6.1935	272.12	2617.50	0.8937	7.8296	4.187	1.975	1553	452.6	433.2	11.10	659.0	21.62
70	0.03120	977.7	5.0395	293.07	2626.10	0.9551	7.7540	4.190	1.986	1555	455.6	403.9	11.26	663.1	22.07
75	0.03860	974.8	4.1289	314.03	2634.60	1.0158	7.6812	4.193	1.999	1555	458.5	377.7	11.43	666.8	22.53
80	0.04741	971.8	3.4052	335.01	2643.02	1.0756	7.6111	4.197	2.012	1554	461.4	354.3	11.59	670.0	23.01
85	0.05787	968.6	2.8258	356.01	2651.33	1.1346	7.5434	4.201	2.027	1553	464.2	333.3	11.76	672.8	23.51
90	0.07018	965.3	2.3591	377.04	2659.53	1.1929	7.4781	4.205	2.043	1550	466.9	314.4	11.93	675.3	24.02
95	0.08461	961.9	1.9806	398.09	2667.61	1.2504	7.4151	4.210	2.061	1547	469.6	297.3	12.10	677.3	24.55
99.97[b]	0.10133	958.4	1.6732	419.06	2675.53	1.3069	7.3544	4.216	2.080	1543	472.2	281.8	12.27	679.1	25.09
100	0.10142	958.3	1.6718	419.17	2675.57	1.3072	7.3541	4.216	2.080	1543	472.2	281.7	12.27	679.1	25.10
105	0.12090	954.7	1.4184	440.27	2683.39	1.3633	7.2952	4.222	2.101	1538	474.7	267.6	12.44	680.5	25.66
110	0.14338	950.9	1.2093	461.42	2691.06	1.4188	7.2381	4.228	2.124	1533	477.1	254.7	12.61	681.7	26.24
115	0.16918	947.1	1.0358	482.59	2698.58	1.4737	7.1828	4.236	2.150	1527	479.5	242.9	12.78	682.6	26.85
120	0.19867	943.1	0.89121	503.81	2705.93	1.5279	7.1291	4.244	2.177	1520	481.7	232.1	12.96	683.2	27.47
125	0.23224	939.0	0.77003	525.07	2713.10	1.5816	7.0770	4.252	2.207	1512	483.9	222.1	13.13	683.6	28.11
130	0.27028	934.8	0.66800	546.38	2720.08	1.6346	7.0264	4.261	2.239	1504	486.0	212.9	13.30	683.7	28.76
135	0.31323	930.5	0.58173	567.74	2726.87	1.6872	6.9772	4.272	2.274	1496	487.9	204.4	13.47	683.6	29.44
140	0.36154	926.1	0.50845	589.16	2733.44	1.7392	6.9293	4.283	2.311	1486	489.8	196.5	13.65	683.3	30.14
145	0.41568	921.6	0.44596	610.64	2739.80	1.7907	6.8826	4.294	2.351	1476	491.6	189.2	13.82	682.8	30.86
150	0.47616	917.0	0.39245	632.18	2745.93	1.8418	6.8371	4.307	2.394	1466	493.3	182.5	13.99	682.0	31.60
155	0.54350	912.3	0.34646	653.79	2751.81	1.8924	6.7926	4.321	2.440	1455	494.8	176.1	14.16	681.1	32.35
160	0.61823	907.4	0.30678	675.47	2757.44	1.9426	6.7491	4.335	2.488	1443	496.3	170.2	14.34	680.0	33.13
165	0.70093	902.5	0.27243	697.24	2762.81	1.9923	6.7066	4.351	2.540	1431	497.6	164.7	14.51	678.6	33.93
170	0.79219	897.5	0.24259	719.08	2767.90	2.0417	6.6650	4.368	2.594	1419	498.9	159.6	14.68	677.0	34.75
175	0.89260	892.3	0.21658	741.02	2772.71	2.0906	6.6241	4.386	2.652	1405	500.0	154.7	14.85	675.3	35.59
180	1.00280	887.0	0.19384	763.05	2777.21	2.1392	6.5840	4.405	2.713	1392	501.0	150.1	15.03	673.3	36.45
185	1.12350	881.6	0.17390	785.19	2781.41	2.1875	6.5447	4.425	2.777	1378	501.9	145.8	15.20	671.1	37.33
190	1.25520	876.1	0.15636	807.43	2785.28	2.2355	6.5059	4.447	2.844	1363	502.7	141.8	15.37	668.8	38.24
195	1.39880	870.4	0.14089	829.79	2788.82	2.2832	6.4678	4.471	2.915	1348	503.4	137.9	15.54	666.1	39.16
200	1.55490	864.7	0.12721	852.27	2792.01	2.3305	6.4302	4.496	2.990	1332	503.9	134.3	15.71	663.3	40.11
205	1.72430	858.8	0.11508	874.88	2794.83	2.3777	6.3930	4.523	3.068	1316	504.3	130.9	15.89	660.3	41.09
210	1.90770	852.7	0.10429	897.63	2797.27	2.4245	6.3563	4.551	3.150	1299	504.6	127.6	16.06	657.0	42.09
215	2.10580	846.5	0.09468	920.53	2799.32	2.4712	6.3200	4.582	3.237	1282	504.8	124.5	16.24	653.4	43.11
220	2.31960	840.2	0.08609	943.58	2800.95	2.5177	6.2840	4.615	3.329	1264	504.8	121.5	16.41	649.7	44.17
225	2.54970	833.7	0.07840	966.80	2802.15	2.5640	6.2483	4.650	3.426	1246	504.6	118.7	16.59	645.6	45.26
230	2.79710	827.1	0.07150	990.19	2802.90	2.6101	6.2128	4.688	3.528	1228	504.4	116.0	16.76	641.3	46.38

APPENDIX D

Electric Water Heater Data Sheet

STIEBEL ELTRON

EHS 15-150

English
Horizontal wall mounted electric storage water heater Instructions for use and installation

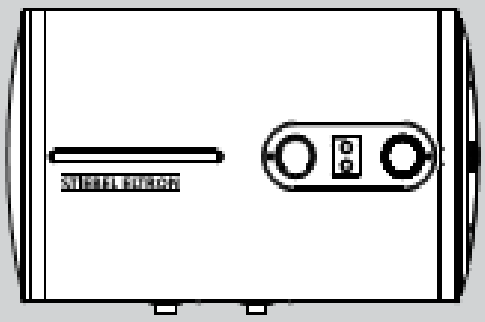
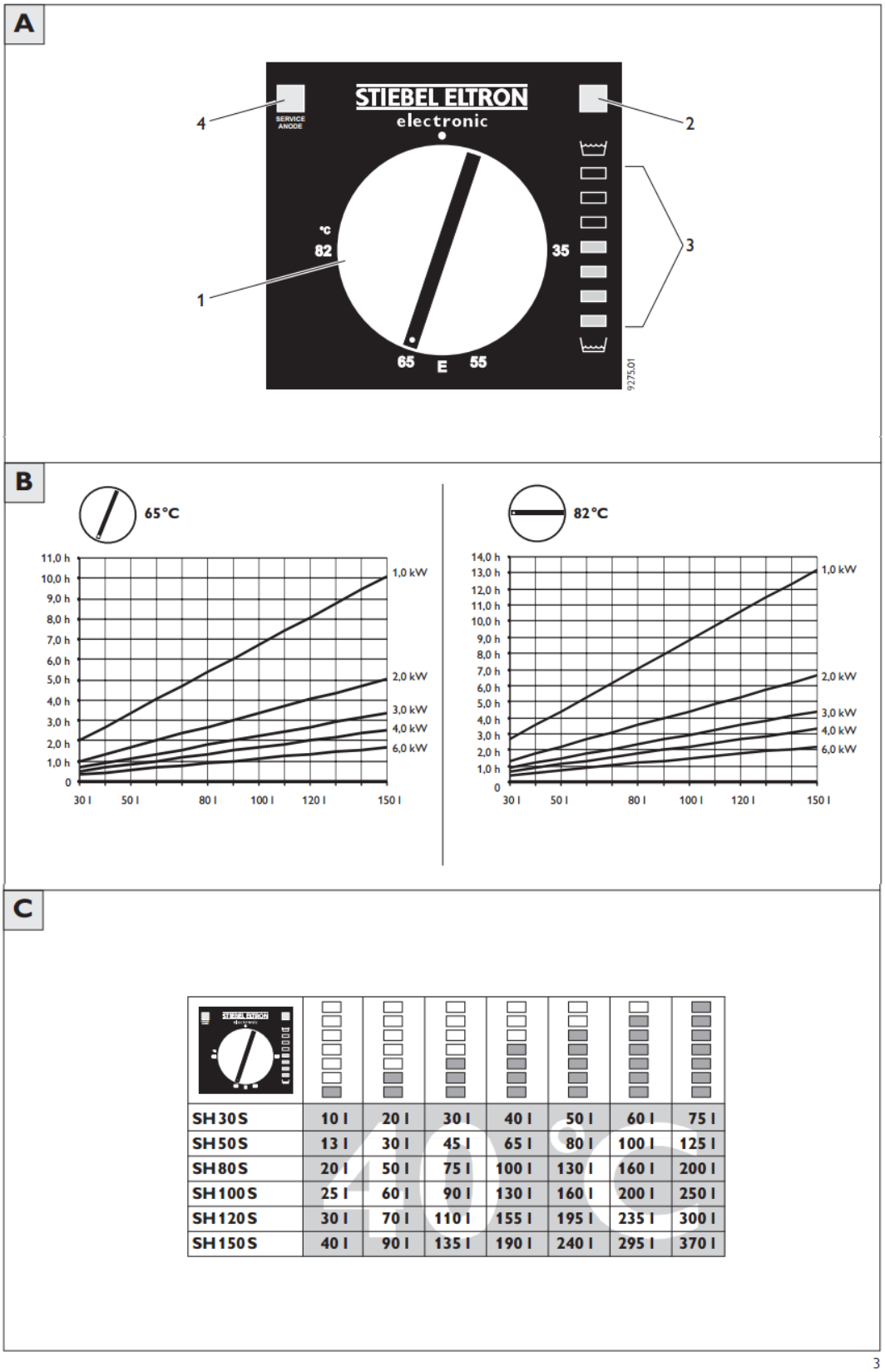


Figure D-1 Electric water heater models



SH 30 S	10 l	20 l	30 l	40 l	50 l	60 l	75 l
SH 50 S	13 l	30 l	45 l	65 l	80 l	100 l	125 l
SH 80 S	20 l	50 l	75 l	100 l	130 l	160 l	200 l
SH 100 S	25 l	60 l	90 l	130 l	160 l	200 l	250 l
SH 120 S	30 l	70 l	110 l	155 l	195 l	235 l	300 l
SH 150 S	40 l	90 l	135 l	190 l	240 l	295 l	370 l

Figure D-2 Electric consumption of water heater

Table D-1 Technical data of electric water heater.

Type			SH 30 S	SH 50 S	SH 80 S	SH 100 S	SH 120 S	SH 150 S
Capacity		l	30	50	80	100	120	150
Mixed water quantity l 40 °C (15 °C / 65 °C)			59	97	159	198	235	292
Weight empty		kg	23.5	30	44	45	50	62.5
Connectable to power sources			1 - 4 kW 1/N/PE ~ 230 V 3 - 4 kW 2/N/PE ~ 400 V 6 kW 3/N/PE ~ 400 V					
Permissible operating pressure			0.6 MPa (6 bar)					
Protection class EN 60529			IP 25 D					
Test marking			See unit rating plate					
Water connection			G ½ (external thread)					
Flow rate			max. 18 l/min					
Dimensions D	a	mm	420	510	510	510	510	510
	b	mm	410	510	510	510	510	510
	h	mm	750	720	1030	1030	1190	1425
	i	mm	–	–	–	–	300	300
	k	mm	700	600	900	900	900	1100
	l	mm	70	140	150	150	310	345

Example: To calculating the performance of the electric water heater from data sheet, the cold water inlet about 15°C and the hot water is desire about 65°C, From Figure D-2 (B), if supply the electric power at 1kWh for the electric water heater volume is 100 liters as following;

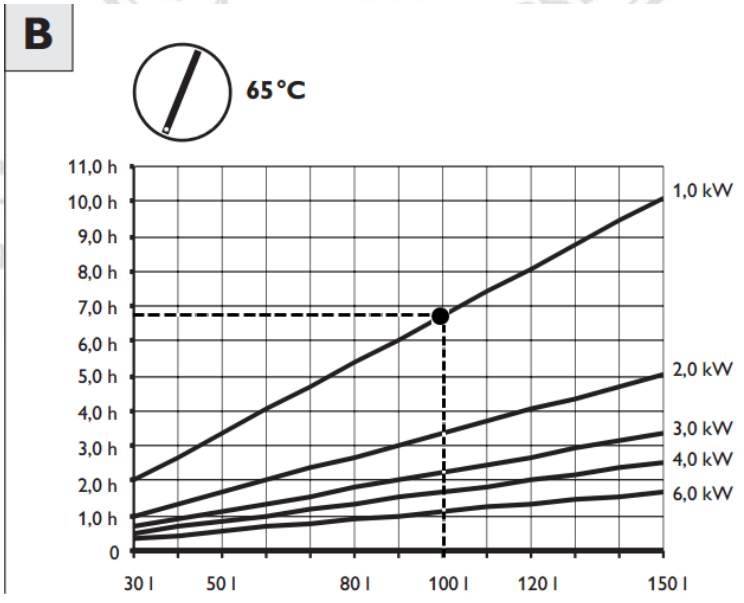


Figure D-3 Electric consumption at 1 kWh of water heater volume with 100 liters for producing hot water at 65°C.

From Figure D-3, the electric water heater volume 100 liters using the electric power at 1 kWh in the period time about 6.8 hours, it can be produced the hot water at 65^{o}C, Applying the conservation of energy as

$$Q_{in} = Q_{out}$$

Where Q_{in} is the electric power (W)

$$Q_{out} = \left(\frac{M_{water} c_{p\_water} (T_{end} - T_{start})}{\Delta t}\right)$$

$$Q_{out} = \left(\frac{100(kg) * 4180(J/kg-K) * (65-15)(K)}{6.8 * 60 * 60}\right)$$

$$Q_{out} = 853.75 \quad Watt$$

Calculate the performance of the electric water heater

$$\eta_{electric} = \frac{Q_{out}}{Q_{in}} = \frac{853.75}{1000} x100 = 85.37\%$$

APPENDIX E

Economics Analysis

E.1 Simple Payback Period (SPP)

Simple Payback Period is calculated by power consumption of electric water heater that produces hot water at 65^{o}C. With this, 6.8 hours is spent for the electric consumption for 1 kWh**.** the average electric cost for producing hot water when considered electric rates is equal to 3.35 Baht/kWh, referred to Provincial Electricity Authority of Thailand, as follow

Cash flow per period = 6.8 (hrs) x 1.0(kWh) x 3.35 (Baht /kWh)
= 22.78 Baht/day
= 18.90 (Baht/day) x 365 (days)
= 8,314.70 Baht/year

Cash flow per period = 8,314.70 Baht /year

The evacuated tube solar water heater has yearly maintenance cost is about 10% of investment cost. It is equal to 2,324 Baht/year. Therefore, the net cash inflow per year, as follow

Net cash inflow = 8,314.70 – 2,324.00
= 5,990.70 Baht/year

The simple payback period of the evacuated tube solar water heater system as:

Simple Payback Period = (23,240) / (5,990.70)
= 3.88 years
= 3 years and 11 months.

E.2 Net Present Value (NPV)

From Equation (2.59) and Table 6.1, the net present value can be calculated as follow:

$$NPV = -23{,}240 + \frac{5{,}990.70 - 2{,}324}{(1+0.065)^{1}} + \ldots + \frac{5{,}990.70 - 2{,}324}{(1+0.065)^{10}} + (0.15 \times 23{,}240)$$

From the results, it can be concluded that the net present value is positive at 23,312.13 Baht which indicates the solar water heater system earnings generated by investment exceed the anticipated costs.

E.3 Internal Rate of Return (IRR)

Table E-1 Internal Rate of Return calculation

Year	Investment cost	Net cash inflow	Cash inflow	Discount rate (r_1=20%)	NPV (r_1=20%)	Discount rate (r_2 = 25%)	NPV (r_2=25%)
0	23,240	-	-23,240	1	-23,240	1	-23,240
1		5,991	5,991	0.83333	4,992	0.80000	4,793
2		5,991	5,991	0.69444	4,160	0.64000	3,834
3		5,991	5,991	0.57870	3,467	0.51200	3,067
4		5,991	5,991	0.48225	2,889	0.40960	2,454
5		5,991	5,991	0.40187	2,408	0.32768	1,963
6		5,991	5,991	0.33489	2,006	0.26214	1,570
7		5,991	5,991	0.27908	1,672	0.20971	1,256
8		5,991	5,991	0.23256	1,393	0.16777	1,005
9		5,991	5,991	0.19380	1,161	0.13421	804
10		5,991	5,991	0.16150	968	0.10737	643
				ΣNPV =	1,876	ΣNPV =	-1,850

The discount rate can be calculated by:

$$\%\ discount\ rate = \frac{1}{(1+(\%discount\ \ rate))^{year}}$$

The NPV can be calculated by:

$$NPV = \frac{Cash\ \ inf\ low}{(1+(\%discount\ \ rate))^{year}}$$

The IRR can be calculated by:

$$\mathrm{IRR} = (r_1) + ((r_2 - r_1))\left(\frac{\sum NPV_{r_1}}{(\sum NPV_{r1} - \sum NPV_{r2})}\right)$$

$$\mathrm{IRR} = (20) + ((25-20))\left(\frac{1{,}876}{(1{,}876-(-1{,}850))}\right)$$

$$\mathrm{IRR} = 22.35\%$$

IRR is calculated at 22.35%. It means that the investment cash flow has an interest rate lower than an IRR; therefore, the evacuated tube solar water heater will be practicality for the investments.

APPENDIX F

List of Publications

1) C.Wannagosit, P. Sakulchangsatjatai, N. Kammuang-lue and P. Terdtoon "Experimental Investigation of Evacuated Tube Thermosyphon Solar Water Heater", The Fifth International Conference on Science, Technology and Innovation for Sustainable Well-Being, Luang Prabang, Lao PDR, September 4-6, 2013.
2) C.Wannagosit, N. Kammuang-lue, P. Sakulchangsatjatai and P. Terdtoon "Computational Study of Water Heater System with Evacuated Glass Tube Solar Collector", The 8th International Conference on Science, Technology and Innovation for Sustainable Well-Being, Yangon, Myanmar, June15–17, 2016.

CURRICULUM VITAE

Name	Mr. Chaiwat Wannagosit
Date of Birth	13 January 1985
Educational	2006 B.Eng in Mechanical Engineering, Naresuan University, Phisanulok, Thailand.
	2010 M.Eng in Mechanical Engineering, Naresuan University, Phisanulok, Thailand.

Papers in International Journal

[1] C.Wannagosit, P. Sakulchangsatjatai, N. Kammuang-lue and P. Terdtoon "Theoretical and experimental evaluation of evacuated tube solar water heater system"

Papers in International Conferences

[1] C.Wannagosit, P. Sakulchangsatjatai, N. Kammuang-lue and P. Terdtoon "Experimental Investigation of Evacuated Tube Thermosyphon Solar Water Heater", The Fifth International Conference on Science, Technology and Innovation for Sustainable Well-Being, Luang Prabang, Lao PDR, September 4-6, 2013.

[2] C.Wannagosit, N. Kammuang-lue, P. Sakulchangsatjatai and P. Terdtoon "Computational Study of Water Heater System with Evacuated Glass Tube Solar Collector", The 8th International Conference on Science, Technology and Innovation for Sustainable Well-Being, Yangon, Myanmar, June15–17, 2016.