DAFTAR PUSTAKA

[1] Jalaluddin., Effendy, Arif., Rustan, Tarakka., *Experimental Study of a SWH System with V-Shaped Plate*, J.Eng. Technol, 48, pp. 2337-5779, 2016.

[2] Sing, Ramkishore., J. Lazarus, Ian., Souliotis, Manolis., *Recent Development in Integrated Collector Storage (ICS) Solar Water Heater : A Review*, Renewable and Sustainable Energy Reviews, 54, pp. 270-298, 2016.

[3] Vengadesan, Elumalai., Senthil, Ramalaingam., *A Review On Recent Development of Termal Performance Enhancement Methods of Flat plate Solar Water Heater*, Solar Energy, 206, pp. 935-961, 2020.

[4] Thantong, Pisut., Chantawong, Preeda., *Experimental Study of Solar – Phase Change Material Wall for Domestic Hot Water Production under the Tropical Climate*, Energy Procedia, 138, pp. 38-43, 2017.

[5] Palacio, Mario., Rincon, Anggie., Carmona, Mauricio., *Experimental Comparative Analysis of Flat Plate Solar Collector With and Without PCM*, Solar Energy, 206, pp. 708-721, 2020.

[6] Yiing Kee, Shin., Munusamy, Yamuna., Seng Ong, Kok., *Review of Solar Water Heaters Incorporating Solid-Liquid Organic Phase Change Materials as Termal Storage*, Applied Termal Energy, 17, pp. 1359-4311, 2017.

[7] Saddegh, Saeid., Wang, Xiaolin., D Henderson, Alan., *A Comparative Study of Termal Behaviour of a Horizontal and Vertical Shell-and-Tube Energy Storage using Phase Change Materials*, Applied Termal Engineering, 93, pp. 348-358, 2015.

[8] Shalaby, S.M., Kabeel, A.E., Moharram, B.E., Fleafl, A.H., *Experimental Study of the Solar Water Heater Integrated with Shell and Finned Tube Latent Heat Storage System*, Journal of Energy Storage, 31, pp. 101628, 2020.

[9] Yanping Du., Ding, Yulong., *Towards Improving Charge / Discharge Rate of Latent Heat Termal Energy Storage (LHTES) by Embedding Metal Foams in Phase Change Materials (PCMs)*, Chemical Engineering and Processing, 108, pp. 181-188, 2016.

[10] Wei, Wu., Suzhou, Dai., Yiping, Dou., *Experimental Study on the Performance of a Novel Solar Water Heating System with and without PCM*, Solar Energy, 171, pp. 604-612, 2018.

[11] Bouhal, T., El Rhafiki, T., Kousksou, T., *PCM Addition Inside Solar Water Heaters : Numerical Comparative Approach*, Energy Storage, 19, pp. 232-246, 2018.

[12] Allouhi, A., Msaad, A.Ait., Amine, M.Benzakour., Saidur, R., *Optimization of Melting and Solidification Processes of PCM : Application to Integrated Collector Storage Solar Water Heaters (ICSSWH)*, Solar Energy, 171, pp. 562-570, 2018.

[13] Tse, Ka-Kui., Chow, Tin-Tai., *Dynamic Model and Experimental Validation of an Indirect Thermosifon Solar Water Heater Coupled with a Parallel Circular Tube Rings Type Heat Exchange Coil*, Solar Energy, 114, pp. 114-133, 2015.

[14] Wannagosit., Sakulchangsatjatai., *Validated Mathematical Models of a Solar Water Heater System with Thermosifon Evacuated Tube Collectors*, Case Studies in Termal Engineering, 12, pp. 528-536, 2018.

[15] Garnier, Celine., Muneer, Tariq., Currie, John., *Numerical and Empirical Evaluation of a Novel Building Integrated Collector Storage Solar Water Heater*, Renewable Energy, 18, pp.30352-5, 2018.

[16] Badiei, Z., Eslami, M., Jafarpur, K., *Performance Improvements in Solar Flat Plate Collectors by Integrating with Phase Change Materials and Fins: A CFD Modeling*, Energy, 19, pp.32414-4, 2019.

[17] Fregah, B., *Design , Development And Optimisation Of A Novel Thermo-Syphon System For Domestic Applications*, 2016.

[18] Liangdong, Ma., Zhen, Lu., Jili, Zhang., Ruobing, Liang., *Termal Performance Analysis of the Glass Evacuated Tube Solar Collector With U-Tube*, Building and Environment, 45, pp.1959-1967, 2010.

[19] Ansys Fluent 18.1, *Software Used Of Numerical Simulation Study*, 2020.

[20] Yazmendra, Rosa., Rino, Sukma., *Rancang Bangun Alat Konversi Energi Surya Menjadi Energi Mekanik*, Jurnal Teknik Mesin, 5(2), ISSN.1829-8958, 2008.

[21] Samanci, A., Berber, A., *Experimental Investigation of Single Phase and Two Phase Closed Thermosifon Solar Water Heater Systems*, Scientific Research and Essays, 6(4), p.688-693, 2011.

[22] Subiantoro, Alison., Kim Tiow, Ooi., *Analytical Model For the Computation and Optimization of Single and Double Glazing Flat Plate Solar Collectors with Normal and Small Air Gap Spacing*, Applied Energy, 104, pp. 392-399, 2013.

[23] F. Jafarkazemi, E. Ahmadifard, *Energetic and exergetic evaluation of flat plate solar collectors*, Renewable Energy 56, pp. 55-63, 2013.

[24] Darwin, H. Syah, S. Yadi, P. Studi, T. Pertanian, F. Pertanian, and U. Syiah Kuala, *Studi Performansi Alat Pemanas Air Dengan Menggunakan Kolektor Surya Plat Datar*, no. 3, pp. 1–5, 2013.

[25] Jalaluddin., Arief. Effendi., Tarakka. Rustan., *Analisis Performansi Kolektor Surya Pemanas Air Dengan Pelat Kolektor Bentuk*-V, Konversi Energi, 35, 2015.

[26] Adnan Kamil, Muhammad., *Analisis Unjuk Kerja Solar Water Heater Termosipon dengan PCM Storage*, Skripsi Departemen Teknik Mesin Universitas Hasanuddin, 2019.

[27] Hamdana Syam, Ari., *Analisis Unjuk Kerja Solar Water Heater Mini dengan PCM Storage*, Skripsi Departemen Teknik Mesin Universitas Hasanuddin, 2019.

[28] A. Cengel, Yunus., *Heat Transfer A Practical Approach*, Second Edition, 2008.

[29] Munahar., *Analisis Unjuk Kerja Kolektor Pemanas Air dengan Pelat Absorber Berbentuk-V*, Jurusan Mesin Universitas Hasanuddin, 2015.

[30] Holman, JP., *Heat Transfer 5th Edition, Mc Graw-Hill International Book Company*, New York, 1981.

[31] Sharma, A., V.V. Tyagi, C.R Chen, D. Buddhi., *Review on Termal Energy Storage with Phase Change Materials and Applications*, Renewable and Sustainable Energy Review, 13: 318-345: 2009.

[32] Chaabane, Monia., Mhiri, Hatem., Bournot, Philippe., *Termal performance of an integrated collector storage solar water heater (ICSSWH) with phase change materials (PCM)*, 0196-8904 : 2013.

[33] A. Reyes., L. Henriquez-Vargaz., J. Rivera., F. Sepulveda., *Theoritical and Experimental Study of Alluminium Foils and Paraffin wax Mixtures As Termal Energy Storage Material*, Renewable Energy, 101: 225-235: 2017.

[34] A. Reyes., Daniela, Negrete., Andrea, Mahn., F. Sepulveda., *Design and Evaluation of a Heat Exchanger That Uses Paraffin Wax and Recycled Materials As Solar Energy Accumulator*, Energy Conversion and Management, 88: 391-398: 2014.

[35] Abbat. A, et al., *Development of Modular Heat Exchanger with an IntegratedLatent Heat Storage*, Report number BMFT FBT 81-500, Germany Ministry of Science and Technology. Bonn : 1981.

[36] Buddhi, D. and R.L Sawhney., *Proceedings on Termal Energy Storage and Energy Conversion*, School of Energy and Environmental Studies. Devi Ahilya University. Indore. India : 1994.

[37] George, A., Handbook of termal design, in: Guyer C, editor., *Phase Change Termal Storage Materials*, Mc. Graw Hill Book Co., 1989.

[38] Nadjib, Muhammad., *Penggunaan Paraffin Wax Sebagai Penyimpan Kalor Pada Pemanas Air Tenaga Matahari Thermosifon*, Vol. 18, No. 3, Pp. 76–85, 2016.

[39] Fauzan, Ahmad., *Computational Fluid Dynamic (CFD)*, Jakarta: 2009.

[40] ANSYS Inc. ANSYS FLUENT 15.0 Theory Guide; 2013.

[41] Selmi, M., Al-Khawaja, MJ., Marafia, A., *Validation of CFD Simulation for Flat Plate Solar Energy Collector*, No. 33, Pp. 383 – 387, 2008.

[42] Gadi, M., *Design and Simulation of a New Energy Conscious System (CFD and Solar Simulation)*, No. 65, Pp. 251 – 256, 2000.

[43] Samdarshi, S.K., Mullick, S.C., *Analysis of the Top Heat Loss Factor of Flat Plate Solar Collectors with Single and Double Glazing*, J Sol Energy – T ASME, 113(2) : 117 – 22, 1991.

[44] Woyessa, Lemi Negera., Koteswararao, Basam., Zeru, Balewgize A., Vijay, P., *Design and CFD Simulation of Solar Water Heater Used In Solar Assisted Biogas System*, Vol. 9 No. 3, ISSN : 2278 – 3075, 2020.

[45] Lahlou, Yasmine., *Design of A Biogas Pilot Unit for Al Akhawayn University*, Dr. El Asli, 2017.

[46] Vladimirova, Natalia., *Model Flame In The Boussinesq Limit: Rising Bubbles*, Vol. 111, No. 3, Pp. 377 – 400, 2007.

[47] Karanth, Vasudeva and A. Q. Cornelio, Jodel., *CFD Analysis of a Flat Plate Solar Collector for Improvement in Termal Performance with Geometric Treatment of Absorber Tube*, Vol. 12, No. 14, Pp. 4415 – 4421, 2017.

LAMPIRAN

LAMPIRAN 1

DATA HASIL PENGUKURAN EKSPERIMENTAL

11 Oktober 2020

			Inlet (Pelat V+PCM)	Outlet (Pelat V+PCM)	Paraffin	Plat Datar (Pelat V+PCM)	Plat Miring (Pelat V+PCM)	Plat dilalui pipa (Pelat V+PCM)	Pipa (Pelat V+PCM)	kaca dalam (Pelat V+PCM)	kaca luar (Pelat V+PCM)	Inlet (Pelat Datar)	Outlet (Pelat Datar)	Plat Datar (Pelat Datar)	Plat dilalui pipa (Pelat Datar)	kaca dalam (Pelat Datar)	kaca Luar (Pelat Datar)	pipa bawah (Pelat V+PCM)	pipa atas (Pelat V+PCM)	tangki (Pelat V+PCM)	Tangki (Pelat Datar)	CH2O(degC) T Lingku	intensitas				
31	09.30	0	29,4	41,7	40,8	60,2	61,7	56,3	51,7	53,3	53,3	29,6	41,2	54,3	52,9	52	51,4	32,4	41,2	32,4	32,9	31,6	699	0,6	LLLL	59,4	53,6
32	09.31	0	29,5	41,7	40,6	60,1	61,6	56,4	51,8	53,2	53,8	29,3	41,5	54,5	52,8	52,1	52,5	32,4	41,5	32,7	32,9	32,1	702	0,8	LLLL	59,3666667	53,65
180	11.59	0	41	52,8	53,4	72,4	69,6	72,4	62,6	60,2	58,3	39,7	52,3	74	67	58,3	55,5	43,9	52,3	46,8	46	32,9	905	4,5	LLLL	71,4666667	70,5
181	12.00	0	41	53,1	53,4	72,3	69,3	72,3	62,6	60,7	58,8	39,6	52,2	74	67	58,6	55,8	44	52,2	47,1	46	33,8	906	3	LLLL	71,3	70,5
182	12.01	0	40,8	52,9	53,5	72,4	69,4	72,4	62,8	60,6	58,4	39,8	52	73,9	67,2	58,6	54,2	43,9	52	46,9	46	31,8	904	3,2	LLLL	71,4	70,55
414	15.53	0	47,8	55,4	56	56,6	56,3	57,8	55	50,9	47,7	46,7	48,9	58,6	56,3	47,4	47,3	50,1	52,1	53,8	52	33,7	402	3,2	LLLL	56,9	57,45
415	15.54	0	47,1	55,5	56	56,8	56,4	57,9	55	51	47,7	46,5	48,9	58,4	56,4	47,7	47,4	49,7	52,1	53,7	52,1	33,9	398	2,9	LLLL	57,0333333	57,4

12 Oktober 2020

	09.32	0	30,6	41,7	42,8	62,1	63,5	58,3	54	50,9	51,5	30,6	41,4	55,7	52,7	49,5	49,9	33,5	43,2	34,9	34,3	32,6	700	2,4	LLLL	61,3	54,2
	09.33	0	30,8	41,7	43,5	62,2	63,6	58,3	54,2	51	53,1	30,8	41,5	56	52,9	49,9	50,7	33,3	43,4	35,2	34,4	32,4	698	2,1	LLLL	61,3666667	54,45
180	11.38	0	39,9	51,3	54,5	74,5	72,1	71,8	64,6	59	58,9	39,4	50,4	74,5	66,6	57,8	57,1	42,8	54,6	46,4	44,6	34,1	1002	3,1	LLLL	72,8	70,55
181	11.39	0	39,9	51,1	54,6	75,1	72,6	72,1	65,2	59,7	58,7	39,6	50,6	75	66,9	58,3	57,2	42,6	54,6	46,5	44,9	33,9	1000	3,9	LLLL	73,2666667	70,95
182	11.40	0	39,9	51,3	54,6	75,3	72,8	72,7	65,6	60,1	55,8	39,4	50,6	75,7	67,2	58,8	57,1	42,9	54,6	46,6	44,9	32,9	1001	4,1	LLLL	73,6	71,45
474	15.47	0	48,4	55,1	57	57,4	57,1	58,1	54,2	51,4	48,1	47,6	51,8	58,6	58,3	49,2	46,8	49,7	53,4	53,8	52,1	33,6	402	1,8	LLLL	57,5333333	58,45
475	15.48	0	48,6	55,1	57,1	57,2	57,1	57,7	54,1	51,4	47,3	48,1	52	58,8	58,1	49,4	46,8	49,8	53,4	53,9	52,3	33,7	405	1,7	LLLL	57,3333333	58,45

13 Oktober 2020

	09.49		30,6	43,8	48,1	64,6	65,5	61	56	55,7	57,8	30,9	42,3	60,3	54,1	54,1	54,4	33,8	41,7	34,7	33,7	34,2	692	2	LLLL	63,7	57,2
	09.50		30,6	43,8	48,4	64,7	65,7	61,2	56	55,5	56,6	30,8	42	60,3	54,1	54	53,6	33,6	41,7	34,5	33,9	33,6	700	2	LLLL	63,8666667	57,2
180	11.44		39,3	52,6	54,9	73,7	71,5	71,2	63,5	59,8	59,3	38,8	50	74,6	66,2	58,5	57,7	42	50,2	45,2	43,7	35,6	966	2,7	LLLL	72,1333333	70,4
181	11.45		39,3	52,7	55	73,8	71,5	71,9	63,9	59,6	55,8	38,9	50,3	74,6	66	58,4	56,5	42,1	50,3	45,2	43,7	33	980	3,1	LLLL	72,4	70,3
182	11.46		39,3	52,8	55,1	73,7	71,6	71,5	63,8	59,4	57,1	39	50,4	74	65,8	58	56,6	42	50,5	45,4	43,8	33,7	959	4	LLLL	72,2666667	69,9
474	15.51		45,1	53,1	57,5	57,3	57,3	58	54,5	51,5	47,1	47,9	49,6	58	58	49	46,2	49,8	55,2	53,9	52	33,5	401	2,8	LLLL	57,5333333	58
475	15.52		46,2	52,4	57,4	57,2	56,9	57,8	54,7	51,1	46,1	45,2	48,2	58,1	58	48,8	45,7	49,8	55,2	53,9	52	32,2	393	3,1	LLLL	57,3	58,05

400		47,1	54,5333333	56,8333333	57,1	56,9	57,9666667	54,5666667	51,2666667	47,6333333	47,4	50,1	58,4	57,5333333	48,5333333	46,7666667	49,8666667	53,5666667	53,8333333	52,0333333	33,6	401,666667	2,6	#VALUE!	57,3222222	57,9666667
		47,3	54,3333333	56,8333333	57,0666667	56,8	57,8	54,6	51,1666667	47,0333333	46,6	49,7	58,4333333	57,5	48,6333333	46,6333333	49,7666667	53,5666667	53,8333333	52,1333333	33,2666667	398,666667	2,56666667	#VALUE!	57,2222222	57,9666667
	Rata-Rata	47,2	54,4333333	56,8333333	57,0833333	56,85	57,8833333	54,5833333	51,2166667	47,3333333	47	49,9	58,4166667	57,5166667	48,5833333	46,7	49,8166667	53,5666667	53,8333333	52,0833333	33,4333333	400,166667	2,58333333	#VALUE!	57,2722222	57,9666667
700		30,2	42,4	43,9	62,3	63,5666667	58,5333333	53,9	53,3	54,2	30,3666667	41,6333333	56,7666667	53,2333333	51,8666667	51,9	33,2333333	42,0333333	34	33,6333333	32,8	697	1,66666667	#VALUE!	61,4666667	55
		30,3	42,4	44,1666667	62,3333333	63,6333333	58,6333333	54	53,2333333	54,5	30,3	41,6666667	56,9333333	53,2666667	52	52,2666667	33,1	42,2	34,1333333	33,7333333	32,7	700	1,63333333	#VALUE!	61,5333333	55,1
	Rata-Rata	30,25	42,4	44,0333333	62,3166667	63,6	58,5833333	53,95	53,2666667	54,35	30,3333333	41,65	56,85	53,25	51,9333333	52,0833333	33,1666667	42,1166667	34,0666667	33,6833333	32,75	698,5	1,65	#VALUE!	61,5	55,05
1000		40,0666667	52,2333333	54,2666667	73,5333333	71,0666667	71,8	63,5666667	59,6666667	58,8333333	39,3	50,9	74,3666667	66,6	58,2	56,7666667	42,9	52,3666667	46,1333333	44,7666667	34,2	957,666667	3,43333333	#VALUE!	72,1333333	70,4833333
		40,0666667	52,3	54,3333333	73,7333333	71,1333333	72,1	63,9	60	57,7666667	39,3666667	51,0333333	74,5333333	66,6333333	58,4333333	56,5	42,9	52,3666667	46,2666667	44,8666667	33,5666667	962	3,33333333	#VALUE!	72,3222222	70,5833333
		40	52,3333333	54,4	73,8	71,2666667	72,2	64,0666667	60,0333333	57,1	39,4	51	74,5333333	66,7333333	58,4666667	55,9666667	42,9333333	52,3666667	46,3	44,9	32,8	954,666667	3,76666667	#VALUE!	72,4222222	70,6333333
	Rata-Rata	40,0444444	52,2888889	54,3333333	73,6888889	71,1555556	72,0333333	63,8444444	59,9	57,9	39,3555556	50,9777778	74,4777778	66,6555556	58,3666667	56,4111111	42,9111111	52,3666667	46,2333333	44,8444444	33,5222222	958,111111	3,51111111	#VALUE!	72,2925926	70,5666667

Lampiran 2

Tabel Sifat – Sifat Udara Pada Tekanan 1 Atm

TABLE A–9

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p J/kg-K	Thermal Conductivity k, W/m-K	Thermal Diffusivity α, m²/s	Dynamic Viscosity μ, kg/m-s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	0.7073
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	0.7041
160	0.8148	1016	0.03511	4.241×10^{-5}	2.420×10^{-5}	2.975×10^{-5}	0.7014
180	0.7788	1019	0.03646	4.593×10^{-5}	2.504×10^{-5}	3.212×10^{-5}	0.6992
200	0.7459	1023	0.03779	4.954×10^{-5}	2.577×10^{-5}	3.455×10^{-5}	0.6974
250	0.6746	1033	0.04104	5.890×10^{-5}	2.760×10^{-5}	4.091×10^{-5}	0.6946
300	0.6158	1044	0.04418	6.871×10^{-5}	2.934×10^{-5}	4.765×10^{-5}	0.6935
350	0.5664	1056	0.04721	7.892×10^{-5}	3.101×10^{-5}	5.475×10^{-5}	0.6937
400	0.5243	1069	0.05015	8.951×10^{-5}	3.261×10^{-5}	6.219×10^{-5}	0.6948
450	0.4880	1081	0.05298	1.004×10^{-4}	3.415×10^{-5}	6.997×10^{-5}	0.6965
500	0.4565	1093	0.05572	1.117×10^{-4}	3.563×10^{-5}	7.806×10^{-5}	0.6986
600	0.4042	1115	0.06093	1.352×10^{-4}	3.846×10^{-5}	9.515×10^{-5}	0.7037
700	0.3627	1135	0.06581	1.598×10^{-4}	4.111×10^{-5}	1.133×10^{-4}	0.7092
800	0.3289	1153	0.07037	1.855×10^{-4}	4.362×10^{-5}	1.326×10^{-4}	0.7149
900	0.3008	1169	0.07465	2.122×10^{-4}	4.600×10^{-5}	1.529×10^{-4}	0.7206
1000	0.2772	1184	0.07868	2.398×10^{-4}	4.826×10^{-5}	1.741×10^{-4}	0.7260
1500	0.1990	1234	0.09599	3.908×10^{-4}	5.817×10^{-5}	2.922×10^{-4}	0.7478
2000	0.1553	1264	0.11113	5.664×10^{-4}	6.630×10^{-5}	4.270×10^{-4}	0.7539

Note: For ideal gases, the properties c_p, k, μ, and Pr are independent of pressure. The properties ρ, ν, and α at a pressure P (in atm) other than 1 atm are determined by multiplying the values of ρ at the given temperature by P and by dividing ν and α by P.

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Original sources: Keenan, Chao, Keyes, Gas Tables, Wiley, 198; and Thermophysical Properties of Matter, Vol. 3: Thermal Conductivity, Y. S. Touloukian, P. E. Liley, S. C. Saxena, Vol. 11: Viscosity, Y. S. Touloukian, S. C. Saxena, and P. Hestermans, IFI/Plenum, NY, 1970, ISBN 0-306067020-8.

Tabel Sifat - Sifat Air Jenuh

TABLE A–9

Properties of saturated water

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³ Liquid	Density ρ, kg/m³ Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg·K Liquid	Specific Heat c_p, J/kg·K Vapor	Thermal Conductivity k, W/m·K Liquid	Thermal Conductivity k, W/m·K Vapor	Dynamic Viscosity μ, kg/m·s Liquid	Dynamic Viscosity μ, kg/m·s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/K Liquid
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	1.792×10^{-3}	0.922×10^{-5}	13.5	1.00	-0.068×10^{-3}
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	1.519×10^{-3}	0.934×10^{-5}	11.2	1.00	0.015×10^{-3}
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	1.307×10^{-3}	0.946×10^{-5}	9.45	1.00	0.733×10^{-3}
15	1.7051	999.1	0.0128	2466	4185	1863	0.589	0.0179	1.138×10^{-3}	0.959×10^{-5}	8.09	1.00	0.138×10^{-3}
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	1.002×10^{-3}	0.973×10^{-5}	7.01	1.00	0.195×10^{-3}
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	0.891×10^{-3}	0.987×10^{-5}	6.14	1.00	0.247×10^{-3}
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	0.798×10^{-3}	1.001×10^{-5}	5.42	1.00	0.294×10^{-3}
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	0.720×10^{-3}	1.016×10^{-5}	4.83	1.00	0.337×10^{-3}
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	0.653×10^{-3}	1.031×10^{-5}	4.32	1.00	0.377×10^{-3}
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	0.596×10^{-3}	1.046×10^{-5}	3.91	1.00	0.415×10^{-3}
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	0.547×10^{-3}	1.062×10^{-5}	3.55	1.00	0.451×10^{-3}
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	0.504×10^{-3}	1.077×10^{-5}	3.25	1.00	0.484×10^{-3}
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	0.467×10^{-3}	1.093×10^{-5}	2.99	1.00	0.517×10^{-3}
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	0.433×10^{-3}	1.110×10^{-5}	2.75	1.00	0.548×10^{-3}
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	0.404×10^{-3}	1.126×10^{-5}	2.55	1.00	0.578×10^{-3}
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	0.378×10^{-3}	1.142×10^{-5}	2.38	1.00	0.607×10^{-3}
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	0.355×10^{-3}	1.159×10^{-5}	2.22	1.00	0.653×10^{-3}
85	57.83	968.1	0.3536	2296	4201	1977	0.673	0.0235	0.333×10^{-3}	1.176×10^{-5}	2.08	1.00	0.670×10^{-3}
90	70.14	965.3	0.4235	2283	4206	1993	0.675	0.0240	0.315×10^{-3}	1.193×10^{-5}	1.96	1.00	0.702×10^{-3}
95	84.55	961.5	0.5045	2270	4212	2010	0.677	0.0246	0.297×10^{-3}	1.210×10^{-5}	1.85	1.00	0.716×10^{-3}
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	0.282×10^{-3}	1.227×10^{-5}	1.75	1.00	0.750×10^{-3}
110	143.27	950.6	0.8263	2230	4229	2071	0.682	0.0262	0.255×10^{-3}	1.261×10^{-5}	1.58	1.00	0.798×10^{-3}
120	198.53	943.4	1.121	2203	4244	2120	0.683	0.0275	0.232×10^{-3}	1.296×10^{-5}	1.44	1.00	0.858×10^{-3}
130	270.1	934.6	1.496	2174	4263	2177	0.684	0.0288	0.213×10^{-3}	1.330×10^{-5}	1.33	1.01	0.913×10^{-3}
140	361.3	921.7	1.965	2145	4286	2244	0.683	0.0301	0.197×10^{-3}	1.365×10^{-5}	1.24	1.02	0.970×10^{-3}
150	475.8	916.6	2.546	2114	4311	2314	0.682	0.0316	0.183×10^{-3}	1.399×10^{-5}	1.16	1.02	1.025×10^{-3}
160	617.8	907.4	3.256	2083	4340	2420	0.680	0.0331	0.170×10^{-3}	1.434×10^{-5}	1.09	1.05	1.145×10^{-3}
170	791.7	897.7	4.119	2050	4370	2490	0.677	0.0347	0.160×10^{-3}	1.468×10^{-5}	1.03	1.05	1.178×10^{-3}
180	1,002.1	887.3	5.153	2015	4410	2590	0.673	0.0364	0.150×10^{-3}	1.502×10^{-5}	0.983	1.07	1.210×10^{-3}
190	1,254.4	876.4	6.388	1979	4460	2710	0.669	0.0382	0.142×10^{-3}	1.537×10^{-5}	0.947	1.09	1.280×10^{-3}
200	1,553.8	864.3	7.852	1941	4500	2840	0.663	0.0401	0.134×10^{-3}	1.571×10^{-5}	0.910	1.11	1.350×10^{-3}
220	2,318	840.3	11.60	1859	4610	3110	0.650	0.0442	0.122×10^{-3}	1.641×10^{-5}	0.865	1.15	1.520×10^{-3}
240	3,344	813.7	16.73	1767	4760	3520	0.632	0.0487	0.111×10^{-3}	1.712×10^{-5}	0.836	1.24	1.720×10^{-3}
260	4,688	783.7	23.69	1663	4970	4070	0.609	0.0540	0.102×10^{-3}	1.788×10^{-5}	0.832	1.35	2.000×10^{-3}
280	6,412	750.8	33.15	1544	5280	4835	0.581	0.0605	0.094×10^{-3}	1.870×10^{-5}	0.854	1.49	2.380×10^{-3}
300	8,581	713.8	46.15	1405	5750	5980	0.548	0.0695	0.086×10^{-3}	1.965×10^{-5}	0.902	1.69	2.950×10^{-3}
320	11,274	667.1	64.57	1239	6540	7900	0.509	0.0836	0.078×10^{-3}	2.084×10^{-5}	1.00	1.97	
340	14,586	610.5	92.62	1028	8240	11,870	0.469	0.110	0.070×10^{-3}	2.255×10^{-5}	1.23	2.43	
360	18,651	528.3	144.0	720	14,690	25,800	0.427	0.178	0.060×10^{-3}	2.571×10^{-5}	2.06	3.73	
374.14	22,090	317.0	317.0	0	—	—	—	—	0.043×10^{-3}	4.313×10^{-5}			

Note 1: Kinematic viscosity ν and thermal diffusivity α can be calculated from their definitions, $\nu = \mu/\rho$ and $\alpha = k/\rho c_p = \nu/\text{Pr}$. The temperatures 0.01°C, 100°C, and 374.14°C are the triple-, boiling-, and critical-point temperatures of water, respectively. The properties listed above (except the vapor density) can be used at any pressure with negligible error except at temperatures near the critical-point value.

Note 2: The unit kJ/kg·°C for specific heat is equivalent to kJ/kg·K, and the unit W/m·°C for thermal conductivity is equivalent to W/m·K.

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EXPERIMENTAL / SIMULATION	Direct Radiation	Temp. Inlet	Temp. Outlet	Temp. Plate	Temp. Paraffin	Temp. Ambient	T In - T Amb	α	τ	S	UL	FR	Plate Area (A)	IT . A	Q Plate	A * FR	S - (UL(Tin-Tamb))	Qu	Efficiency (η)
	W/m^2	(C)								W/m^2	W/m^2 K		m^2	W	W			W	
Simulation Without PCM Storage	400	33,512	47,644	54,545		36	-2,488	0,87	0,975	342,693	6,594	0,7845	0,0578	23,12	23,120	0,0453441	359,098872	16,28301516	0,704282663
Experimental Without PCM Storage	400	29,2	32,1	40,616		36	-6,8	0,87	0,975	342,693	6,594	0,7845	0,0578	23,12		0,0453441	387,5322	17,57229883	0,760047527
Simulation Without PCM Storage	700	38,314	62,746	74,654		36	2,314	0,87	0,975	599,71275	6,594	0,7845	0,0578	40,46	40,460	0,0453441	584,454234	26,50155123	0,655006209
Experimental Without PCM Storage	700	30,333	41,65	56,85		36	-5,667	0,87	0,975	599,71275	6,594	0,7845	0,0578	40,46		0,0453441	637,080948	28,88786221	0,71398572
Simulation Without PCM Storage	1000	44,51	82,066	100,396		36	8,51	0,87	0,975	856,7325	6,594	0,7845	0,0578	57,8	57,800	0,0453441	800,61756	36,3032827	0,628084476
Experimental Without PCM Storage	1000	39,355	50,977	74,477		36	3,355	0,87	0,975	856,7325	6,594	0,7845	0,0578	57,8		0,0453441	834,60963	37,84462252	0,654751255
Simulation With PCM Storage 15 mm Thickness	400	32,812	40,53	48,58	46,115	36	-3,188	0,87	0,975	342,693	6,594	0,7845	0,0578	23,12	23,120	0,0453441	363,714672	16,49231446	0,7133354
Experimental With PCM Storage 15 mm Thickness	400	29,2	32,95	37,267	36,214	36	-6,8	0,87	0,975	342,693	6,594	0,7845	0,0578	23,12		0,0453441	387,5322	17,57229883	0,760047527
Simulation With PCM Storage 15 mm Thickness	700	36,728	49,071	61,022	57,19	36	0,728	0,87	0,975	599,71275	6,594	0,7845	0,0578	40,46	40,460	0,0453441	594,912318	26,97576364	0,666726734
Experimental With PCM Storage 15 mm Thickness	700	33,166	42,116	58,583	44,033	36	-2,834	0,87	0,975	599,71275	6,594	0,7845	0,0578	40,46		0,0453441	618,400146	28,04079806	0,693049878
Simulation With PCM Storage 15 mm Thickness	1000	41,261	58,989	75,295	70,215	36	5,261	0,87	0,975	856,7325	6,594	0,7845	0,0578	57,8	57,800	0,0453441	822,041466	37,27473044	0,64489153
Experimental With PCM Storage 15 mm Thickness	1000	42,6	54,6	72,033	54,333	36	6,6	0,87	0,975	856,7325	6,594	0,7845	0,0578	57,8		0,0453441	813,2121	36,87437078	0,637964892
Simulation With PCM Storage 10 mm Thickness	400	33,153	40,642	46,634	45,938	36	-2,847	0,87	0,975	342,693	6,594	0,7845	0,0578	23,12	23,120	0,0453441	361,466118	16,3903558	0,708925424
Simulation With PCM Storage 10 mm Thickness	700	37,437	50,02	60,016	59,823	36	1,437	0,87	0,975	599,71275	6,594	0,7845	0,0578	40,46	40,460	0,0453441	590,237172	26,76377335	0,661487231
Simulation With PCM Storage 10 mm Thickness	1000	42,244	60,588	77,207	73,674	36	6,244	0,87	0,975	856,7325	6,594	0,7845	0,0578	57,8	57,800	0,0453441	815,559564	36,98081443	0,639806478
Simulation With PCM Storage 6 mm Thickness	400	34,214	42,933	49,894	49,804	36	-1,786	0,87	0,975	342,693	6,594	0,7845	0,0578	23,12	23,120	0,0453441	354,469884	16,07311787	0,69520406
Simulation With PCM Storage 6 mm Thickness	700	39,086	53,621	65,103	65,021	36	3,086	0,87	0,975	599,71275	6,594	0,7845	0,0578	40,46	40,460	0,0453441	579,363666	26,27072401	0,649301137
Simulation With PCM Storage 6 mm Thickness	1000	44,604	65,719	82,346	82,097	36	8,604	0,87	0,975	856,7325	6,594	0,7845	0,0578	57,8	57,800	0,0453441	799,997724	36,2751768	0,627598214