

DAFTAR PUSTAKA

- Ambarita, H. *et al.* (2020) ‘Performansi Pemanas Air Tenaga Surya Dengan Penambahan Sirip Pada Pipa Kolektor’, *Sprocket Journal of Mechanical Engineering*, 1(2), pp. 57–64.
- A. Reyes, L. Henríquez-Vargas, J. Rivera, and F. Sepúlveda, “Theoretical and experimental study of aluminum foils and *Paraffin Wax* mixtures as thermal energy storage material,” *Renew. Energy*, vol. 101, pp. 225–235, 2017, doi: 10.1016/j.renene.2016.08.057.
- Badiei, Z., Eslami, M., Jafarpur, K. (2019). *Performance Improvements in Solar Flat Plate Collectors by Integrating with Phase Change Materials and Fins: A CFD Modeling*, *Energy*, 19, pp.32414-4,
- Garnier, Celine., Muneer, Tariq., Currie, John. (2018). *Numerical and Empirical Evaluation of a Novel Building Integrated Collector Storage Solar Water Heater* *Renewable Energy*, 18, pp.30352-5,
- Gihon Matondang, Azridjal Aziz, R.I.M. (2016) ‘Jurnal Unjuk Kerja Kolektor Pemanas Air Tenaga Surya Sistem Termosifon Dengan Pemanfaatan Kaleng Minuman Bekas Sebagai Absorber’, *Jom FTEKNIK Volume 3*, 3(1), p. 1.
- Holman, JP. (1981). *Heat Transfer*, 5th Edition. McGraw – Hill International Book Company. New York.
- Hudon, K. (2013) ‘Solar Energy - Water Heating’, *Future Energy: Improved, Sustainable and Clean Options for our Planet*, pp. 433–451.
- Jalaluddin, Saiful Akmal, Nasrul Za, Ishak (2019). *Analisa Profil Aliran Fluida Cair dan Pressure Drop pada Pipa L menggunakan Metode Simulasi Computational Fluid Dynamic (CFD)*. Aceh. Universitas Malikussaleh
- Jalaluddin, Himran, S., Arief, S., Khalik, A. (2016). *Studi Eksperimental Performansi Modul Photovoltaik dengan Pendinginan Air*, *Proceeding Seminar Nasional Tahunan Teknik Mesin XV (SNTTM XV)* Bandung 5 – 7 Oktober 2016.
- Junianto, A.P. and Slamet, R. (2019) ‘Perancangan Pemanas Air Tenaga Surya Pasif Kapasitas 20 Liter’, *Media Teknologi*, 06(01 Agustus 2019), pp. 185–194.
- Kalogirou, S.A. (2004) *Solar thermal collectors and applications*, *Progress in Energy and Combustion Science*.
- M. Chaabane, H. Mhiri, and P. Bournot, “Thermal performance of an integrated collector storage solar water heater (ICSSWH) with phase change materials (PCM),” *Energy Convers. Manag.*, vol. 78, pp. 897–903, 2014, doi: 10.1016/j.enconman.2013.07.089.

- Ogie, N. A., Oghogho, I., & Jesumirewhe, J. (2013). *Design and Construction of a Solar Water Heater Based on the Thermosyphon Principle*.
- Sambada, F.A.R. (2019) 'Unjuk Kerja Pemanas Air Energi Matahari Sederhana', *Universitas*, 3(November), pp. 59–70..
- W. Zuo, *Pengenalan Dinamika Fluida Komputasi*, JASS 05, St.Petersburg, 2005.
- Wiratama, Caesara., "Modul Pengantar Ansys Simulasi Fluida", aeroengineering.co.id, 2021.
- 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.

LAMPIRAN

Lampiran 1. Tabel Properties of miscellaneous material

853

APPENDIX 1

TABLE A-8

Properties of miscellaneous materials

(Values are at 300 K unless indicated otherwise)

Material	Density, ρ kg/m ³	Thermal Conductivity, k W/m · K	Specific Heat, c_p J/kg · K	Material	Density, ρ kg/m ³	Thermal Conductivity, k W/m · K	Specific Heat, c_p J/kg · K
Asphalt	2115	0.062	920	Ice			
Bakelite	1300	1.4	1465	273 K	920	1.88	2040
Brick, refractory				253 K	922	2.03	1945
Chrome brick				173 K	928	3.49	1460
473 K	3010	2.3	835	Leather, sole	998	0.159	—
823 K	—	2.5	—	Linoleum	535	0.081	—
1173 K	—	2.0	—	1180	1180	0.186	—
Fire clay, burnt				Mica	2900	0.523	—
1600 K				Paper	930	0.180	1340
773 K	2050	1.0	960	Plastics			
1073 K	—	1.1	—	Plexiglass	1190	0.19	1465
1373 K	—	1.1	—	Teflon			
Fire clay, burnt				300 K	2200	0.35	1050
1725 K				400 K	—	0.45	—
773 K	2325	1.3	960	Lexan	1200	0.19	1260
1073 K	—	1.4	—	Nylon	1145	0.29	—
1373 K	—	1.4	—	Polypropylene	910	0.12	1925
Fire clay brick				Polyester	1395	0.15	1170
478 K	2645	1.0	960	PVC, vinyl	1470	0.1	840
922 K	—	1.5	—	Porcelain	2300	1.5	—
1478 K	—	1.8	—	Rubber, natural	1150	0.28	—
Magnesite				Rubber, vulcanized			
478 K	—	3.8	1130	Soft	1100	0.13	2010
922 K	—	2.8	—	Hard	1190	0.16	—
1478 K	—	1.9	—	Sand	1515	0.2–1.0	800
Chicken meat,				Snow, fresh	100	0.60	—
white (74.4%				Snow, 273 K	500	2.2	—
water content)				Soil, dry	1500	1.0	1900
198 K	—	1.60	—	Soil, wet	1900	2.0	2200
233 K	—	1.49	—	Sugar	1600	0.58	—
253 K	—	1.35	—	Tissue, human			
273 K	—	0.48	—	Skin	—	0.37	—
293 K	—	0.49	—	Fat layer	—	0.2	—
Clay, dry	1550	0.930	—	Muscle	—	0.41	—
Clay, wet	1495	1.675	—	Vaseline	—	0.17	—
Coal, anthracite	1350	0.26	1260	Wood, cross-grain			
Concrete (stone				Balsa	140	0.055	—
mix)	2300	1.4	880	Fir	415	0.11	2720
Cork	86	0.048	2030	Oak	545	0.17	2385
Cotton	80	0.06	1300	White pine	435	0.11	—
Fat	—	0.17	—	Yellow pine	640	0.15	2805
Glass				Wood, radial			
Window	2800	0.7	750	Oak	545	0.19	2385
Pyrex	2225	1–1.4	835	Fir	420	0.14	2720
Crown	2500	1.05	—	Wool, ship	145	0.05	—
Lead	3400	0.85	—				

Source: Compiled from various sources.

Lampiran 2. Tabel Properties of insulating material

850
APPENDIX 1

TABLE A-6

Properties of insulating materials
(at a mean temperature of 24°C)

Material	Thickness, L mm	Density, ρ kg/m ³	Thermal Conductivity, k W/m · K	Specific Heat, c_p kJ/kg · K	R-value (for listed thickness, L/k), K · m ² /W
Blanket and Batt					
Mineral fiber (fibrous form processed from rock, slag, or glass)	50 to 70 mm	4.8–32	—	0.71–0.96	1.23
	75 to 90 mm	4.8–32	—	0.71–0.96	1.94
	135 to 165 mm	4.8–32	—	0.71–0.96	3.32
Board and Slab					
Cellular glass		136	0.055	1.0	—
Glass fiber (organic bonded)		64–144	0.036	0.96	—
Expanded polystyrene (molded beads)		16	0.040	1.2	—
Expanded polyurethane (R-11 expanded)		24	0.023	1.6	—
Expanded perlite (organic bonded)		16	0.052	1.26	—
Expanded rubber (rigid)		72	0.032	1.68	—
Mineral fiber with resin binder		240	0.042	0.71	—
Cork		120	0.039	1.80	—
Sprayed or Formed in Place					
Polyurethane foam		24–40	0.023–0.026	—	—
Glass fiber		56–72	0.038–0.039	—	—
Urethane, two-part mixture (rigid foam)		70	0.026	1.045	—
Mineral wool granules with asbestos/inorganic binders (sprayed)		190	0.046	—	—
Loose Fill					
Mineral fiber (rock, slag, or glass)	~75 to 125 mm	9.6–32	—	0.71	1.94
	~165 to 222 mm	9.6–32	—	0.71	3.35
	~191 to 254 mm	—	—	0.71	3.87
	~185 mm	—	—	0.71	5.28
Silica aerogel		122	0.025	—	—
Vermiculite (expanded)		122	0.068	—	—
Perlite, expanded		32–66	0.039–0.045	1.09	—
Sawdust or shavings		128–240	0.065	1.38	—
Cellulosic insulation (milled paper or wood pulp)		37–51	0.039–0.046	—	—
Roof Insulation					
Cellular glass	—	144	0.058	1.0	—
Preformed, for use above deck	13 mm	—	—	1.0	0.24
	25 mm	—	—	2.1	0.49
	50 mm	—	—	3.9	0.93
Reflective Insulation					
Silica powder (evacuated)		160	0.0017	—	—
Aluminum foil separating fluffy glass mats; 10–12 layers (evacuated); for cryogenic applications (150 K)		40	0.00016	—	—
Aluminum foil and glass paper laminate; 75–150 layers (evacuated); for cryogenic applications (150 K)		120	0.000017	—	—

Lampiran 3. Tabel Properties of air at 1 atm pressure.

860		APPENDIX 1						
TABLE A-15								
Properties of air at 1 atm pressure								
Temp. $T, ^\circ\text{C}$	Density $\rho, \text{kg/m}^3$	Specific Heat $c_p, \text{J/kg} \cdot \text{K}$	Thermal Conductivity $k, \text{W/m} \cdot \text{K}$	Thermal Diffusivity $\alpha, \text{m}^2/\text{s}^2$	Dynamic Viscosity $\mu, \text{kg/m} \cdot \text{s}$	Kinematic Viscosity $\nu, \text{m}^2/\text{s}$	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^{-6}	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.

Lampiran 4. Tabel *Properties of saturated water*854
APPENDIX 1

TABLE A-9

Properties of saturated water

Temp. <i>T</i> , °C	Saturation Pressure <i>P</i> _{sat} , kPa	Density <i>ρ</i> , kg/m ³		Enthalpy of Vaporization <i>h</i> _{fg} , kJ/kg	Specific Heat <i>c</i> _p , J/kg · K		Thermal Conductivity <i>k</i> , W/m · K		Dynamic Viscosity <i>μ</i> , kg/m · s		Prandtl Number Pr		Volume Expansion Coefficient <i>β</i> , 1/K
		Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	
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 $\alpha = k/\rho c_p = \nu/Pr$. 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.

Source: Viscosity and thermal conductivity data are from J. V. Sengers and J. T. R. Watson, *Journal of Physical and Chemical Reference Data* 15 (1986), pp. 1291–1322. Other data are obtained from various sources or calculated.

Lampiran 5. Tabel Pengambilan Data PCM 4 mm

Plat Kolektor PCM 4 mm								
t	IN (T _{fi})C	OUT (T _{fo})C	Plat datar (TP1)C	Material PCM	Kaca Dalam (T _{c-dalam})C	Kaca Luar (T _{c-Luar})C	Ling (T _a)C	Illum (I) Kw
0	28.00	28.00	28.00	28.00	28.00	28.00	28.00	1.000
5	29.21	31.03	31.09	30.83	48.33	48.33	28.00	1.000
10	30.41	32.80	33.49	33.28	50.26	50.26	28.00	1.000
15	31.34	34.41	35.53	35.35	55.36	55.36	28.00	1.000
20	32.15	35.74	37.18	37.04	54.90	54.90	28.00	1.000
25	32.77	36.85	38.59	38.47	57.28	57.28	28.00	1.000
30	33.30	37.78	39.74	39.64	56.57	56.57	28.00	1.000
35	33.77	38.62	40.73	40.64	59.59	59.59	28.00	1.000
40	34.09	39.26	41.56	41.49	58.65	58.65	28.00	1.000
45	34.41	39.81	42.25	42.19	62.44	62.44	28.00	1.000
50	34.71	40.30	42.85	42.80	64.77	64.77	28.00	1.000
55	34.93	40.71	43.34	43.30	61.78	61.78	28.00	1.000
60	35.12	41.10	43.77	43.73	59.74	59.74	28.00	1.000
65	35.30	41.39	44.16	44.12	61.57	61.57	28.00	1.000
70	35.47	41.64	44.48	44.45	63.40	63.40	28.00	1.000
75	35.61	41.91	44.77	44.74	64.72	64.72	28.00	1.000
80	35.74	42.09	45.04	45.01	61.32	61.32	28.00	1.000
85	35.80	42.29	45.27	45.25	63.12	63.12	28.00	1.000
90	35.91	42.45	45.50	45.48	62.02	62.02	28.00	1.000
95	35.99	42.56	45.69	45.67	67.02	67.02	28.00	1.000
100	36.11	42.74	45.88	45.86	65.45	65.45	28.00	1.000
105	36.23	42.88	46.06	46.04	63.61	63.61	28.00	1.000
110	36.24	43.08	46.26	46.24	69.65	69.65	28.00	1.000
115	36.30	43.22	46.43	46.41	67.32	67.32	28.00	1.000
120	36.38	43.36	46.59	46.58	68.07	68.07	28.00	1.000
125	36.47	43.42	46.72	46.71	67.97	67.97	28.00	1.000
130	36.54	43.62	46.84	46.83	64.72	64.72	28.00	1.000
135	36.57	43.67	47.01	47.00	68.30	68.30	28.00	1.000
140	36.69	43.78	47.17	47.15	69.26	69.26	28.00	1.000
145	36.74	43.91	47.33	47.31	72.35	72.35	28.00	1.000
150	36.78	44.09	47.48	47.47	68.25	68.25	28.00	1.000
155	36.85	44.23	47.66	47.64	70.85	70.85	28.00	1.000
160	36.96	44.36	47.82	47.80	71.20	71.20	28.00	1.000
165	36.97	44.51	47.98	47.97	72.74	72.74	28.00	1.000
170	37.09	44.63	48.15	48.13	70.71	70.71	28.00	1.000
175	37.12	44.75	48.34	48.32	70.71	70.71	28.00	1.000
180	37.28	44.95	48.51	48.49	71.66	71.66	28.00	1.000

Lampiran 6. Tabel Pengambilan Data PCM 7 mm

Plat Kolektor PCM 7 mm								
t	IN (T _{fi})C	OUT (T _{fo})C	Plat datar (TP1)C	Material PCM	Kaca Dalam (T _{c-dalam})C	Kaca Luar (T _{c-Luar})C	Ling (T _a)C	Illum (I) Kw
0	28.00	28.00	28.00	28.00	28.00	28.00	28.00	1.000
5	28.90	29.74	30.00	29.42	47.63	47.63	28.00	1.000
10	29.79	31.69	32.33	31.79	50.11	50.11	28.00	1.000
15	30.40	33.22	34.35	33.88	49.94	49.94	28.00	1.000
20	31.07	34.52	36.07	35.67	55.58	55.58	28.00	1.000
25	31.58	35.67	37.56	37.22	56.01	56.01	28.00	1.000
30	32.46	36.59	38.84	38.54	58.03	58.03	28.00	1.000
35	32.31	37.41	39.96	39.69	61.32	61.32	28.00	1.000
40	33.08	38.11	40.88	40.66	58.64	58.64	28.00	1.000
45	33.65	38.72	41.70	41.50	59.19	59.19	28.00	1.000
50	33.70	39.27	42.42	42.24	62.43	62.43	28.00	1.000
55	33.92	39.67	43.02	42.87	61.02	61.02	28.00	1.000
60	33.93	40.13	43.60	43.46	62.54	62.54	28.00	1.000
65	34.42	40.46	44.08	43.96	60.59	60.59	28.00	1.000
70	34.37	40.76	44.51	44.40	62.83	62.83	28.00	1.000
75	34.96	41.03	44.88	44.79	68.42	68.42	28.00	1.000
80	35.22	41.30	45.22	45.13	63.91	63.91	28.00	1.000
85	35.24	41.54	45.53	45.45	64.17	64.17	28.00	1.000
90	35.44	41.74	45.83	45.75	66.03	66.03	28.00	1.000
95	35.22	41.96	46.10	46.02	65.57	65.57	28.00	1.000
100	35.22	42.19	46.33	46.26	65.70	65.70	28.00	1.000
105	35.36	42.33	46.59	46.52	67.79	67.79	28.00	1.000
110	35.57	42.46	46.79	46.73	69.06	69.06	28.00	1.000
115	35.65	42.68	47.00	46.93	69.69	69.69	28.00	1.000
120	35.86	42.84	47.18	47.12	70.16	70.16	28.00	1.000
125	35.56	42.94	47.37	47.31	67.05	67.05	28.00	1.000
130	36.00	43.18	47.56	47.51	71.61	71.61	28.00	1.000
135	35.46	43.27	47.76	47.69	74.25	74.25	28.00	1.000
140	36.20	43.36	47.93	47.87	68.21	68.21	28.00	1.000
145	35.99	43.50	48.09	48.03	69.33	69.33	28.00	1.000
150	36.39	43.67	48.29	48.23	70.56	70.56	28.00	1.000
155	36.41	43.84	48.46	48.42	70.56	70.56	28.00	1.000
160	36.49	43.94	48.60	48.55	72.35	72.35	28.00	1.000
165	36.47	44.07	48.78	48.71	72.81	72.81	28.00	1.000
170	36.72	44.18	48.99	48.93	79.10	79.10	28.00	1.000
175	36.82	44.40	49.20	49.13	72.11	72.11	28.00	1.000
180	36.63	44.58	49.40	49.34	76.15	76.15	28.00	1.000

Lampiran 7. Tabel Pengambilan Data PCM 10 mm

Plat Kolektor PCM 10 mm								
t	IN (T _{fi})C	OUT (T _{fo})C	Plat datar (T _{P1})C	Material PCM	Kaca Dalam (T _{c-dalam})C	Kaca Luar (T _{c-Luar})C	Ling (T _a)C	Illum (I) Kw
0	28.00	28.00	28.00	28.00	28.00	28.00	28.00	1.000
5	29.69	31.93	32.88	31.09	51.05	51.05	28.00	1.000
10	30.23	32.71	33.60	32.78	51.80	51.80	28.00	1.000
15	30.80	33.73	34.86	34.10	52.26	52.26	28.00	1.000
20	31.32	34.64	36.03	35.33	55.77	55.77	28.00	1.000
25	31.75	35.47	37.08	36.45	56.23	56.23	28.00	1.000
30	32.16	36.18	38.02	37.45	52.88	52.88	28.00	1.000
35	32.48	36.87	38.88	38.36	54.81	54.81	28.00	1.000
40	32.76	37.46	39.66	39.19	56.67	56.67	28.00	1.000
45	33.11	37.99	40.35	39.93	55.46	55.46	28.00	1.000
50	33.33	38.51	40.99	40.60	58.36	58.36	28.00	1.000
55	33.68	38.93	41.55	41.20	59.22	59.22	28.00	1.000
60	33.85	39.37	42.07	41.75	61.35	61.35	28.00	1.000
65	33.97	39.74	42.54	42.25	62.26	62.26	28.00	1.000
70	34.16	40.07	42.98	42.71	63.63	63.63	28.00	1.000
75	34.32	40.39	43.36	43.12	62.10	62.10	28.00	1.000
80	34.50	40.68	43.72	43.49	60.84	60.84	28.00	1.000
85	34.62	40.92	44.07	43.85	61.95	61.95	28.00	1.000
90	34.82	41.18	44.38	44.19	64.11	64.11	28.00	1.000
95	34.84	41.39	44.68	44.49	65.12	65.12	28.00	1.000
100	34.93	41.63	44.94	44.77	64.41	64.41	28.00	1.000
105	35.14	41.85	45.20	45.03	65.91	65.91	28.00	1.000
110	35.15	42.01	45.44	45.29	64.46	64.46	28.00	1.000
115	35.30	42.15	45.67	45.52	64.85	64.85	28.00	1.000
120	35.42	42.33	45.88	45.75	68.17	68.17	28.00	1.000
125	35.42	42.58	46.09	45.95	72.42	72.42	28.00	1.000
130	35.43	42.73	46.31	46.16	71.23	71.23	28.00	1.000
135	35.49	42.89	46.49	46.36	68.77	68.77	28.00	1.000
140	35.67	42.98	46.69	46.55	67.28	67.28	28.00	1.000
145	35.83	43.11	46.85	46.74	69.06	69.06	28.00	1.000
150	35.83	43.30	47.07	46.93	71.41	71.41	28.00	1.000
155	35.90	43.46	47.23	47.11	67.08	67.08	28.00	1.000
160	35.96	43.60	47.41	47.29	68.55	68.55	28.00	1.000
165	36.07	43.78	47.58	47.46	69.93	69.93	28.00	1.000
170	36.17	43.89	47.79	47.65	71.17	71.17	28.00	1.000
175	36.20	44.07	48.01	47.87	71.19	71.19	28.00	1.000
180	36.29	44.25	48.22	48.08	77.08	77.08	28.00	1.000

Lampiran 8. Tabel Hasil Perhitungan Data PCM 4 mm

Plat Kolektor PCM 4 mm								
t	Ut (W/m ² .K)	Ub (W/m ² .K)	U _l (W/m ² .K)	Q _{loss} (W/m ² .K)	S (W/m ²)	V (m ³ /s)	Qu (Watt)	η (%)
0	3.91352	1.92	5.83424	0.87514	844.8	0.00000	0.00000	0.00
5	4.987	1.92	6.907	9.370	844.8	9.26E-07	7.0433809	19.40
10	5.043	1.92	6.964	17.819	844.8	9.26E-07	9.2526312	25.49
15	5.185	1.92	7.106	24.809	844.8	9.26E-07	11.87458	32.71
20	5.180	1.92	7.100	30.498	844.8	9.26E-07	13.879447	38.24
25	5.247	1.92	7.168	35.237	844.8	9.26E-07	15.800729	43.53
30	5.234	1.92	7.154	38.973	844.8	9.26E-07	17.325134	47.73
35	5.317	1.92	7.238	42.815	844.8	9.26E-07	18.784618	51.75
40	5.294	1.92	7.215	45.038	844.8	9.26E-07	19.979935	55.04
45	5.398	1.92	7.318	48.025	844.8	9.26E-07	20.849146	57.44
50	5.461	1.92	7.381	50.627	844.8	9.26E-07	21.610817	59.53
55	5.387	1.92	7.307	51.773	844.8	9.26E-07	22.318636	61.48
60	5.333	1.92	7.254	52.755	844.8	9.26E-07	23.105408	63.65
65	5.384	1.92	7.305	54.423	844.8	9.26E-07	23.519521	64.79
70	5.434	1.92	7.355	56.025	844.8	9.26E-07	23.87347	65.77
75	5.469	1.92	7.390	57.375	844.8	9.26E-07	24.346221	67.07
80	5.381	1.92	7.301	57.604	844.8	9.26E-07	24.545099	67.62
85	5.430	1.92	7.351	58.419	844.8	9.26E-07	25.100921	69.15
90	5.401	1.92	7.322	59.021	844.8	9.26E-07	25.288541	69.67
95	5.534	1.92	7.454	60.711	844.8	9.26E-07	25.378852	69.91
100	5.494	1.92	7.415	61.204	844.8	9.26E-07	25.63725	70.63
105	5.446	1.92	7.367	61.746	844.8	9.26E-07	25.687241	70.76
110	5.604	1.92	7.525	63.104	844.8	9.26E-07	26.46046	72.89
115	5.546	1.92	7.467	63.097	844.8	9.26E-07	26.745124	73.68
120	5.567	1.92	7.487	63.884	844.8	9.26E-07	26.967886	74.29
125	5.565	1.92	7.486	64.558	844.8	9.26E-07	26.865163	74.01
130	5.480	1.92	7.401	64.336	844.8	9.26E-07	27.369021	75.40
135	5.575	1.92	7.496	65.384	844.8	9.26E-07	27.412528	75.52
140	5.601	1.92	7.522	66.513	844.8	9.26E-07	27.414297	75.52
145	5.680	1.92	7.601	67.549	844.8	9.26E-07	27.73927	76.42
150	5.577	1.92	7.498	66.952	844.8	9.26E-07	28.24545	77.81
155	5.645	1.92	7.565	68.057	844.8	9.26E-07	28.541583	78.63
160	5.652	1.92	7.572	68.953	844.8	9.26E-07	28.606163	78.80
165	5.694	1.92	7.615	69.477	844.8	9.26E-07	29.134395	80.26
170	5.643	1.92	7.564	69.897	844.8	9.26E-07	29.126092	80.24
175	5.645	1.92	7.566	70.105	844.8	9.26E-07	29.490893	81.24
180	5.670	1.92	7.591	71.592	844.8	9.26E-07	29.640487	81.65

Lampiran 9. Tabel Hasil Perhitungan Data PCM 7 mm

Plat Kolektor PCM 7 mm								
t	Ut (W/m ² .K)	Ub (W/m ² .K)	U _I (W/m ² .K)	Q _{loss} (W/m ² .K)	S (W/m ²)	V (m ³ /s)	Qu (Watt)	η (%)
0	3.91352	1.92	5.83424	0.87514	844.8	0.00000	0.00000	0.00
5	4.970	1.92	6.890	7.250	844.8	9.26E-07	0.003247	8.95
10	5.040	1.92	6.960	13.510	844.8	9.26E-07	0.007367	20.29
15	5.039	1.92	6.960	17.763	844.8	9.26E-07	0.010876	29.96
20	5.192	1.92	7.113	22.912	844.8	9.26E-07	0.013347	36.77
25	5.208	1.92	7.128	26.553	844.8	9.26E-07	0.015802	43.53
30	5.263	1.92	7.184	33.106	844.8	9.26E-07	0.015976	44.01
35	5.354	1.92	7.274	32.459	844.8	9.26E-07	0.019697	54.26
40	5.286	1.92	7.207	37.625	844.8	9.26E-07	0.019461	53.61
45	5.306	1.92	7.227	41.877	844.8	9.26E-07	0.019627	54.07
50	5.392	1.92	7.313	42.779	844.8	9.26E-07	0.02155	59.37
55	5.358	1.92	7.279	44.219	844.8	9.26E-07	0.02221	61.18
60	5.399	1.92	7.320	44.495	844.8	9.26E-07	0.023995	66.10
65	5.351	1.92	7.272	47.731	844.8	9.26E-07	0.023353	64.33
70	5.411	1.92	7.332	47.804	844.8	9.26E-07	0.02468	67.99
75	5.555	1.92	7.476	53.133	844.8	9.26E-07	0.023482	64.69
80	5.444	1.92	7.365	54.309	844.8	9.26E-07	0.023482	64.69
85	5.450	1.92	7.371	54.486	844.8	9.26E-07	0.024338	67.05
90	5.502	1.92	7.423	56.365	844.8	9.26E-07	0.024322	67.00
95	5.491	1.92	7.412	54.613	844.8	9.26E-07	0.026064	71.80
100	5.495	1.92	7.416	54.707	844.8	9.26E-07	0.026932	74.19
105	5.551	1.92	7.472	56.150	844.8	9.26E-07	0.026945	74.23
110	5.584	1.92	7.505	57.918	844.8	9.26E-07	0.026646	73.41
115	5.603	1.92	7.524	58.697	844.8	9.26E-07	0.027147	74.78
120	5.615	1.92	7.535	60.376	844.8	9.26E-07	0.026978	74.32
125	5.538	1.92	7.459	57.467	844.8	9.26E-07	0.028556	78.67
130	5.654	1.92	7.575	61.753	844.8	9.26E-07	0.027736	76.41
135	5.721	1.92	7.641	58.018	844.8	9.26E-07	0.030206	83.21
140	5.571	1.92	7.492	62.568	844.8	9.26E-07	0.027683	76.26
145	5.600	1.92	7.520	61.163	844.8	9.26E-07	0.029028	79.97
150	5.634	1.92	7.555	64.517	844.8	9.26E-07	0.028151	77.55
155	5.634	1.92	7.555	64.636	844.8	9.26E-07	0.028749	79.20
160	5.681	1.92	7.602	65.648	844.8	9.26E-07	0.028828	79.42
165	5.693	1.92	7.614	65.640	844.8	9.26E-07	0.029382	80.94
170	5.848	1.92	7.769	68.904	844.8	9.26E-07	0.028841	79.45
175	5.678	1.92	7.599	68.167	844.8	9.26E-07	0.029297	80.71
180	5.780	1.92	7.701	67.646	844.8	9.26E-07	0.030704	84.58

Lampiran 10. Tabel Hasil Perhitungan Data PCM 10 mm

Plat Kolektor PCM 10 mm								
t	Ut (W/m ² .K)	Ub (W/m ² .K)	U _I (W/m ² .K)	Q _{loss} (W/m ² .K)	S (W/m ²)	V (m ³ /s)	Qu (Watt)	η (%)
0	3.91352	1.92	5.83424	0.87514	844.8	0.00000	0.00000	0.00
5	5.061	1.92	6.982	12.845	844.8	9.26E-07	8.6580869	23.85
10	5.082	1.92	7.003	16.693	844.8	9.26E-07	9.5891641	26.42
15	5.102	1.92	7.023	20.732	844.8	9.26E-07	11.316563	31.18
20	5.198	1.92	7.119	24.695	844.8	9.26E-07	12.817582	35.31
25	5.214	1.92	7.135	27.824	844.8	9.26E-07	14.387767	39.64
30	5.127	1.92	7.048	30.407	844.8	9.26E-07	15.535921	42.80
35	5.181	1.92	7.102	32.861	844.8	9.26E-07	16.978602	46.77
40	5.234	1.92	7.154	35.155	844.8	9.26E-07	18.158442	50.02
45	5.204	1.92	7.124	37.500	844.8	9.26E-07	18.862141	51.96
50	5.285	1.92	7.206	39.523	844.8	9.26E-07	20.003748	55.11
55	5.309	1.92	7.229	42.170	844.8	9.26E-07	20.286743	55.89
60	5.370	1.92	7.290	43.774	844.8	9.26E-07	21.307623	58.70
65	5.394	1.92	7.315	44.740	844.8	9.26E-07	22.332116	61.52
70	5.432	1.92	7.353	46.424	844.8	9.26E-07	22.822052	62.87
75	5.394	1.92	7.315	47.353	844.8	9.26E-07	23.429973	64.55
80	5.363	1.92	7.284	48.421	844.8	9.26E-07	23.884029	65.80
85	5.394	1.92	7.315	49.537	844.8	9.26E-07	24.353197	67.09
90	5.452	1.92	7.372	51.376	844.8	9.26E-07	24.577525	67.71
95	5.480	1.92	7.401	51.745	844.8	9.26E-07	25.313874	69.74
100	5.463	1.92	7.384	52.283	844.8	9.26E-07	25.885946	71.31
105	5.502	1.92	7.422	54.104	844.8	9.26E-07	25.950094	71.49
110	5.466	1.92	7.387	53.939	844.8	9.26E-07	26.503501	73.01
115	5.477	1.92	7.398	55.127	844.8	9.26E-07	26.491227	72.98
120	5.566	1.92	7.486	56.683	844.8	9.26E-07	26.711904	73.59
125	5.674	1.92	7.594	57.482	844.8	9.26E-07	27.668381	76.22
130	5.644	1.92	7.565	57.354	844.8	9.26E-07	28.189474	77.66
135	5.583	1.92	7.504	57.340	844.8	9.26E-07	28.592049	78.77
140	5.546	1.92	7.467	58.372	844.8	9.26E-07	28.242514	77.80
145	5.593	1.92	7.514	59.970	844.8	9.26E-07	28.131751	77.50
150	5.654	1.92	7.575	60.443	844.8	9.26E-07	28.881339	79.56
155	5.544	1.92	7.465	60.088	844.8	9.26E-07	29.24141	80.55
160	5.583	1.92	7.504	60.876	844.8	9.26E-07	29.525477	81.34
165	5.619	1.92	7.540	61.994	844.8	9.26E-07	29.794877	82.08
170	5.653	1.92	7.574	63.017	844.8	9.26E-07	29.837336	82.20
175	5.655	1.92	7.576	63.237	844.8	9.26E-07	30.441948	83.86
180	5.803	1.92	7.724	65.221	844.8	9.26E-07	30.731367	84.66