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Lampiran 1. Tabel Properties of miscellaneous material

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APPENDIX 1

TABLE A-8

Properties of miscellaneous materials  
(Values are at 300 K unless indicated otherwise)

| Material                       | Density, $\rho$<br>kg/m <sup>3</sup> | Thermal<br>Conductivity, $k$<br>W/m · K | Specific<br>Heat, $c_p$<br>J/kg · K | Material           | Density, $\rho$<br>kg/m <sup>3</sup> | Thermal<br>Conductivity, $k$<br>W/m · K | Specific<br>Heat, $c_p$<br>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                                 | 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%<br>water content) |                                      |                                         |                                     | Snow, 273 K        | 500                                  | 2.2                                     | —                                   |
| 198 K                          | —                                    | 1.60                                    | —                                   | Soil, dry          | 1500                                 | 1.0                                     | 1900                                |
| 233 K                          | —                                    | 1.49                                    | —                                   | Soil, wet          | 1900                                 | 2.0                                     | 2200                                |
| 253 K                          | —                                    | 1.35                                    | —                                   | Sugar              | 1600                                 | 0.58                                    | —                                   |
| 273 K                          | —                                    | 0.48                                    | —                                   | Tissue, human      |                                      |                                         |                                     |
| 293 K                          | —                                    | 0.49                                    | —                                   | Skin               | —                                    | 0.37                                    | —                                   |
| Clay, dry                      | 1550                                 | 0.930                                   | —                                   | Fat layer          | —                                    | 0.2                                     | —                                   |
| Clay, wet                      | 1495                                 | 1.675                                   | —                                   | Muscle             | —                                    | 0.41                                    | —                                   |
| Coal, anthracite               | 1350                                 | 0.26                                    | 1260                                | Vaseline           | —                                    | 0.17                                    | —                                   |
| Concrete (stone<br>mix)        | 2300                                 | 1.4                                     | 880                                 | Wood, cross-grain  |                                      |                                         |                                     |
| Cork                           | 86                                   | 0.048                                   | 2030                                | Balsa              | 140                                  | 0.055                                   | —                                   |
| Cotton                         | 80                                   | 0.06                                    | 1300                                | Fir                | 415                                  | 0.11                                    | 2720                                |
| Fat                            | —                                    | 0.17                                    | —                                   | Oak                | 545                                  | 0.17                                    | 2385                                |
| Glass                          |                                      |                                         |                                     | White pine         | 435                                  | 0.11                                    | —                                   |
| Window                         | 2800                                 | 0.7                                     | 750                                 | Yellow pine        | 640                                  | 0.15                                    | 2805                                |
| Pyrex                          | 2225                                 | 1–1.4                                   | 835                                 | Wood, radial       |                                      |                                         |                                     |
| Crown                          | 2500                                 | 1.05                                    | —                                   | Oak                | 545                                  | 0.19                                    | 2385                                |
| Lead                           | 3400                                 | 0.85                                    | —                                   | Fir                | 420                                  | 0.14                                    | 2720                                |
|                                |                                      |                                         |                                     | Wool, ship         | 145                                  | 0.05                                    | —                                   |

Source: Compiled from various sources.

## Lampiran 2. Tabel Properties of insulating material

| 850<br>APPENDIX 1                                                                                           |                                                              |                                      |                                              |                                                     |                                                                                     |
|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------|----------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------|
| TABLE A-6                                                                                                   |                                                              |                                      |                                              |                                                     |                                                                                     |
| Properties of insulating materials<br>(at a mean temperature of 24°C)                                       |                                                              |                                      |                                              |                                                     |                                                                                     |
| Material                                                                                                    | Thickness,<br><i>L</i> mm                                    | Density, $\rho$<br>kg/m <sup>3</sup> | Thermal<br>Conductivity, <i>k</i><br>W/m · K | Specific<br>Heat, <i>c<sub>p</sub></i><br>kJ/kg · K | <i>R</i> -value<br>(for listed<br>thickness, <i>L/k</i> ),<br>K · m <sup>2</sup> /W |
| <b>Blanket and Batt</b>                                                                                     |                                                              |                                      |                                              |                                                     |                                                                                     |
| Mineral fiber (fibrous form<br>processed from rock, slag,<br>or glass)                                      | 50 to 70 mm<br>75 to 90 mm<br>135 to 165 mm                  | 4.8–32<br>4.8–32<br>4.8–32           | —<br>—<br>—                                  | 0.71–0.96<br>0.71–0.96<br>0.71–0.96                 | 1.23<br>1.94<br>3.32                                                                |
| <b>Board and Slab</b>                                                                                       |                                                              |                                      |                                              |                                                     |                                                                                     |
| 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 ( <i>R</i> -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                                                | —                                                                                   |
| <b>Sprayed or Formed in Place</b>                                                                           |                                                              |                                      |                                              |                                                     |                                                                                     |
| 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/<br>inorganic binders (sprayed)                                         |                                                              | 190                                  | 0.046                                        | —                                                   | —                                                                                   |
| <b>Loose Fill</b>                                                                                           |                                                              |                                      |                                              |                                                     |                                                                                     |
| Mineral fiber (rock, slag, or glass)                                                                        | ~75 to 125 mm<br>~165 to 222 mm<br>~191 to 254 mm<br>~185 mm | 9.6–32<br>9.6–32<br>—<br>—           | —<br>—<br>—<br>—                             | 0.71<br>0.71<br>0.71<br>0.71                        | 1.94<br>3.35<br>3.87<br>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                                  | —                                                   | —                                                                                   |
| <b>Roof Insulation</b>                                                                                      |                                                              |                                      |                                              |                                                     |                                                                                     |
| Cellular glass                                                                                              | —                                                            | 144                                  | 0.058                                        | 1.0                                                 | —                                                                                   |
| Preformed, for use above deck                                                                               | 13 mm<br>25 mm<br>50 mm                                      | —<br>—<br>—                          | —<br>—<br>—                                  | 1.0<br>2.1<br>3.9                                   | 0.24<br>0.49<br>0.93                                                                |
| <b>Reflective Insulation</b>                                                                                |                                                              |                                      |                                              |                                                     |                                                                                     |
| Silica powder (evacuated)                                                                                   |                                                              | 160                                  | 0.0017                                       | —                                                   | —                                                                                   |
| Aluminum foil separating fluffy glass mats; 10–12 layers<br>(evacuated); for cryogenic applications (150 K) |                                                              | 40                                   | 0.00016                                      | —                                                   | —                                                                                   |
| Aluminum foil and glass paper laminate; 75–150<br>layers (evacuated); for cryogenic applications (150 K)    |                                                              | 120                                  | 0.000017                                     | —                                                   | —                                                                                   |

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

| 860<br>APPENDIX 1                   |                                  |                                                       |                                                           |                                                         |                                                           |                                                      |                         |
|-------------------------------------|----------------------------------|-------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------|-------------------------|
| TABLE A-15                          |                                  |                                                       |                                                           |                                                         |                                                           |                                                      |                         |
| Properties of air at 1 atm pressure |                                  |                                                       |                                                           |                                                         |                                                           |                                                      |                         |
| Temp.<br>$T, ^\circ\text{C}$        | Density<br>$\rho, \text{kg/m}^3$ | Specific<br>Heat<br>$c_p, \text{J/kg} \cdot \text{K}$ | Thermal<br>Conductivity<br>$k, \text{W/m} \cdot \text{K}$ | Thermal<br>Diffusivity<br>$\alpha, \text{m}^2/\text{s}$ | Dynamic<br>Viscosity<br>$\mu, \text{kg/m} \cdot \text{s}$ | Kinematic<br>Viscosity<br>$\nu, \text{m}^2/\text{s}$ | Prandtl<br>Number<br>Pr |
| -150                                | 2.866                            | 983                                                   | 0.01171                                                   | $4.158 \times 10^{-6}$                                  | $8.636 \times 10^{-6}$                                    | $3.013 \times 10^{-6}$                               | 0.7246                  |
| -100                                | 2.038                            | 966                                                   | 0.01582                                                   | $8.036 \times 10^{-6}$                                  | $1.189 \times 10^{-5}$                                    | $5.837 \times 10^{-6}$                               | 0.7263                  |
| -50                                 | 1.582                            | 999                                                   | 0.01979                                                   | $1.252 \times 10^{-5}$                                  | $1.474 \times 10^{-5}$                                    | $9.319 \times 10^{-6}$                               | 0.7440                  |
| -40                                 | 1.514                            | 1002                                                  | 0.02057                                                   | $1.356 \times 10^{-5}$                                  | $1.527 \times 10^{-5}$                                    | $1.008 \times 10^{-5}$                               | 0.7436                  |
| -30                                 | 1.451                            | 1004                                                  | 0.02134                                                   | $1.465 \times 10^{-5}$                                  | $1.579 \times 10^{-5}$                                    | $1.087 \times 10^{-5}$                               | 0.7425                  |
| -20                                 | 1.394                            | 1005                                                  | 0.02211                                                   | $1.578 \times 10^{-5}$                                  | $1.630 \times 10^{-5}$                                    | $1.169 \times 10^{-5}$                               | 0.7408                  |
| -10                                 | 1.341                            | 1006                                                  | 0.02288                                                   | $1.696 \times 10^{-5}$                                  | $1.680 \times 10^{-5}$                                    | $1.252 \times 10^{-5}$                               | 0.7387                  |
| 0                                   | 1.292                            | 1006                                                  | 0.02364                                                   | $1.818 \times 10^{-5}$                                  | $1.729 \times 10^{-5}$                                    | $1.338 \times 10^{-5}$                               | 0.7362                  |
| 5                                   | 1.269                            | 1006                                                  | 0.02401                                                   | $1.880 \times 10^{-5}$                                  | $1.754 \times 10^{-5}$                                    | $1.382 \times 10^{-5}$                               | 0.7350                  |
| 10                                  | 1.246                            | 1006                                                  | 0.02439                                                   | $1.944 \times 10^{-5}$                                  | $1.778 \times 10^{-5}$                                    | $1.426 \times 10^{-5}$                               | 0.7336                  |
| 15                                  | 1.225                            | 1007                                                  | 0.02476                                                   | $2.009 \times 10^{-5}$                                  | $1.802 \times 10^{-5}$                                    | $1.470 \times 10^{-5}$                               | 0.7323                  |
| 20                                  | 1.204                            | 1007                                                  | 0.02514                                                   | $2.074 \times 10^{-5}$                                  | $1.825 \times 10^{-5}$                                    | $1.516 \times 10^{-5}$                               | 0.7309                  |
| 25                                  | 1.184                            | 1007                                                  | 0.02551                                                   | $2.141 \times 10^{-5}$                                  | $1.849 \times 10^{-5}$                                    | $1.562 \times 10^{-5}$                               | 0.7296                  |
| 30                                  | 1.164                            | 1007                                                  | 0.02588                                                   | $2.208 \times 10^{-5}$                                  | $1.872 \times 10^{-5}$                                    | $1.608 \times 10^{-5}$                               | 0.7282                  |
| 35                                  | 1.145                            | 1007                                                  | 0.02625                                                   | $2.277 \times 10^{-5}$                                  | $1.895 \times 10^{-5}$                                    | $1.655 \times 10^{-5}$                               | 0.7268                  |
| 40                                  | 1.127                            | 1007                                                  | 0.02662                                                   | $2.346 \times 10^{-5}$                                  | $1.918 \times 10^{-5}$                                    | $1.702 \times 10^{-5}$                               | 0.7255                  |
| 45                                  | 1.109                            | 1007                                                  | 0.02699                                                   | $2.416 \times 10^{-5}$                                  | $1.941 \times 10^{-5}$                                    | $1.750 \times 10^{-5}$                               | 0.7241                  |
| 50                                  | 1.092                            | 1007                                                  | 0.02735                                                   | $2.487 \times 10^{-5}$                                  | $1.963 \times 10^{-5}$                                    | $1.798 \times 10^{-5}$                               | 0.7228                  |
| 60                                  | 1.059                            | 1007                                                  | 0.02808                                                   | $2.632 \times 10^{-5}$                                  | $2.008 \times 10^{-5}$                                    | $1.896 \times 10^{-5}$                               | 0.7202                  |
| 70                                  | 1.028                            | 1007                                                  | 0.02881                                                   | $2.780 \times 10^{-5}$                                  | $2.052 \times 10^{-5}$                                    | $1.995 \times 10^{-5}$                               | 0.7177                  |
| 80                                  | 0.9994                           | 1008                                                  | 0.02953                                                   | $2.931 \times 10^{-5}$                                  | $2.096 \times 10^{-5}$                                    | $2.097 \times 10^{-5}$                               | 0.7154                  |
| 90                                  | 0.9718                           | 1008                                                  | 0.03024                                                   | $3.086 \times 10^{-5}$                                  | $2.139 \times 10^{-5}$                                    | $2.201 \times 10^{-5}$                               | 0.7132                  |
| 100                                 | 0.9458                           | 1009                                                  | 0.03095                                                   | $3.243 \times 10^{-5}$                                  | $2.181 \times 10^{-5}$                                    | $2.306 \times 10^{-5}$                               | 0.7111                  |
| 120                                 | 0.8977                           | 1011                                                  | 0.03235                                                   | $3.565 \times 10^{-5}$                                  | $2.264 \times 10^{-5}$                                    | $2.522 \times 10^{-5}$                               | 0.7073                  |
| 140                                 | 0.8542                           | 1013                                                  | 0.03374                                                   | $3.898 \times 10^{-5}$                                  | $2.345 \times 10^{-5}$                                    | $2.745 \times 10^{-5}$                               | 0.7041                  |
| 160                                 | 0.8148                           | 1016                                                  | 0.03511                                                   | $4.241 \times 10^{-5}$                                  | $2.420 \times 10^{-5}$                                    | $2.975 \times 10^{-5}$                               | 0.7014                  |
| 180                                 | 0.7788                           | 1019                                                  | 0.03646                                                   | $4.593 \times 10^{-5}$                                  | $2.504 \times 10^{-5}$                                    | $3.212 \times 10^{-5}$                               | 0.6992                  |
| 200                                 | 0.7459                           | 1023                                                  | 0.03779                                                   | $4.954 \times 10^{-5}$                                  | $2.577 \times 10^{-5}$                                    | $3.455 \times 10^{-5}$                               | 0.6974                  |
| 250                                 | 0.6746                           | 1033                                                  | 0.04104                                                   | $5.890 \times 10^{-5}$                                  | $2.760 \times 10^{-5}$                                    | $4.091 \times 10^{-5}$                               | 0.6946                  |
| 300                                 | 0.6158                           | 1044                                                  | 0.04418                                                   | $6.871 \times 10^{-5}$                                  | $2.934 \times 10^{-5}$                                    | $4.765 \times 10^{-5}$                               | 0.6935                  |
| 350                                 | 0.5664                           | 1056                                                  | 0.04721                                                   | $7.892 \times 10^{-5}$                                  | $3.101 \times 10^{-5}$                                    | $5.475 \times 10^{-5}$                               | 0.6937                  |
| 400                                 | 0.5243                           | 1069                                                  | 0.05015                                                   | $8.951 \times 10^{-5}$                                  | $3.261 \times 10^{-5}$                                    | $6.219 \times 10^{-5}$                               | 0.6948                  |
| 450                                 | 0.4880                           | 1081                                                  | 0.05298                                                   | $1.004 \times 10^{-4}$                                  | $3.415 \times 10^{-5}$                                    | $6.997 \times 10^{-5}$                               | 0.6965                  |
| 500                                 | 0.4565                           | 1093                                                  | 0.05572                                                   | $1.117 \times 10^{-4}$                                  | $3.563 \times 10^{-5}$                                    | $7.806 \times 10^{-5}$                               | 0.6986                  |
| 600                                 | 0.4042                           | 1115                                                  | 0.06093                                                   | $1.352 \times 10^{-4}$                                  | $3.846 \times 10^{-5}$                                    | $9.515 \times 10^{-5}$                               | 0.7037                  |
| 700                                 | 0.3627                           | 1135                                                  | 0.06581                                                   | $1.598 \times 10^{-4}$                                  | $4.111 \times 10^{-5}$                                    | $1.133 \times 10^{-4}$                               | 0.7092                  |
| 800                                 | 0.3289                           | 1153                                                  | 0.07037                                                   | $1.855 \times 10^{-4}$                                  | $4.362 \times 10^{-5}$                                    | $1.326 \times 10^{-4}$                               | 0.7149                  |
| 900                                 | 0.3008                           | 1169                                                  | 0.07465                                                   | $2.122 \times 10^{-4}$                                  | $4.600 \times 10^{-5}$                                    | $1.529 \times 10^{-4}$                               | 0.7206                  |
| 1000                                | 0.2772                           | 1184                                                  | 0.07868                                                   | $2.398 \times 10^{-4}$                                  | $4.826 \times 10^{-5}$                                    | $1.741 \times 10^{-4}$                               | 0.7260                  |
| 1500                                | 0.1990                           | 1234                                                  | 0.09599                                                   | $3.908 \times 10^{-4}$                                  | $5.817 \times 10^{-5}$                                    | $2.922 \times 10^{-4}$                               | 0.7478                  |
| 2000                                | 0.1553                           | 1264                                                  | 0.11113                                                   | $5.664 \times 10^{-4}$                                  | $6.630 \times 10^{-5}$                                    | $4.270 \times 10^{-4}$                               | 0.7539                  |

Note: For ideal gases, the properties  $c_p$ ,  $k$ ,  $\mu$ , and Pr are independent of pressure. The properties  $\rho$ ,  $\nu$ , and  $\alpha$  at a pressure  $P$  (in atm) other than 1 atm are determined by multiplying the values of  $\rho$  at the given temperature by  $P$  and by dividing  $\nu$  and  $\alpha$  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

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APPENDIX 1

TABLE A-9

Properties of saturated water

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

Note 1: Kinematic viscosity  $\nu$  and thermal diffusivity  $\alpha$  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.

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 Pelat kolektor standar.

| Plat Kolektor Standar |                           |                            |                                   |                  |                                        |                                     |                                    |                            |                |
|-----------------------|---------------------------|----------------------------|-----------------------------------|------------------|----------------------------------------|-------------------------------------|------------------------------------|----------------------------|----------------|
| t                     | IN<br>(T <sub>fi</sub> )C | OUT<br>(T <sub>fo</sub> )C | Plat datar<br>(T <sub>P1</sub> )C | Plat<br>Absorber | Kaca Dalam<br>(T <sub>c-dalam</sub> )C | Kaca Lua<br>(T <sub>c-Luar</sub> )C | Tanki<br>(T <sub>T.Tangki</sub> )C | Ling<br>(T <sub>a</sub> )C | Ilum<br>(I) Kw |
| 0                     | 27,002                    | 27,002                     | 26,40                             | 27,20            | 26,70                                  | 26,70                               | 26,937                             | 27,132                     | 0,947          |
| 5                     | 27,269                    | 28,990                     | 38,320                            | 38,32            | 33,500                                 | 40,920                              | 26,920                             | 28,680                     | 0,965          |
| 10                    | 27,235                    | 29,191                     | 41,860                            | 41,86            | 40,460                                 | 50,820                              | 26,900                             | 29,020                     | 0,970          |
| 15                    | 27,201                    | 29,277                     | 42,500                            | 42,50            | 45,320                                 | 54,940                              | 26,900                             | 29,120                     | 0,997          |
| 20                    | 27,178                    | 29,337                     | 43,020                            | 43,02            | 48,780                                 | 57,660                              | 26,900                             | 29,240                     | 0,982          |
| 25                    | 27,153                    | 29,337                     | 43,360                            | 43,36            | 50,860                                 | 59,140                              | 26,860                             | 29,220                     | 0,986          |
| 30                    | 27,125                    | 29,271                     | 43,480                            | 43,48            | 52,260                                 | 60,580                              | 26,820                             | 29,180                     | 0,983          |
| 35                    | 27,125                    | 29,250                     | 43,640                            | 43,64            | 53,460                                 | 60,940                              | 26,740                             | 29,200                     | 0,982          |
| 40                    | 27,128                    | 29,244                     | 43,780                            | 43,78            | 54,320                                 | 61,780                              | 26,760                             | 29,240                     | 0,977          |
| 45                    | 27,033                    | 29,208                     | 43,800                            | 43,80            | 54,800                                 | 61,960                              | 26,700                             | 29,200                     | 0,978          |
| 50                    | 26,927                    | 29,156                     | 43,880                            | 43,88            | 55,220                                 | 62,300                              | 26,680                             | 29,200                     | 0,994          |
| 55                    | 26,970                    | 29,240                     | 43,940                            | 43,94            | 55,480                                 | 62,480                              | 26,740                             | 29,180                     | 1,053          |
| 60                    | 27,385                    | 29,697                     | 44,400                            | 44,40            | 55,680                                 | 63,140                              | 27,060                             | 29,560                     | 1,052          |
| 65                    | 27,325                    | 29,574                     | 44,500                            | 44,50            | 55,980                                 | 63,080                              | 27,020                             | 29,580                     | 1,051          |
| 70                    | 27,262                    | 29,576                     | 44,520                            | 44,52            | 56,100                                 | 63,260                              | 27,040                             | 29,580                     | 1,048          |
| 75                    | 27,216                    | 29,559                     | 44,600                            | 44,60            | 56,260                                 | 63,700                              | 26,900                             | 29,540                     | 1,048          |
| 80                    | 27,188                    | 29,491                     | 44,600                            | 44,60            | 56,360                                 | 63,280                              | 26,920                             | 29,500                     | 1,046          |
| 85                    | 27,362                    | 29,664                     | 44,700                            | 44,70            | 56,380                                 | 63,340                              | 27,140                             | 29,600                     | 1,046          |
| 90                    | 27,396                    | 29,709                     | 44,800                            | 44,80            | 56,540                                 | 63,120                              | 27,200                             | 29,720                     | 1,045          |
| 95                    | 27,371                    | 29,648                     | 44,800                            | 44,80            | 56,540                                 | 62,920                              | 27,180                             | 29,620                     | 1,047          |
| 100                   | 27,260                    | 29,537                     | 44,780                            | 44,78            | 56,320                                 | 62,280                              | 27,040                             | 29,520                     | 1,048          |
| 105                   | 27,177                    | 29,479                     | 44,800                            | 44,80            | 56,060                                 | 62,320                              | 26,920                             | 29,400                     | 1,048          |
| 110                   | 27,310                    | 29,598                     | 44,720                            | 44,72            | 55,680                                 | 61,940                              | 27,060                             | 29,480                     | 1,048          |
| 115                   | 27,492                    | 29,787                     | 44,800                            | 44,80            | 55,740                                 | 61,420                              | 27,260                             | 29,660                     | 1,046          |
| 120                   | 27,473                    | 29,757                     | 44,820                            | 44,82            | 55,720                                 | 61,500                              | 27,200                             | 29,640                     | 1,046          |
| 125                   | 27,423                    | 29,729                     | 44,800                            | 44,80            | 55,700                                 | 61,540                              | 27,180                             | 29,620                     | 1,046          |
| 130                   | 27,335                    | 29,633                     | 44,740                            | 44,74            | 55,600                                 | 61,220                              | 27,140                             | 29,540                     | 1,047          |
| 135                   | 27,244                    | 29,552                     | 44,600                            | 44,60            | 55,300                                 | 60,720                              | 26,960                             | 29,400                     | 1,046          |
| 140                   | 27,169                    | 29,486                     | 44,580                            | 44,58            | 55,180                                 | 61,180                              | 26,920                             | 29,340                     | 1,047          |
| 145                   | 27,548                    | 29,834                     | 44,700                            | 44,70            | 55,180                                 | 61,640                              | 27,360                             | 29,600                     | 1,046          |
| 150                   | 27,703                    | 30,003                     | 44,900                            | 44,90            | 55,360                                 | 61,140                              | 27,440                             | 29,840                     | 1,043          |
| 155                   | 27,593                    | 29,977                     | 43,760                            | 44,92            | 55,540                                 | 61,740                              | 27,380                             | 29,800                     | 1,043          |
| 160                   | 27,799                    | 30,111                     | 40,680                            | 45,04            | 55,660                                 | 61,860                              | 27,440                             | 29,980                     | 1,043          |
| 165                   | 27,998                    | 30,299                     | 41,460                            | 50,10            | 57,240                                 | 62,220                              | 27,480                             | 29,720                     | 1,042          |
| 170                   | 27,670                    | 29,854                     | 40,680                            | 44,84            | 56,900                                 | 63,200                              | 27,440                             | 29,740                     | 1,042          |
| 175                   | 27,618                    | 29,754                     | 38,620                            | 44,38            | 56,400                                 | 61,500                              | 27,400                             | 29,660                     | 1,042          |
| 180                   | 27,548                    | 29,573                     | 38,460                            | 44,46            | 56,280                                 | 61,720                              | 27,400                             | 29,680                     | 1,041          |
| 185                   | 27,445                    | 27,895                     | 38,600                            | 33,20            | 49,660                                 | 45,980                              | 27,260                             | 27,980                     | 0,833          |
| 190                   | 27,644                    | 27,889                     | 38,780                            | 30,00            | 43,240                                 | 38,480                              | 27,500                             | 27,900                     | 0,625          |
| 195                   | 27,726                    | 27,879                     | 29,380                            | 29,38            | 38,860                                 | 35,020                              | 27,580                             | 27,860                     | 0,417          |
| 200                   | 27,659                    | 27,760                     | 28,840                            | 28,84            | 35,780                                 | 32,760                              | 27,520                             | 27,760                     | 0,210          |
| 205                   | 27,604                    | 27,677                     | 28,440                            | 28,44            | 33,560                                 | 31,380                              | 27,500                             | 27,680                     | 0,002          |
| 210                   | 27,519                    | 27,563                     | 28,120                            | 28,12            | 32,020                                 | 30,420                              | 27,420                             | 27,560                     | 0,002          |
| 215                   | 27,449                    | 27,457                     | 27,880                            | 27,88            | 30,940                                 | 29,660                              | 27,300                             | 27,480                     | 0,002          |
| 220                   | 27,428                    | 27,419                     | 27,640                            | 27,64            | 30,000                                 | 29,240                              | 27,240                             | 27,420                     | 0,002          |
| 225                   | 27,584                    | 27,537                     | 27,620                            | 27,62            | 29,400                                 | 28,760                              | 27,380                             | 27,500                     | 0,002          |
| 230                   | 27,576                    | 27,516                     | 27,600                            | 27,60            | 29,000                                 | 28,600                              | 27,380                             | 27,500                     | 0,002          |
| 235                   | 27,460                    | 27,412                     | 27,440                            | 27,44            | 28,660                                 | 28,260                              | 27,280                             | 27,420                     | 0,002          |
| 240                   | 27,629                    | 27,582                     | 27,300                            | 27,30            | 28,300                                 | 28,020                              | 27,220                             | 27,380                     | 0,002          |

Lampiran 6. Tabel pengambilan data Pelat Standar dengan penambahan lilin (PCM)

| t   | IN<br>(T <sub>fi</sub> )C | OUT<br>(T <sub>fo</sub> )C | Plat datar<br>(T <sub>PI</sub> )C | Plat<br>Absorber | Material<br>PCM | Kaca Dalam<br>(T <sub>c-dalam</sub> )C | Kaca Luar<br>(T <sub>c-luar</sub> )C | Tanki<br>(T <sub>Tangki</sub> )C | Ling<br>(T <sub>a</sub> )C | Illum<br>(I) Kw |
|-----|---------------------------|----------------------------|-----------------------------------|------------------|-----------------|----------------------------------------|--------------------------------------|----------------------------------|----------------------------|-----------------|
| 0   | 26,97                     | 26,97                      | 26,27                             | 26,40            | 26,40           | 26,80                                  | 26,57                                | 27,12                            | 26,95                      | 0,988           |
| 5   | 27,449                    | 28,852                     | 29,700                            | 38,280           | 30,900          | 47,000                                 | 27,260                               | 28,560                           | 0,965                      | 0,965           |
| 10  | 27,442                    | 29,064                     | 30,900                            | 40,680           | 35,820          | 54,220                                 | 27,180                               | 28,840                           | 0,970                      | 0,970           |
| 15  | 27,421                    | 29,203                     | 32,180                            | 41,660           | 44,080          | 57,620                                 | 27,160                               | 29,000                           | 0,997                      | 0,997           |
| 20  | 27,402                    | 29,261                     | 33,300                            | 42,400           | 48,380          | 60,260                                 | 27,100                               | 29,200                           | 0,982                      | 0,982           |
| 25  | 27,391                    | 29,262                     | 34,180                            | 42,940           | 50,060          | 61,820                                 | 27,080                               | 29,200                           | 0,986                      | 0,986           |
| 30  | 27,391                    | 29,352                     | 34,860                            | 43,280           | 51,100          | 62,840                                 | 27,020                               | 29,280                           | 0,983                      | 0,983           |
| 35  | 27,391                    | 29,348                     | 35,460                            | 43,480           | 51,580          | 63,760                                 | 27,060                               | 29,240                           | 0,982                      | 0,982           |
| 40  | 27,391                    | 29,333                     | 35,820                            | 43,380           | 51,900          | 63,580                                 | 26,960                               | 29,160                           | 0,977                      | 0,977           |
| 45  | 27,283                    | 29,320                     | 36,140                            | 43,000           | 52,040          | 63,700                                 | 26,960                               | 29,200                           | 0,978                      | 0,978           |
| 50  | 27,297                    | 29,480                     | 36,420                            | 43,100           | 51,960          | 64,060                                 | 26,960                               | 29,200                           | 0,994                      | 0,994           |
| 55  | 27,460                    | 29,710                     | 36,720                            | 43,960           | 52,140          | 65,580                                 | 27,200                               | 29,460                           | 1,053                      | 1,053           |
| 60  | 27,448                    | 29,729                     | 36,860                            | 44,980           | 52,160          | 66,580                                 | 27,160                               | 29,500                           | 1,052                      | 1,052           |
| 65  | 27,469                    | 29,744                     | 37,100                            | 45,020           | 52,000          | 66,640                                 | 27,240                               | 29,540                           | 1,051                      | 1,051           |
| 70  | 27,563                    | 29,839                     | 37,320                            | 44,940           | 51,800          | 66,180                                 | 27,380                               | 29,700                           | 1,048                      | 1,048           |
| 75  | 27,551                    | 29,845                     | 37,520                            | 44,900           | 51,840          | 66,400                                 | 27,320                               | 29,760                           | 1,048                      | 1,048           |
| 80  | 27,496                    | 29,809                     | 37,680                            | 44,980           | 52,060          | 66,940                                 | 27,300                               | 29,720                           | 1,046                      | 1,046           |
| 85  | 27,452                    | 29,796                     | 37,820                            | 45,040           | 52,100          | 67,420                                 | 27,260                               | 29,700                           | 1,046                      | 1,046           |
| 90  | 27,628                    | 29,944                     | 37,980                            | 45,100           | 52,280          | 67,640                                 | 27,460                               | 29,860                           | 1,045                      | 1,045           |
| 95  | 27,756                    | 30,080                     | 38,060                            | 45,100           | 52,520          | 67,960                                 | 27,520                               | 30,040                           | 1,047                      | 1,047           |
| 100 | 27,732                    | 30,075                     | 38,200                            | 45,200           | 52,640          | 67,500                                 | 27,480                               | 29,980                           | 1,048                      | 1,048           |
| 105 | 27,785                    | 30,123                     | 38,340                            | 45,200           | 52,700          | 67,180                                 | 27,620                               | 30,060                           | 1,048                      | 1,048           |
| 110 | 27,910                    | 30,261                     | 38,520                            | 45,240           | 52,640          | 67,060                                 | 27,740                               | 30,200                           | 1,048                      | 1,048           |
| 115 | 27,882                    | 30,256                     | 38,600                            | 45,280           | 52,780          | 66,940                                 | 27,740                               | 30,160                           | 1,046                      | 1,046           |
| 120 | 27,807                    | 30,208                     | 38,660                            | 45,360           | 52,580          | 67,000                                 | 27,680                               | 30,120                           | 1,046                      | 1,046           |
| 125 | 27,780                    | 30,164                     | 38,800                            | 45,320           | 52,580          | 67,640                                 | 27,620                               | 30,140                           | 1,046                      | 1,046           |
| 130 | 27,743                    | 30,126                     | 38,800                            | 45,440           | 52,560          | 66,300                                 | 27,520                               | 30,100                           | 1,047                      | 1,047           |
| 135 | 27,729                    | 30,120                     | 38,900                            | 45,520           | 52,420          | 66,300                                 | 27,540                               | 30,100                           | 1,046                      | 1,046           |
| 140 | 27,701                    | 30,097                     | 39,000                            | 45,560           | 52,500          | 67,160                                 | 27,500                               | 30,080                           | 1,047                      | 1,047           |
| 145 | 27,646                    | 30,071                     | 39,020                            | 45,600           | 52,540          | 66,900                                 | 27,460                               | 30,040                           | 1,046                      | 1,046           |
| 150 | 27,575                    | 30,026                     | 39,020                            | 45,620           | 52,500          | 66,400                                 | 27,440                               | 30,000                           | 1,043                      | 1,043           |
| 155 | 27,545                    | 29,999                     | 39,080                            | 45,720           | 52,540          | 66,960                                 | 27,440                               | 30,020                           | 1,043                      | 1,043           |
| 160 | 27,491                    | 29,935                     | 39,100                            | 45,760           | 52,480          | 65,760                                 | 27,360                               | 29,960                           | 1,043                      | 1,043           |
| 165 | 27,449                    | 29,917                     | 39,100                            | 45,760           | 52,560          | 65,400                                 | 27,320                               | 29,980                           | 1,042                      | 1,042           |
| 170 | 27,416                    | 29,901                     | 39,100                            | 45,760           | 52,520          | 65,440                                 | 27,240                               | 29,920                           | 1,042                      | 1,042           |
| 175 | 27,389                    | 29,850                     | 39,080                            | 45,800           | 52,460          | 65,240                                 | 27,200                               | 29,820                           | 1,042                      | 1,042           |
| 180 | 27,366                    | 29,694                     | 39,080                            | 45,800           | 52,400          | 65,060                                 | 27,140                               | 29,800                           | 1,041                      | 0,833           |
| 185 | 27,284                    | 28,214                     | 38,380                            | 35,480           | 44,340          | 44,220                                 | 27,120                               | 28,420                           | 0,002                      | 0,625           |
| 190 | 27,229                    | 27,895                     | 37,340                            | 31,480           | 38,820          | 39,080                                 | 27,000                               | 27,960                           | 0,002                      | 0,520           |
| 195 | 27,410                    | 27,884                     | 36,260                            | 30,640           | 35,500          | 35,960                                 | 27,280                               | 27,880                           | 0,002                      | 0,260           |
| 200 | 27,511                    | 27,886                     | 35,140                            | 29,960           | 33,440          | 34,080                                 | 27,380                               | 27,860                           | 0,002                      | 0,000           |
| 205 | 27,447                    | 27,759                     | 34,100                            | 29,420           | 31,940          | 32,660                                 | 27,340                               | 27,760                           | 0,002                      | 0,000           |
| 210 | 27,549                    | 27,763                     | 33,080                            | 29,040           | 30,900          | 31,480                                 | 27,380                               | 27,700                           | 0,002                      | 0,000           |
| 215 | 27,642                    | 27,787                     | 32,220                            | 28,760           | 30,140          | 30,600                                 | 27,480                               | 27,700                           | 0,003                      | 0,000           |
| 220 | 27,594                    | 27,721                     | 31,520                            | 28,460           | 29,600          | 30,000                                 | 27,460                               | 27,660                           | 0,003                      | 0,000           |
| 225 | 27,533                    | 27,624                     | 30,840                            | 28,200           | 29,180          | 29,440                                 | 27,380                               | 27,540                           | 0,002                      | 0,365           |
| 230 | 27,481                    | 27,542                     | 30,280                            | 27,980           | 28,800          | 29,000                                 | 27,220                               | 27,420                           | 0,002                      | 0,729           |
| 235 | 27,421                    | 27,462                     | 29,840                            | 27,840           | 28,520          | 28,700                                 | 27,200                               | 27,380                           | 0,002                      | 0,728           |
| 240 | 27,595                    | 27,617                     | 29,480                            | 27,700           | 28,300          | 28,400                                 | 27,120                               | 27,280                           | 0,002                      | 0,728           |



Lampiran 7. Tabel Pengambilan Data Gabungan Serbuk Tembaga Dan Lilin (Cu Powder+PCM)

| Plat Kolektor PCM + Cu Powder |              |               |                      |                  |                 |                           |                         |                      |               |                |
|-------------------------------|--------------|---------------|----------------------|------------------|-----------------|---------------------------|-------------------------|----------------------|---------------|----------------|
| t                             | IN<br>(Tfi)C | OUT<br>(Tfo)C | Plat datar<br>(TP1)C | Plat<br>Absorber | Material<br>PCM | Kaca Dalam<br>(Tc-dalam)C | Kaca Luar<br>(Tc-Luar)C | Tanki<br>(T.Tangki)C | Ling<br>(Ta)C | Ilum<br>(I) Kw |
| 0                             | 26,9694      | 26,9694       | 26,57                | 26,47            | 26,47           | 27,27                     | 27,13                   | 27,0020              | 26,87         | 0,98730        |
| 5                             | 27,159       | 28,408        | 27,460               | 42,180           | 34,060          | 44,080                    | 27,400                  | 28,200               | 1,004         | 1,004          |
| 10                            | 27,348       | 29,176        | 28,560               | 45,310           | 35,020          | 50,140                    | 27,620                  | 28,980               | 1,011         | 1,011          |
| 15                            | 27,500       | 29,564        | 29,940               | 46,370           | 38,000          | 51,040                    | 27,860                  | 29,360               | 1,015         | 1,015          |
| 20                            | 27,704       | 29,747        | 31,140               | 47,220           | 39,780          | 44,080                    | 27,980                  | 29,760               | 1,013         | 1,013          |
| 25                            | 27,837       | 29,750        | 32,200               | 47,820           | 41,060          | 43,660                    | 27,980                  | 30,040               | 1,010         | 1,010          |
| 30                            | 27,909       | 30,102        | 32,960               | 48,280           | 41,980          | 43,740                    | 27,900                  | 30,220               | 1,008         | 1,008          |
| 35                            | 27,910       | 30,385        | 33,600               | 48,540           | 42,580          | 45,180                    | 27,740                  | 30,300               | 1,013         | 1,013          |
| 40                            | 27,911       | 30,330        | 34,040               | 48,370           | 43,260          | 44,700                    | 27,620                  | 30,300               | 1,010         | 1,010          |
| 45                            | 27,860       | 30,307        | 34,420               | 47,980           | 43,840          | 44,320                    | 27,520                  | 30,260               | 0,999         | 0,999          |
| 50                            | 27,747       | 30,289        | 34,720               | 48,110           | 44,200          | 44,260                    | 27,440                  | 30,200               | 0,998         | 0,998          |
| 55                            | 27,714       | 30,286        | 34,980               | 47,580           | 48,020          | 44,020                    | 27,440                  | 30,200               | 0,655         | 0,931          |
| 60                            | 27,694       | 30,275        | 35,260               | 45,300           | 52,960          | 61,740                    | 27,440                  | 30,240               | 1,002         | 1,002          |
| 65                            | 27,647       | 30,239        | 35,460               | 45,070           | 53,540          | 61,380                    | 27,400                  | 30,220               | 1,011         | 1,011          |
| 70                            | 27,611       | 30,224        | 35,600               | 45,070           | 53,840          | 61,380                    | 27,420                  | 30,260               | 1,010         | 1,010          |
| 75                            | 27,574       | 30,209        | 35,720               | 45,060           | 54,040          | 61,400                    | 27,400                  | 30,240               | 1,012         | 1,012          |
| 80                            | 27,538       | 30,210        | 35,840               | 45,160           | 54,200          | 61,780                    | 27,300                  | 30,220               | 1,012         | 1,012          |
| 85                            | 27,509       | 30,193        | 35,900               | 45,230           | 54,340          | 61,220                    | 27,240                  | 30,260               | 1,012         | 1,012          |
| 90                            | 27,444       | 30,146        | 36,000               | 45,270           | 54,520          | 61,500                    | 27,220                  | 30,200               | 1,010         | 1,010          |
| 95                            | 27,469       | 30,159        | 36,020               | 45,310           | 54,600          | 62,180                    | 27,260                  | 30,160               | 1,009         | 1,009          |
| 100                           | 27,477       | 30,189        | 36,160               | 45,440           | 54,580          | 61,440                    | 27,220                  | 30,220               | 1,011         | 1,011          |
| 105                           | 27,450       | 30,178        | 36,200               | 45,500           | 54,720          | 62,180                    | 27,200                  | 30,220               | 1,016         | 1,016          |
| 110                           | 27,438       | 30,180        | 36,300               | 45,620           | 54,800          | 62,400                    | 27,200                  | 30,260               | 1,017         | 1,017          |
| 115                           | 27,400       | 30,146        | 36,320               | 45,720           | 54,820          | 62,820                    | 27,200                  | 30,200               | 1,018         | 1,018          |
| 120                           | 27,392       | 30,166        | 36,320               | 45,860           | 54,840          | 63,180                    | 27,180                  | 30,220               | 1,019         | 1,019          |
| 125                           | 27,403       | 30,174        | 36,420               | 45,910           | 54,960          | 63,060                    | 27,200                  | 30,300               | 1,019         | 1,019          |
| 130                           | 27,617       | 30,383        | 36,480               | 46,070           | 54,940          | 63,020                    | 27,380                  | 30,440               | 1,016         | 1,016          |
| 135                           | 27,688       | 30,462        | 36,620               | 46,200           | 55,260          | 63,540                    | 27,420                  | 30,560               | 1,019         | 1,019          |
| 140                           | 27,663       | 30,457        | 36,660               | 46,250           | 55,240          | 63,980                    | 27,380                  | 30,500               | 1,020         | 1,020          |
| 145                           | 27,633       | 30,459        | 36,720               | 46,320           | 55,400          | 63,760                    | 27,380                  | 30,500               | 1,020         | 1,020          |
| 150                           | 27,598       | 30,434        | 36,720               | 46,330           | 55,440          | 63,960                    | 27,280                  | 30,480               | 1,020         | 1,020          |
| 155                           | 27,714       | 30,512        | 36,820               | 46,470           | 55,600          | 63,980                    | 27,500                  | 30,560               | 1,022         | 1,022          |
| 160                           | 27,915       | 30,690        | 36,860               | 46,610           | 55,460          | 63,940                    | 27,660                  | 30,720               | 1,022         | 1,022          |
| 165                           | 27,924       | 30,714        | 36,980               | 46,670           | 55,440          | 64,140                    | 27,680                  | 30,740               | 1,024         | 1,024          |
| 170                           | 27,882       | 30,678        | 37,000               | 46,680           | 55,560          | 64,000                    | 27,660                  | 30,740               | 1,022         | 1,022          |
| 175                           | 27,822       | 30,638        | 37,000               | 46,720           | 55,620          | 64,620                    | 27,600                  | 30,640               | 1,023         | 1,023          |
| 180                           | 27,787       | 30,629        | 37,060               | 46,760           | 55,640          | 64,460                    | 27,500                  | 30,600               | 1,008         | 0,821          |
| 185                           | 27,774       | 29,402        | 36,920               | 35,850           | 51,100          | 47,860                    | 27,560                  | 29,420               | 0,004         | 0,616          |
| 190                           | 27,874       | 28,684        | 36,180               | 31,640           | 45,180          | 38,940                    | 27,700                  | 28,700               | 0,004         | 0,513          |
| 195                           | 27,901       | 28,490        | 35,260               | 30,740           | 40,980          | 35,600                    | 27,760                  | 28,600               | 0,004         | 0,257          |
| 200                           | 27,827       | 28,284        | 34,220               | 30,060           | 37,840          | 33,740                    | 27,680                  | 28,320               | 0,004         | 0,000          |
| 205                           | 27,787       | 28,157        | 33,240               | 29,520           | 35,460          | 32,280                    | 27,620                  | 28,160               | 0,004         | 0,000          |
| 210                           | 27,762       | 28,037        | 32,320               | 29,140           | 33,760          | 31,360                    | 27,540                  | 28,020               | 0,004         | 0,000          |
| 215                           | 27,712       | 27,915        | 31,680               | 28,870           | 32,560          | 30,760                    | 27,540                  | 28,020               | 0,004         | 0,000          |
| 220                           | 27,656       | 27,811        | 31,060               | 28,580           | 31,520          | 29,940                    | 27,480                  | 27,900               | 0,004         | 0,000          |
| 225                           | 27,602       | 27,744        | 30,460               | 28,300           | 30,680          | 29,420                    | 27,400                  | 27,740               | 0,004         | 0,365          |
| 230                           | 27,536       | 27,636        | 30,060               | 28,110           | 30,100          | 29,060                    | 27,360                  | 27,640               | 0,004         | 0,729          |
| 235                           | 27,487       | 27,569        | 29,640               | 27,940           | 29,580          | 28,800                    | 27,260                  | 27,520               | 0,004         | 0,728          |
| 240                           | 27,438       | 27,502        | 29,320               | 27,810           | 29,180          | 28,560                    | 27,160                  | 27,420               | 0,004         | 0,728          |

Lampiran 8. Tabel hasil perhitungan Pelat kolektor standar

| Plat Kolektor Standar |                             |                             |                                         |                                            |                          |                          |              |          |
|-----------------------|-----------------------------|-----------------------------|-----------------------------------------|--------------------------------------------|--------------------------|--------------------------|--------------|----------|
| t                     | Ut<br>(W/m <sup>2</sup> .K) | Ub<br>(W/m <sup>2</sup> .K) | U <sub>L</sub><br>(W/m <sup>2</sup> .K) | Q <sub>loss</sub><br>(W/m <sup>2</sup> .K) | S<br>(W/m <sup>2</sup> ) | V<br>(m <sup>3</sup> /s) | Qu<br>(Watt) | η<br>(%) |
| 0                     | 4,126                       | 1,95                        | 6,076                                   | -0,791                                     | 799,67                   | 2,79E-06                 | 0,00         | 0,00     |
| 5                     | 4,669                       | 1,95                        | 6,619                                   | 9,374                                      | 849,110                  | 8,33E-06                 | 59,74        | 53,48425 |
| 10                    | 4,720                       | 1,95                        | 6,670                                   | 11,906                                     | 855,035                  | 8,33E-06                 | 67,86        | 60,35763 |
| 15                    | 4,881                       | 1,95                        | 6,831                                   | 13,115                                     | 857,328                  | 8,33E-06                 | 72,03        | 63,88967 |
| 20                    | 5,035                       | 1,95                        | 6,985                                   | 14,404                                     | 855,745                  | 8,33E-06                 | 74,88        | 66,54383 |
| 25                    | 5,109                       | 1,95                        | 7,059                                   | 14,591                                     | 859,768                  | 8,33E-06                 | 75,74        | 66,99352 |
| 30                    | 5,156                       | 1,95                        | 7,106                                   | 14,606                                     | 861,644                  | 8,33E-06                 | 74,42        | 65,68596 |
| 35                    | 5,193                       | 1,95                        | 7,143                                   | 14,822                                     | 861,297                  | 8,33E-06                 | 73,70        | 65,06977 |
| 40                    | 5,221                       | 1,95                        | 7,171                                   | 15,148                                     | 860,270                  | 8,33E-06                 | 73,36        | 64,84811 |
| 45                    | 5,235                       | 1,95                        | 7,185                                   | 15,568                                     | 859,050                  | 8,33E-06                 | 75,39        | 66,73783 |
| 50                    | 5,247                       | 1,95                        | 7,197                                   | 16,360                                     | 857,907                  | 8,33E-06                 | 77,25        | 68,47299 |
| 55                    | 5,255                       | 1,95                        | 7,205                                   | 15,922                                     | 864,517                  | 8,33E-06                 | 78,66        | 69,19393 |
| 60                    | 5,269                       | 1,95                        | 7,219                                   | 15,698                                     | 867,607                  | 8,33E-06                 | 80,09        | 70,20175 |
| 65                    | 5,277                       | 1,95                        | 7,227                                   | 16,296                                     | 865,219                  | 8,33E-06                 | 77,89        | 68,46335 |
| 70                    | 5,281                       | 1,95                        | 7,231                                   | 16,761                                     | 863,660                  | 8,33E-06                 | 80,16        | 70,57846 |
| 75                    | 5,286                       | 1,95                        | 7,236                                   | 16,819                                     | 866,802                  | 8,33E-06                 | 81,17        | 71,21171 |
| 80                    | 5,287                       | 1,95                        | 7,237                                   | 16,729                                     | 865,706                  | 8,33E-06                 | 79,76        | 70,06086 |
| 85                    | 5,289                       | 1,95                        | 7,239                                   | 16,198                                     | 864,748                  | 8,33E-06                 | 79,69        | 70,07646 |
| 90                    | 5,295                       | 1,95                        | 7,245                                   | 16,837                                     | 864,030                  | 8,33E-06                 | 80,11        | 70,50498 |
| 95                    | 5,293                       | 1,95                        | 7,243                                   | 16,288                                     | 863,351                  | 8,33E-06                 | 78,84        | 69,44156 |
| 100                   | 5,283                       | 1,95                        | 7,233                                   | 16,346                                     | 862,640                  | 8,33E-06                 | 78,83        | 69,49708 |
| 105                   | 5,274                       | 1,95                        | 7,224                                   | 16,056                                     | 862,664                  | 8,33E-06                 | 79,67        | 70,22873 |
| 110                   | 5,264                       | 1,95                        | 7,214                                   | 15,652                                     | 862,471                  | 8,33E-06                 | 79,18        | 69,81192 |
| 115                   | 5,266                       | 1,95                        | 7,216                                   | 15,645                                     | 861,320                  | 8,33E-06                 | 79,42        | 70,12308 |
| 120                   | 5,266                       | 1,95                        | 7,216                                   | 15,636                                     | 861,799                  | 8,33E-06                 | 79,04        | 69,74587 |
| 125                   | 5,265                       | 1,95                        | 7,215                                   | 15,854                                     | 859,444                  | 8,33E-06                 | 79,81        | 70,62086 |
| 130                   | 5,260                       | 1,95                        | 7,210                                   | 15,899                                     | 860,208                  | 8,33E-06                 | 79,54        | 70,31835 |
| 135                   | 5,248                       | 1,95                        | 7,198                                   | 15,519                                     | 859,065                  | 8,33E-06                 | 79,86        | 70,69251 |
| 140                   | 5,245                       | 1,95                        | 7,195                                   | 15,620                                     | 861,428                  | 8,33E-06                 | 80,18        | 70,78256 |
| 145                   | 5,250                       | 1,95                        | 7,200                                   | 14,779                                     | 862,231                  | 8,33E-06                 | 79,09        | 69,75867 |
| 150                   | 5,258                       | 1,95                        | 7,208                                   | 15,402                                     | 861,552                  | 8,33E-06                 | 79,57        | 70,2369  |
| 155                   | 5,264                       | 1,95                        | 7,214                                   | 15,922                                     | 863,165                  | 8,33E-06                 | 82,47        | 72,65583 |
| 160                   | 5,271                       | 1,95                        | 7,221                                   | 15,745                                     | 862,887                  | 8,33E-06                 | 79,97        | 70,4934  |
| 165                   | 5,304                       | 1,95                        | 7,254                                   | 12,377                                     | 862,185                  | 8,33E-06                 | 79,58        | 70,18026 |
| 170                   | 5,305                       | 1,95                        | 7,255                                   | 15,015                                     | 864,687                  | 8,33E-06                 | 75,54        | 66,43867 |
| 175                   | 5,284                       | 1,95                        | 7,234                                   | 14,770                                     | 868,779                  | 8,33E-06                 | 73,85        | 64,6469  |
| 180                   | 5,282                       | 1,95                        | 7,232                                   | 15,421                                     | 696,066                  | 8,33E-06                 | 70,03        | 66,52    |

Lampiran 9. Tabel pengambilan data Pelat Standar dengan penambahan lilin (PCM)

| Plat Kolektor PCM |                           |                           |                                       |                                          |                          |                          |              |          |
|-------------------|---------------------------|---------------------------|---------------------------------------|------------------------------------------|--------------------------|--------------------------|--------------|----------|
| t                 | Ut<br>W/m <sup>2</sup> .K | Ub<br>W/m <sup>2</sup> .K | U <sub>L</sub><br>W/m <sup>2</sup> .K | Q <sub>loss</sub><br>W/m <sup>2</sup> .K | S<br>(W/m <sup>2</sup> ) | V<br>(m <sup>3</sup> /s) | Qu<br>(Watt) | η<br>(%) |
| 0                 | 4,27                      | 1,95                      | 6,22                                  | 1,22                                     | 730,68                   | 0,00                     | 0,02         | 25,09    |
| 5                 | 4,369                     | 1,95                      | 6,319                                 | 7,041                                    | 823,152                  | 8,33E-06                 | 55,17        | 50,96    |
| 10                | 4,649                     | 1,95                      | 6,599                                 | 9,229                                    | 827,662                  | 8,33E-06                 | 63,80        | 58,61664 |
| 15                | 4,920                     | 1,95                      | 6,870                                 | 10,854                                   | 851,012                  | 8,33E-06                 | 70,07        | 62,64074 |
| 20                | 5,048                     | 1,95                      | 6,998                                 | 12,585                                   | 838,225                  | 8,33E-06                 | 73,10        | 66,3166  |
| 25                | 5,096                     | 1,95                      | 7,046                                 | 12,747                                   | 841,360                  | 8,33E-06                 | 73,53        | 66,46463 |
| 30                | 5,128                     | 1,95                      | 7,078                                 | 13,371                                   | 839,121                  | 8,33E-06                 | 77,07        | 69,84852 |
| 35                | 5,144                     | 1,95                      | 7,094                                 | 13,117                                   | 837,538                  | 8,33E-06                 | 76,91        | 69,83726 |
| 40                | 5,151                     | 1,95                      | 7,101                                 | 12,562                                   | 833,615                  | 8,33E-06                 | 76,29        | 69,59589 |
| 45                | 5,156                     | 1,95                      | 7,106                                 | 13,620                                   | 834,395                  | 8,33E-06                 | 80,01        | 72,91823 |
| 50                | 5,156                     | 1,95                      | 7,106                                 | 13,523                                   | 847,792                  | 8,33E-06                 | 85,73        | 76,94362 |
| 55                | 5,170                     | 1,95                      | 7,120                                 | 14,243                                   | 898,198                  | 8,33E-06                 | 88,36        | 74,80988 |
| 60                | 5,175                     | 1,95                      | 7,125                                 | 14,622                                   | 897,376                  | 8,33E-06                 | 89,59        | 75,91938 |
| 65                | 5,172                     | 1,95                      | 7,122                                 | 14,747                                   | 896,545                  | 8,33E-06                 | 89,31        | 75,75429 |
| 70                | 5,168                     | 1,95                      | 7,118                                 | 15,211                                   | 894,414                  | 8,33E-06                 | 89,34        | 75,95961 |
| 75                | 5,171                     | 1,95                      | 7,121                                 | 15,730                                   | 894,067                  | 8,33E-06                 | 90,02        | 76,5675  |
| 80                | 5,179                     | 1,95                      | 7,129                                 | 15,854                                   | 892,793                  | 8,33E-06                 | 90,79        | 77,33792 |
| 85                | 5,181                     | 1,95                      | 7,131                                 | 16,031                                   | 892,631                  | 8,33E-06                 | 92,01        | 78,38387 |
| 90                | 5,189                     | 1,95                      | 7,139                                 | 15,932                                   | 892,005                  | 8,33E-06                 | 90,89        | 77,48371 |
| 95                | 5,199                     | 1,95                      | 7,149                                 | 16,331                                   | 893,171                  | 8,33E-06                 | 91,18        | 77,63627 |
| 100               | 5,200                     | 1,95                      | 7,150                                 | 16,071                                   | 893,866                  | 8,33E-06                 | 91,92        | 78,19897 |
| 105               | 5,202                     | 1,95                      | 7,152                                 | 16,275                                   | 894,005                  | 8,33E-06                 | 91,75        | 78,04367 |
| 110               | 5,203                     | 1,95                      | 7,153                                 | 16,382                                   | 894,005                  | 8,33E-06                 | 92,24        | 78,46664 |
| 115               | 5,206                     | 1,95                      | 7,156                                 | 16,301                                   | 892,569                  | 8,33E-06                 | 93,12        | 79,33745 |
| 120               | 5,200                     | 1,95                      | 7,150                                 | 16,541                                   | 892,129                  | 8,33E-06                 | 94,17        | 80,26854 |
| 125               | 5,203                     | 1,95                      | 7,153                                 | 16,883                                   | 892,731                  | 8,33E-06                 | 93,51        | 79,65508 |
| 130               | 5,197                     | 1,95                      | 7,147                                 | 16,844                                   | 893,140                  | 8,33E-06                 | 93,45        | 79,5693  |
| 135               | 5,194                     | 1,95                      | 7,144                                 | 16,939                                   | 892,522                  | 8,33E-06                 | 93,75        | 79,88171 |
| 140               | 5,199                     | 1,95                      | 7,149                                 | 17,009                                   | 893,565                  | 8,33E-06                 | 93,98        | 79,98433 |
| 145               | 5,198                     | 1,95                      | 7,148                                 | 17,113                                   | 892,461                  | 8,33E-06                 | 95,07        | 81,00827 |
| 150               | 5,195                     | 1,95                      | 7,145                                 | 17,325                                   | 890,214                  | 8,33E-06                 | 96,07        | 82,06949 |
| 155               | 5,198                     | 1,95                      | 7,148                                 | 17,689                                   | 889,859                  | 8,33E-06                 | 96,19        | 82,20554 |
| 160               | 5,192                     | 1,95                      | 7,142                                 | 17,631                                   | 889,511                  | 8,33E-06                 | 95,81        | 81,91086 |
| 165               | 5,193                     | 1,95                      | 7,143                                 | 18,080                                   | 889,364                  | 8,33E-06                 | 96,73        | 82,7123  |
| 170               | 5,191                     | 1,95                      | 7,141                                 | 17,884                                   | 889,372                  | 8,33E-06                 | 97,42        | 83,30196 |
| 175               | 5,187                     | 1,95                      | 7,137                                 | 17,353                                   | 888,855                  | 8,33E-06                 | 96,47        | 82,53264 |
| 180               | 5,185                     | 1,95                      | 7,135                                 | 17,367                                   | 710,767                  | 8,33E-06                 | 91,23        | 80,57    |

Lampiran 10. Tabel Pengambilan Data Gabungan Serbuk Tembaga Dan Lilin (Cu Powder+PCM)

| Plat Kolektor PCM + Cu Powder |                           |                           |                                       |                                          |                          |                          |              |          |
|-------------------------------|---------------------------|---------------------------|---------------------------------------|------------------------------------------|--------------------------|--------------------------|--------------|----------|
| t                             | Ut<br>W/m <sup>2</sup> .K | Ub<br>W/m <sup>2</sup> .K | U <sub>I</sub><br>W/m <sup>2</sup> .K | Q <sub>loss</sub><br>W/m <sup>2</sup> .K | S<br>(W/m <sup>2</sup> ) | V<br>(m <sup>3</sup> /s) | Qu<br>(Watt) | η<br>(%) |
| 0                             | 4,144                     | 1,95                      | 6,094312                              | 1,474                                    | 508,3031                 | 0,00001                  | 0,00         | 0,00     |
| 5                             | 4,584                     | 1,95                      | 6,534                                 | 6,807                                    | 857,081                  | 8,33E-06                 | 46,22        | 40,95    |
| 10                            | 4,637                     | 1,95                      | 6,587                                 | 10,750                                   | 862,772                  | 8,33E-06                 | 67,63        | 59,61329 |
| 15                            | 4,736                     | 1,95                      | 6,686                                 | 12,435                                   | 866,223                  | 8,33E-06                 | 76,37        | 67,04296 |
| 20                            | 4,773                     | 1,95                      | 6,723                                 | 13,826                                   | 864,200                  | 8,33E-06                 | 75,61        | 66,52814 |
| 25                            | 4,811                     | 1,95                      | 6,761                                 | 14,896                                   | 862,169                  | 8,33E-06                 | 82,33        | 73,32642 |
| 30                            | 4,839                     | 1,95                      | 6,789                                 | 15,691                                   | 859,753                  | 8,33E-06                 | 81,10        | 71,74792 |
| 35                            | 4,861                     | 1,95                      | 6,811                                 | 16,279                                   | 864,331                  | 8,33E-06                 | 89,25        | 80,53424 |
| 40                            | 4,879                     | 1,95                      | 6,829                                 | 16,311                                   | 861,729                  | 8,33E-06                 | 89,44        | 78,93499 |
| 45                            | 4,893                     | 1,95                      | 6,843                                 | 16,427                                   | 852,440                  | 8,33E-06                 | 90,49        | 80,73033 |
| 50                            | 4,902                     | 1,95                      | 6,852                                 | 16,809                                   | 851,807                  | 8,33E-06                 | 93,98        | 83,9057  |
| 55                            | 5,001                     | 1,95                      | 6,951                                 | 17,279                                   | 794,421                  | 8,33E-06                 | 94,95        | 89,14981 |
| 60                            | 5,186                     | 1,95                      | 7,136                                 | 18,166                                   | 855,102                  | 8,33E-06                 | 95,38        | 84,82167 |
| 65                            | 5,199                     | 1,95                      | 7,149                                 | 18,394                                   | 862,895                  | 8,33E-06                 | 95,77        | 84,40423 |
| 70                            | 5,207                     | 1,95                      | 7,157                                 | 18,956                                   | 862,138                  | 8,33E-06                 | 96,51        | 85,13205 |
| 75                            | 5,212                     | 1,95                      | 7,162                                 | 19,092                                   | 863,289                  | 8,33E-06                 | 97,35        | 85,75599 |
| 80                            | 5,217                     | 1,95                      | 7,167                                 | 19,220                                   | 863,111                  | 8,33E-06                 | 98,71        | 86,96735 |
| 85                            | 5,219                     | 1,95                      | 7,169                                 | 19,724                                   | 863,706                  | 8,33E-06                 | 99,15        | 87,30118 |
| 90                            | 5,224                     | 1,95                      | 7,174                                 | 19,771                                   | 861,752                  | 8,33E-06                 | 99,79        | 88,05811 |
| 95                            | 5,228                     | 1,95                      | 7,178                                 | 19,312                                   | 861,196                  | 8,33E-06                 | 99,32        | 87,70339 |
| 100                           | 5,226                     | 1,95                      | 7,176                                 | 19,683                                   | 863,034                  | 8,33E-06                 | 100,15       | 88,24546 |
| 105                           | 5,232                     | 1,95                      | 7,182                                 | 19,895                                   | 866,864                  | 8,33E-06                 | 100,74       | 88,3791  |
| 110                           | 5,236                     | 1,95                      | 7,186                                 | 20,277                                   | 867,466                  | 8,33E-06                 | 101,23       | 88,74799 |
| 115                           | 5,237                     | 1,95                      | 7,187                                 | 20,124                                   | 868,455                  | 8,33E-06                 | 101,38       | 88,77159 |
| 120                           | 5,239                     | 1,95                      | 7,189                                 | 20,330                                   | 869,180                  | 8,33E-06                 | 102,40       | 89,59502 |
| 125                           | 5,243                     | 1,95                      | 7,193                                 | 20,834                                   | 869,134                  | 8,33E-06                 | 102,28       | 89,49569 |
| 130                           | 5,245                     | 1,95                      | 7,195                                 | 20,311                                   | 866,764                  | 8,33E-06                 | 102,10       | 89,58011 |
| 135                           | 5,256                     | 1,95                      | 7,206                                 | 20,699                                   | 869,512                  | 8,33E-06                 | 102,38       | 89,5447  |
| 140                           | 5,256                     | 1,95                      | 7,206                                 | 20,443                                   | 870,632                  | 8,33E-06                 | 103,10       | 90,05885 |
| 145                           | 5,260                     | 1,95                      | 7,210                                 | 20,668                                   | 870,624                  | 8,33E-06                 | 104,26       | 91,07186 |
| 150                           | 5,261                     | 1,95                      | 7,211                                 | 20,781                                   | 870,601                  | 8,33E-06                 | 104,65       | 91,41541 |
| 155                           | 5,267                     | 1,95                      | 7,217                                 | 20,542                                   | 871,667                  | 8,33E-06                 | 103,25       | 90,08202 |
| 160                           | 5,266                     | 1,95                      | 7,216                                 | 20,241                                   | 871,860                  | 8,33E-06                 | 102,40       | 89,31786 |
| 165                           | 5,267                     | 1,95                      | 7,217                                 | 20,325                                   | 873,844                  | 8,33E-06                 | 102,96       | 89,59794 |
| 170                           | 5,269                     | 1,95                      | 7,219                                 | 20,633                                   | 872,107                  | 8,33E-06                 | 103,14       | 89,93375 |
| 175                           | 5,271                     | 1,95                      | 7,221                                 | #NAME?                                   | 873,118                  | 8,33E-06                 | 103,87       | 90,47315 |
| 180                           | 5,271                     | 1,95                      | 7,221                                 | 20,313                                   | 700,336                  | 8,33E-06                 | 104,85       | 89,40    |

*Lampiran 11. Dokumentasi kegiatan*









