

## LAMPIRAN

### Lampiran 1

#### FAKTOR KONVERSI

##### Panjang

$$\begin{aligned} 12 \text{ in} &= 1 \text{ ft} \\ 1 \text{ in} &= 2.54 \text{ cm} \\ 1 \mu\text{m} &= 10^{-6} \text{ m} = 10^{-4} \text{ cm} \end{aligned}$$

##### Konduktivitas thermal

$$1 \text{ Btu/h} \cdot \text{ft} \cdot ^\circ\text{F} = 1.7307 \text{ W/m} \cdot ^\circ\text{C}$$

##### Koefisien perpindahan kalor

$$1 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F} = 5.6782 \text{ W/m}^2 \cdot ^\circ\text{C}$$

##### Massa

$$\begin{aligned} 1 \text{ kg} &= 2.205 \text{ lb}_m \\ 1 \text{ slug} &= 32.16 \text{ lb}_m \\ 454 \text{ g} &= 1 \text{ lb}_{\text{fm}} \\ 1 \text{ lb}_m &= 0.45359237 \text{ kg} \end{aligned}$$

##### Volume

$$\begin{aligned} 1 \text{ in}^3 &= 1.63871 \times 10^{-5} \text{ m}^3 \\ 1 \text{ ft}^3 &= 0.0283168 \text{ m}^3 \\ 1 \text{ gal} &= 231 \text{ in}^3 = 0.0038 \text{ m}^3 \end{aligned}$$

##### Gaya

$$\begin{aligned} 1 \text{ dyn} &= 2.248 \times 10^{-6} \text{ lb}_f \\ 1 \text{ lb}_f &= 4.448 \text{ N} \\ 10^5 &= 1 \text{ N} \\ 1 \text{ dyn} &= 10^{-5} \text{ N} \end{aligned}$$

##### Energi

$$\begin{aligned} 1 \text{ Btu} &= 1055.04 \text{ J} \\ 1 \text{ erg} &= 10^{-7} \text{ J} \\ 1 \text{ cal (15}^\circ\text{C)} &= 4.1855 \text{ J} \\ 1 \text{ ft} \cdot \text{lb}_f &= 1.35582 \text{ J} \\ 1 \text{ hp} \cdot \text{h} &= 2545 \text{ Btu} \\ 1 \text{ Btu} &= 778 \text{ ft} \cdot \text{lb}_f \\ 1 \text{ Btu} &= 252 \text{ cal} \\ 1 \text{ kWh} &= 3413 \text{ Btu} \end{aligned}$$

##### Tekanan

$$\begin{aligned} 1 \text{ N/m}^2 &= 1 \text{ Pa} \\ 1 \text{ atm} &= 1.01325 \times 10^5 \text{ Pa} \\ 1 \text{ lbf/in}^2 &= 6894.76 \text{ Pa} \\ 1 \text{ in Hg} &= 70.73 \text{ lb}_f/\text{ft}^2 \end{aligned}$$

##### Densitas

$$\begin{aligned} 1 \text{ lbm/ft}^3 &= 16.0185 \text{ kg/m}^3 \\ 1 \text{ lbm/in}^3 &= 2.76799 \times 10^4 \text{ kg/m}^3 \end{aligned}$$

### Daya

$$1 \text{ hp} = 745.7 \text{ W}$$

$$1 \text{ Btu/h} = 0.293 \text{ W}$$

### Suhu

$$1 \text{ }^\circ\text{R} = (5/9) \text{ }^\circ\text{K}$$

$$t \text{ (}^\circ\text{F)} = (\text{K}-273) 9/5 + 32$$

$$1 \text{ }^\circ\text{K} = 1.8 \text{ }^\circ\text{F}$$

$$1 \text{ }^\circ\text{C} = 1.8 \text{ }^\circ\text{F}$$

$$1 \text{ Rankine} = 1 \text{ F}$$

### Viskositas

$$1 \text{ lb}_m/\text{h ft} = 4.13 \times 10^{-4} \text{ Ns/m}^2$$

$$1 \text{ lb}_m/\text{s ft} = 1.488 \text{ Ns/m}^2$$

$$1 \text{ ft}^2/\text{s} = 0.0929 \text{ m}^2/\text{s}$$

$$1 \text{ lb}_f \text{ s/ft}^2 = 32.174 \text{ lb}_m / \text{s ft}$$

### Laju aliran panas

$$1 \text{ Btu/h} = 0.293 \text{ W}$$

$$1 \text{ cal/s cm}^2 = 13.272 \text{ Btu/h.ft}^2$$

$$1 \text{ watt/cm}^2 = 3171 \text{ Btu/h.ft}^2$$

$$1 \text{ cal/h cm}^2 = 3.687 \text{ Btu/h.ft}^2$$

### Kapasitas panas spesifik

$$1 \text{ Btu/lb F} = 4.184 \text{ J kg}^{-1} \text{ K}^{-1}$$

### Laju aliran massa

$$1 \text{ lb/h} = 0.000126 \text{ kg/s}$$

## Lampiran 2

Tabel A-9 Sifat-sifat Air (Zat cair Jenuh)

°F	°C	$C_p$ kJ/kg, °C	$\rho$ kg/m <sup>3</sup>	$\mu$ kg/m.s	k W/m.°C	Pr	$g\beta\rho^2 C_p / \mu k$ 1/m <sup>3</sup> .°C
32	0	4.225	999.8	$1.79 \times 10^{-3}$	0.566	13.25	
40	4.44	4.208	999.8	1.55	0.575	11.35	$1.91 \times 10^9$
50	10	4.195	999.2	1.31	0.585	9.40	$6.34 \times 10^9$
60	15.56	4.186	998.6	1.12	0.595	7.88	$1.08 \times 10^{10}$
70	21.11	4.179	997.4	$9.8 \times 10^{-4}$	0.604	6.78	$1.46 \times 10^{10}$
80	26.67	4.179	995.8	8.60	0.614	5.85	$1.91 \times 10^{10}$
90	32.22	4.174	994.9	7.65	0.623	5.12	$2.48 \times 10^{10}$
100	37.78	4.174	993.0	6.82	0.63	4.53	$3.3 \times 10^{10}$
110	43.33	4.174	99.6	6.16	0.637	4.04	$4.19 \times 10^{10}$
120	48.89	4.174	988.8	5.62	0.644	3.64	$4.89 \times 10^{10}$
130	54.44	4.179	985.7	5.13	0.649	3.30	$5.66 \times 10^{10}$
140	60	4.179	983.3	4.71	0.654	3.01	$6.48 \times 10^{10}$
150	65.55	4.183	980.3	4.30	0.659	2.73	$7.62 \times 10^{10}$
160	71.11	4.186	977.3	4.01	0.665	2.53	$8.84 \times 10^{10}$
170	76.67	4.191	973.7	3.72	0.668	2.33	$9.85 \times 10^{10}$
180	82.22	4.195	970.2	3.47	0.673	2.16	$1.09 \times 10^{11}$
190	87.78	4.199	966.7	3.27	0.675	2.03	
200	93.33	4.204	963.2	3.06	0.678	1.90	
220	104.4	4.216	955.1	2.67	0.684	1.66	
240	115.6	4.229	946.7	2.44	0.685	1.51	
260	126.7	4.250	937.2	2.19	0.685	1.36	
280	137.8	4.271	928.1	1.98	0.685	1.24	
300	148.9	4.296	918.0	1.86	0.684	1.17	
350	176.7	4.271	890.4	1.57	0.677	1.02	
400	204.4	4.467	859.4	1.36	0.665	1.00	
450	232.2	4.585	825.7	1.20	0.646	0.85	
500	260	4.731	785.2	1.07	0.616	0.83	
550	287.7	5.024	735.5	$9.51 \times 10^{-5}$			
600	315.6	5.703	678.7	8.68			

### Lampiran 3

#### DAFTAR SIMBOL

Simbol	Besaran	Satuan Teknik AS	Satuan SI
C	Laju kapasitas panas per jam	Btu/h F	W/K
Cc	Laju kapasitas panas per jam fluida dingin dalam penukar panas	Btu/h F	W/K
Ch	Laju kapasitas panas fluida panas dalam penukar panas	Btu/h F	W/K
$\epsilon$	Keefektifan penukar panas	Btu/ h ft <sup>2</sup>	W/m <sup>2</sup>
F	Gaya	Lbf	Newton
g	Percepatan gravitasi	ft /s <sup>2</sup>	m/s <sup>2</sup>
G	Kecepatan massa atau laju aliran per luas satuan	lbm/ h ft <sup>2</sup>	kg/ m <sup>2</sup> s
h	Enthalpi per massa satuan	Btu/ lbm	J/ kg
k	Konduktifitas termal	Btu/ h ft F	W/m <sup>2</sup> K
ks	Konduktifitas termal benda padat	Btu/ h ft F	W/m <sup>2</sup> K
k <sub>f</sub>	Konduktifitas termal fluida	Btu/ h ft F	W/m <sup>2</sup> K
K	Konduktansi termal	Btu/ h F	W/ K
K <sub>k</sub>	Konduktansi termal untuk perpindahan panas konduksi	Btu/ h F	W/ K
K <sub>c</sub>	Konduktansi termal konveksi	Btu/ h F	W/ K
l	Panjang, umum	ft atau in	m/s <sup>2</sup>
L	Panjang sepanjang lintasan aliran panas atau panjang karakteristik benda	ft atau in	m/s <sup>2</sup>
m	Laju aliran massa	Lem / s	kg/s
M	massa	lbm	kg
N	Jumlah (umum); jumlah pipa, dsb		

p	Tekanan statik; $p_c$ , tekanan kritis; $p_A$	psi	pascal
P	Keliling basah	ft	M
P	Tekanan total	atm	$N/m^2$
q	Laju aliran panas	Btu/ h	W(J/s)
$q_k$	Laju aliran panas konduksi	Btu/ h	W(J/s)
$q_c$	Laju aliran panas konveksi	Btu/ h	W(J/s)
Q	Jumlah panas	Btu	J (joule)
Q	Laju volume aliran fluida	$ft^3/hr$	$m^3/s$
r	jari-jari	ft	m
$r_o$	jari-jari luar	ft	m
$r_i$	jari-jari dalam	ft	m
R	Tahanan termal, $R_c$ tahanan perpindahan panas konveksi	h F/ Btu	s / W
$R_k$	Tahanan termal perpindahan panas konduksi	h F/ Btu	s / W
T	Suhu	F atau R	
U	Konduktansi satuan keseluruhan	F	$W/ m^2 K$
v	Kecepatan rata-rata terhadap waktu dalam arah	ft/ s	m/ s
V	Volume	$ft^3$	$m^3$

## LAMPIRAN 4

### Hasil Perhitungan

#### 4.1 Tabel hasil perhitungan *Heat Exchanger* dengan bahan Aluminium

Jml/jarar fin	Debit Vc (lt/s)	Debit aktual Vc <sub>act</sub> (lt/s)	Kecepatan u (m/s)	Bilangan Reynold (Re)	Bilangan Nuselt (Nu <sub>c</sub> )
4/10	0.473	0.478	0.1611	12578.144	75.75
4/15	0.473	0.478	0.1611	12475.494	75.47
4/20	0.473	0.478	0.1611	12432.018	75.35
6/10	0.473	0.478	0.1639	9022.472	57.84
6/15	0.473	0.478	0.1639	8947.95	57.62
6/20	0.473	0.478	0.1639	8881.937	57.43

Bilangan Nuselt (Nu <sub>h</sub> )	Debit Vc (lt/s)	Debit aktual Vc <sub>act</sub> (lt/s)	Penurunan Tekanan ΔP (N/m <sup>2</sup> )	Koefisien Cc (J/s K)
215.999	0.21	0.24	4352.9	1990.42
216.759	0.21	0.24	4028.59	1990.62
217.048	0.21	0.24	3982.97	1990.70
215.999	0.21	0.24	4768.46	1990.13
216.589	0.21	0.24	4439.22	1990.33
217.219	0.21	0.24	4106.28	1990.51

Lanjutan lampiran 1 tabel hasil perhitungan *Heat Exchanger* dengan bahan Aluminium

Koefisien Ch (J/s K)	Laju kalor $Q_{c,act}$ (W)	Laju kalor $Q_{h,act}$ (W)	Laju kalor ideal $Q_{ideal}$ (W)	$\Delta T_{l,md}$ ( $^{\circ}C$ )
982.572	13932.937	14414.331	110806.66	44.72
982.225	12540.911	12768.928	110817.86	45.94
982.094	11944.242	12148.507	110822.66	46.41
982.572	15921.058	16379.475	112780.79	44.19
982.302	14529.434	15097.980	112792.19	45.21
982.017	13276.732	13748.245	112802.46	46.29

Koef. Perpindahan Kalor $U_c$ ( $W/m^2C$ )	Koef. Perpindahan Kalor $U_h$ ( $W/m^2C$ )	$U_c$ teoritis	$h_0$	$h_1$
793.782	4041.377	704.225	487.37	11277.64
659.502	3484.978	606.061	485.05	1132.68
655.703	3282.071	591.716	484.06	11353.61
1150.690	4615.052	1075.269	713.91	11277.64
1033.622	4187.174	1010.101	710.48	11320.43
922.568	3724.291	909.091	707.43	11365.95

#### 4.2 Tabel hasil perhitungan *Heat Exchanger* dengan bahan Tembaga

Jml/jarar fin	Debit Vc (lt/s)	Debit aktual Vc <sub>act</sub> (lt/s)	Kecepatan u (m/s)	Bilangan Reynold (Re)	Bilangan Nuselt (Nu <sub>c</sub> )
4/10	0.473	0.478	0.1611	12622.662	75.88
4/15	0.473	0.478	0.1611	12529.539	75.62
4/20	0.473	0.478	0.1611	12475.494	75.47
6/10	0.473	0.478	0.1639	9052.967	57.92
6/15	0.473	0.478	0.1639	9020.649	57.83
6/20	0.473	0.478	0.1639	8914.591	57.52

Bilangan Nuselt (Nu <sub>h</sub> )	Debit Vh (lt/s)	Debit aktual Vh <sub>act</sub> (lt/s)	Penurunan Tekanan ΔP (N/m <sup>2</sup> )	Koefisien Cc (J/s K)
216.285	0.21	0.24	4352.9	1990.333
217.219	0.21	0.24	4028.59	1990.514
217.683	0.21	0.24	3982.97	1990.621
216.590	0.21	0.24	4788.81	1990.046
215.999	0.21	0.24	4398.53	1990.132
216.135	0.21	0.24	4106.28	1990.420



Lanjutan lampiran 2 tabel hasil perhitungan *Heat Exchanger* dengan bahan tembaga

Koefisien Ch (J/s K)	Laju kalor $Q_{c_{act}}$ (W)	Laju kalor $Q_{h_{act}}$ (W)	Laju kalor ideal $Q_{ideal}$ (W)	$\Delta T_{lmtd}$ ( $^{\circ}C$ )
982.441	14529.434	15031.35	112055.77	44.88
982.017	13276.732	13748.24	112802.46	46.24
981.810	12540.911	12763.53	112808.48	46.94
982.424	16517.382	17064.71	114765.95	44.78
982.764	15921.058	16382.68	112780.79	44.19
982.686	13932.937	14121.20	110806.66	44.88

Koef. Perpindahan Kalor $U_c$ ( $W/m^2C$ )	Koef. Perpindahan Kalor $U_h$ ( $W/m^2C$ )	$U_c$ teoritis	$h_0$	$h_1$
824.814	4199.347	769.231	488.37	11298.32
731.533	3727.916	719.242	486.27	11365.95
680.685	3409.292	657.895	485.05	11399.48
1186.567	4778.057	1098.90	715.39	11320.43
1158.999	4648.337	1020.41	713.91	112773.64
998.677	3945.075	942.51	709.03	11287.48

### 4.3 Tabel hasil perhitungan *Heat Exchanger* dengan bahan Stainless Steel

Jml/jarar fin	Debit Vc (lt/s)	Debit aktual Vc <sub>act</sub> (lt/s)	Kecepatan u (m/s)	Bilangan Reynold (Re)	Bilangan Nuselt (Nu <sub>c</sub> )
4/10	0.473	0.478	0.1611	12432.018	75.35
4/15	0.473	0.478	0.1611	12289.29	74.95
4/20	0.473	0.478	0.1611	12191.339	74.68
6/10	0.473	0.478	0.1639	8914.591	57.52
6/15	0.473	0.478	0.1639	8841.839	57.30
6/20	0.473	0.478	0.1639	8739.969	57

Bilangan Nuselt (Nu <sub>h</sub> )	Debit Vh (lt/s)	Debit aktual Vh <sub>act</sub> (lt/s)	Penurunan Tekanan ΔP (N/m <sup>2</sup> )	Koefisien Cc (J/s K)
216.911	0.21	0.24	4352.90	1990.710
219.559	0.21	0.24	4028.59	1990.994
216.421	0.21	0.24	3982.97	1991.196
216.910	0.21	0.24	4809.16	1990.420
218.273	0.21	0.24	4398.53	1990.621
218.447	0.21	0.24	4106.28	1990.910

Lanjutan lampiran 3 tabel hasil perhitungan *Heat Exchanger* dengan bahan Stainless Steel

Koefisien Ch (J/s K)	Laju kalor $Q_{c_{act}}$ (W)	Laju kalor $Q_{h_{act}}$ (W)	Laju kalor ideal $Q_{ideal}$ (W)	$\Delta T_{l_{mtd}}$ (°C)
982.157	11944.242	12443.925	110822.66	46.25
980.766	9954.972	10101.885	114083.98	49.60
982.521	8562.141	8842.688	106130.73	46.61
982.241	13932.937	14409.471	112797.08	45.25
981.473	12540.911	12759.151	114062.57	47.57
981.376	10551.814	11158.247	112824.77	48.27

Koef. Perpindahan Kalor $U_c$ (W/m <sup>2</sup> C)	Koef. Perpindahan Kalor $U_h$ (W/m <sup>2</sup> C)	$U_c$ teoritis	$h_0$	$h_1$
657.972	3373.512	617.284	484.061	11343.63
511.351	2553.626	476.190	480.8	11534.67
468.019	2378.712	434.783	478.548	11308.21
990.511	3992.694	892.857	709.03	11343.63
848.069	3362.987	793.651	705.65	11442.06
703.210	2898.380	699.301	700.89	11454.64