

BAB IV
HASIL DAN PEMBAHASAN

4.1 Kebutuhan Air

4.1.1 Kebutuhan air pendingin

Tabel 4.1 Kebutuhan Air Pendingin(kg/jam)

Alat	Kode	Kebutuhan air pendingin, kg/jam
<i>Cooler</i>	Co-01	635,22
<i>Cooler</i>	Co-02	844.808,71
<i>Condensor</i>	Cd-01	2.215.401,53
<i>Condensor</i>	Cd-02	1.619.162,92
Jumlah		4.680.008,37

Kebutuhan air pendingin = 4.680.008,37 kg/jam

Perancangan dibuat *over design* 20%, sehingga :

Kebutuhan air pendingin = 5.616.010,04 kg/ja

4.1.2 Kebutuhan air untuk umpan boiler

Tabel 4.2 Kebutuhan air umpan boiler(kg/jam)

Alat	Kode	Kebutuhan Steam, kg/jam
<i>Heater</i>	HE-01	341.792,47
<i>Heater</i>	HE-02	4.394.245,55
<i>Reboiler</i>	RB-01	110.260,91
<i>Reboiler</i>	RB-02	45.717,04
Jumlah		4.892.015,96

Kebutuhan total *steam* = 4.892.015,96 kg/jam

Perancangan dibuat *over design* 20%, sehingga :

Kebutuhan total *steam* = 5.870.419,16 kg/jam

4.1.3 Kebutuhan air domestik

1. Air untuk karyawan

Diperkirakan kebutuhan air untuk karyawan = 150 L/orang/hari

Jumlah karyawan = 100 orang

Total kebutuhan air untuk karyawan = 639,29 kg/jam

2. Air untuk instalasi (laboratorium, kantor dan lain-lain)

Air untuk kebutuhan ini diperkirakan = 10% x kebutuhan karyawan

= 10% x 639,29 kg/jam

= 63,93 kg/jam

3. Air untuk distribusi (taman, pemadam kebakaran dan lain-lain)

Air untuk kebutuhan ini diperkirakan = 30% x kebutuhan karyawan

= 30% x 639,29 kg/jam

= 191,79 kg/jam

Over design dirancang 20%, sehingga kebutuhan air domestik = 1.074,02 kg/ja

4.1.4 Kebutuhan air proses

Air proses untuk *mixer* = 306.805,77 kg/jam. Akan tetapi, karena digunakan sistem sirkulasi maka *make up* air yang digunakan sebagai berikut:

1. Air pendingin hilang karena menguap, *blow down* dan terbawa aliran uap keluar *tower* = 880.562,87 kg/jam

2. *Steam* hilang karena menguap dan *blow down* = 1.174.083,83 kg/jam

Jadi total kebutuhan air yang disuplai

= *make up* air pendingin + *make up* air umpan

boiler+ air domestik + air untuk proses

= 880.562,87 kg/jam + 1.174.083,83 kg/jam + 1.074,02 kg/jam + 306.805,77

kg/jam

= 2.362.526,49 kg/jam

Untuk mengantisipasi hilangnya air karena terjadinya kebocoran saat pendistribusian *make up* air diledihkan 10%, sehingga air yang harus diambil dari sungai sebesar 2.835.031,79 kg/jam.

1.Data Boiler

Tahun pembuatan = 2001

Negara Pembuat = INDOMARINE

Kapasitas Boiler = 20 ton / jam

2.DATA UNJUK KERJA BOILER

Water Press = Bar

Water Temp = 105 °C

Steam Press = 21 bar (gauge)

Steam Temp = 265 °C

Steam Flow = 20 ton / jam

Suhu Boiler Furnace = 1400 °C

Bahan bakar	= 1,6 ton cangkang sawit/jam
	= 3,483 ton Fiber/jam
Pemakaian bahan bakar	= 5, 083 ton / jam
Air penambah	= 20 ton / jam
Kapasitas Turbin	= 2.000 Kwatt
Kapasitas Generator	= 3.360 KVA

4.2 Hasil Observasi Limbah Sawit

4.2.1 FIBER

1. CARBON (Wt % daf) = 50,1
2. HIDROGEN(Wt % daf) = 3,1
3. OXYGEN (Wt % db) = 19,12
4. NITROGEN (Wt % ar) = 19,22
5. Sulfur = 0,30
6. Ash Cont = 3, 19
7. Water = 5,27



4.2.2 CANGKANG/SHELL

1. CARBON (Wt % daf) = 61.35
2. HIDROGEN(Wt % daf) = 3,25
3. OXYGEN (Wt % db) = 21,41

4. NITROGEN (Wt % ar) = 2,45
5. Ash Cont = 1, 8
6. Sulfur = 0.18
7. Water = 9,74



A. Nilai Kalor Untuk Fiber

$$1. \text{Gross calor value} = 81 C + 340 \left(H - \frac{O}{8} \right) + 25 S \text{ Kcal / Kg bb}$$

$$\begin{aligned} \text{GCV} &= (81 \times 50,1) + 340 \left(3,1 - \frac{19,12}{8} \right) + (25 \times 0) \\ &= 4870,7 \text{ kCal / Kgbb} \end{aligned}$$

$$2. \text{Net calor value} = 81 C + 340 \left(H - \frac{O}{8} \right) + 25 S - 6 W \text{ kcal/kg bb}$$

$$\begin{aligned} \text{NCV} &= 81(x 50,1) 340 \left(3,1 - \frac{6,28}{8} \right) + 0 - 6 (5,27) \\ &= 4839,08 \text{ kcal/kg} \end{aligned}$$

B. Nilai Kalor Untuk Cangkang

$$1. \text{Gross Calor Value} = 81 C + 340 \left(H - \frac{O}{8} \right) + 25 S \text{ Kcal/kg bb}$$

$$\begin{aligned} \text{GCV} &= (81 \times 61,35) + 340 \left(3,25 - \frac{21,41}{8} \right) + (25 \times 0) \\ &= 5164,425 \text{ Kcal/kg bb} \end{aligned}$$

$$2. \text{ Net Calor Value} = 81 C + 340 \left(H - \frac{O}{8} \right) + 25 S - 6 W \text{ Kcal/kg bb}$$

$$\text{NCV} = 81 (x 61,35) + 340 \left(3,25 - \frac{6,28}{8} \right) - 6 (9,74)$$

$$= 5105,985 \text{ Kcal/kg}$$

$$\text{Fiber} = 75 \% = 3/4$$

$$\underline{\text{Cangkang} = 25 \% = 1/4}$$

$$100 \%$$

$$\text{Carbon} = 0,75 x 50,1 + 0,25 x 61,35$$

$$= 52,9125 \%$$

$$\text{Hidrogen} = 0,75 x 3,1 + 0,25 x 3,25$$

$$= 3,1375 \%$$

$$\text{Oxygen} = 0,75 x 19,12 + 0,25 x 21,4$$

$$= 19,6925 \%$$

$$\text{Nitrogen} = 0,75 x 19,22 + 0,25 x 2,45$$

$$= 14,978 \%$$

$$\text{Sulfur} = 0,75 x 0,18 + 0,25 x 0,30$$

$$= 0,21 \%$$

$$\text{Water} = 0,75 x 5,27 + 0,25 x 9,74$$

$$= 6,3875 \%$$

$$\text{NCV} = 81 (x 52,9125) + 340 \left(3,1375 - \frac{19,69}{8} \right) - 6 (6,3875)$$

$$= 4,663,56 \text{ kkal/kg}$$

$$= 4,663,56 \text{ kkal/kg} x 4,186$$

$$= 19521,66 \text{ kj/kg}$$

4.3 Batas Kontrol Kualitas Air Boiler Berdasarkan Tekanan Boiler

Tabel 4.3 Batas kontrol kualitas air boiler.

PARAMETER	SATUAN	CONTROL LIMIT	
		20 Barg	30 Barg
pH	Units	10.5 – 11,5	10,5 – 11,5
TDS	Ppm	< 2000	< 2000
P-Alkalinity,ppm CaCO ₃	as ppm CaCO ₃		
M-Alkalinity,ppm,CaCO ₃	as ppm CaCO ₃	< 700	< 700
O-Alkalinity,CaCO ₃	as ppm CaCO ₃	>2,5 x SiO ₂	>2,5 x SiO ₂
T-Hardness,ppm,CaCO ₃	as ppm CaCO ₃	Trace	Trace
Silica,ppm SiO ₂	as ppm SiO ₃	< 150	< 90
Phospate,ppm,PO ₄	as ppm PO ₄	20 - 30	20 - 30
Sulfite,ppm,SO ₃	as ppm SO ₃	30 - 50	30 - 50
Iron,ppm,Fe	as ppm Fe	< 1	< 1

PARAMETER	SATUAN	CONTROL LIMIT		
		20 Barg	30 Barg	40 Barg
pH	Units	10.5 – 11,5	10,5 – 11,5	9,5 – 10,5
TDS	Ppm	< 2000	< 2000	< 500
P-Alkalinity,ppm CaCO ₃	as ppm CaCO ₃			
M-Alkalinity,ppm,CaCO ₃	as ppm CaCO ₃	< 700	< 700	< 200
O-Alkalinity,CaCO ₃	as ppm CaCO ₃	>2,5 x SiO ₂	>2,5 x SiO ₂	> 2,5 x SiO ₂
T-Hardness,ppm,CaCO ₃	as ppm CaCO ₃	Trace	Trace	Trace
Silica,ppm SiO ₂	as ppm SiO ₃	< 150	< 90	< 20
Phospate,ppm,PO ₄	as ppm PO ₄	30 – 70	30 – 70	15 – 25
Sulfite,ppm,SO ₃	as ppm SO ₃	30 – 50	30 - 50	20 - 40
Iron,ppm,Fe	as ppm Fe	< 2	< 2	< 2

$$t = 105 \text{ }^{\circ}\text{C}$$

$$= \frac{105-100}{110-100} \times (419.04 - 461.30) + 461.30$$

$$= 440,17 \text{ kJ/kg}$$

$$P = 20 \text{ bar}$$

$$P_{uap} = 20 + 1 = 21 \text{ bar}$$

$$h_g = \frac{21-20}{25-20} \times (2803,1 - 2799,5) + 2799,5$$

$$= 2800,22 \text{ kJ/kg}$$

$$\eta_b = \frac{\dot{m}_u (h_{g1} - 440,17)}{\dot{m}_{bb} \times LHV}$$

$$= \frac{20 (2758,29 - 440,17)}{5,083 \times 19521,61} \times 100 \%$$

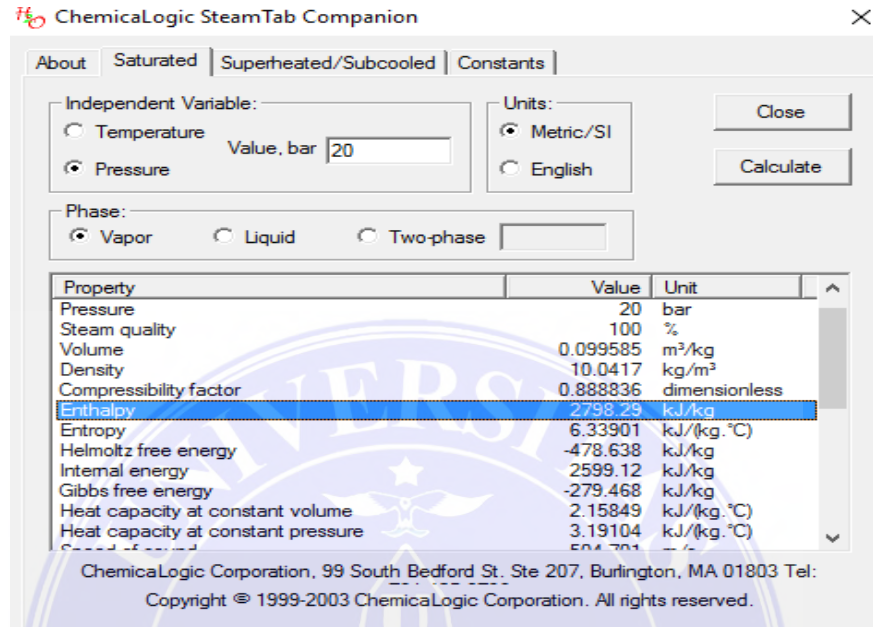
$$= 0,4682$$

$$= 46,82 \%$$

Untuk mencari entalpy pada $T_3 = 105^\circ\text{C}$ dicari dengan menggunakan *software chemicallogic steamtab companion* maka di peroleh : 440,274 kJ/kg

Property	Value	Unit
Pressure	1.20903	bar
Steam quality	0	%
Volume	0.00104744	m³/kg
Density	954.704	kg/m³
Compressibility factor	0.000725631	dimensionless
Enthalpy	440.274	kJ/kg
Entropy	1.36335	kJ/(kg·°C)
Helmholtz free energy	-75.4026	kJ/kg
Internal energy	440.147	kJ/kg
Gibbs free energy	-75.276	kJ/kg
Heat capacity at constant volume	3.74229	kJ/(kg·°C)
Heat capacity at constant pressure	4.2217	kJ/(kg·°C)

Untuk mencari entalpy pada $P_3 = 20$ bar, dicari dengan menggunakan *software chemicallogic steamtab companion* maka diperoleh: $h_1 = 2798,29$ kJ/kg



$$\begin{aligned}
 t &= 105 \text{ }^{\circ}\text{C} \\
 &= \frac{105 - 100}{110 - 100} \times (419.04 - 461.30) + 461.30 \\
 &= 440.17 \text{ kJ/kg}
 \end{aligned}$$

$$P = 30 \text{ barg}$$

$$P_{\text{uap}} = 31 + 1 = 31 \text{ bar}$$

$$\begin{aligned}
 h_g &= \frac{31 - 30}{35 - 30} \times (2803,4 - 2804,2) + 2803,4 \\
 &= 2804,04 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \eta_b &= \frac{m_u (h_{g1} - 1345,75)}{m_{bb} \times LHV} \\
 &= \frac{30 (2800,04 - 440,17)}{5.083 \times 19521,61} \times 100 \% \\
 &= 0,7136 \\
 &= 71,35 \%
 \end{aligned}$$

Untuk mencari entalpy pada $T_3 = 105\text{ }^\circ\text{C}$ dicari dengan menggunakan *software chemicallogic steamtab copanion* maka di peroleh : 440,274 kJ/kg

ChemicalLogic SteamTab Companion

Independent Variable: Temperature Value, °C Pressure

Units: Metric/SI English

Phase: Vapor Liquid Two-phase

Property	Value	Unit
Pressure	1.20903	bar
Steam quality	0	%
Volume	0.00104744	m ³ /kg
Density	954.704	kg/m ³
Compressibility factor	0.000725631	dimensionless
Enthalpy	440.274	kJ/kg
Entropy	1.36335	kJ/(kg.°C)
Helmoltz free energy	-75.4026	kJ/kg
Internal energy	440.147	kJ/kg
Gibbs free energy	-75.276	kJ/kg
Heat capacity at constant volume	3.74229	kJ/(kg.°C)
Heat capacity at constant pressure	4.2217	kJ/(kg.°C)

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Untuk mencari entalpy pada $P_3 = 30\text{ bar}$, dicari dengan menggunakan *software chemicallogic steamtab copanion* maka diperoleh: $h_1 = 2803,15\text{ kJ/kg}$

ChemicalLogic SteamTab Companion

Independent Variable: Temperature Value, bar Pressure

Units: Metric/SI English

Phase: Vapor Liquid Two-phase

Property	Value	Unit
Pressure	30	bar
Steam quality	100	%
Volume	0.0666644	m ³ /kg
Density	15.0005	kg/m ³
Compressibility factor	0.854704	dimensionless
Enthalpy	2803.15	kJ/kg
Entropy	6.18558	kJ/(kg.°C)
Helmoltz free energy	-532.95	kJ/kg
Internal energy	2603.16	kJ/kg
Gibbs free energy	-332.957	kJ/kg
Heat capacity at constant volume	2.32825	kJ/(kg.°C)
Heat capacity at constant pressure	3.61191	kJ/(kg.°C)

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$$t = 105 \text{ }^{\circ}\text{C}$$

$$= \frac{105-100}{110-100} \times (419.04 - 461.30) + 461.30$$

$$= 440,17 \text{ kJ/kg}$$

$$P = 40 \text{ bar}$$

$$h_g = \frac{41-40}{45-40} \times (2798,3 - 2801,4) + 2801,4$$

$$= 2800,78 \text{ kJ/kg}$$

$$\eta_b = \frac{m_u (h_{g1} - 440,17)}{m_{bb} \times LHV}$$

$$= \frac{40 (2803,15 - 440,17)}{5.083 \times 19521,61} \times 100 \%$$

$$= 0.9522$$

$$= 95.22 \%$$

Untuk mencari entalpy pada $T_3 = 105 \text{ }^{\circ}\text{C}$ dicari dengan menggunakan *software chemicallogic steamtab copanion* maka di peroleh : 440,274 kJ/kg

Property	Value	Unit
Pressure	1.20903	bar
Steam quality	0	%
Volume	0.00104744	m³/kg
Density	954.704	kg/m³
Compressibility factor	0.000725631	dimensionless
Enthalpy	440.274	kJ/kg
Entropy	1.36335	kJ/(kg.°C)
Helmoltz free energy	-75.4026	kJ/kg
Internal energy	440.147	kJ/kg
Gibbs free energy	-75.276	kJ/kg
Heat capacity at constant volume	3.74229	kJ/(kg.°C)
Heat capacity at constant pressure	4.2217	kJ/(kg.°C)

Untuk mencari entalpy pada $P_3 = 40$ bar, dicari dengan menggunakan *software chemicallogic steamtab copanion* maka diperoleh : $h_1 = 2800,82$ kJ/kg

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Property	Value	Unit
Pressure	40	bar
Steam quality	100	%
Volume	0.0497761	m ³ /kg
Density	20.09	kg/m ³
Compressibility factor	0.824086	dimensionless
Enthalpy	2800.82	kJ/kg
Entropy	6.06957	kJ/(kg·°C)
Helmholtz free energy	-575.729	kJ/kg
Internal energy	2601.72	kJ/kg
Gibbs free energy	-376.625	kJ/kg
Heat capacity at constant volume	2.46858	kJ/(kg·°C)
Heat capacity at constant pressure	4.02032	kJ/(kg·°C)