LAMPIRAN A
NERACA MASSA

Kapasitas produksi = 32.000 ton/tahun

$= 32.000\ \frac{ton}{tahun}\ x\ \frac{1tahun}{300\ hari}\ x\ \frac{1\ hari}{24\ jam}\ x\ \frac{1000\ kg}{1\ ton}$

= 444.444,444 kg/jam

Operasi Pabrik = 300 hari

Basis Perhitungan = 1000 kg/jam

Kapasitas Produksi Basis = 302,53 kg/jam

Faktor Pengali $= \frac{Kapasitas\ Sebenarnya}{Kapasitas\ \ Basis} = \frac{4.444,444\ kg/jam}{302,53\ kg/jam} = 14,69$

Bahan baku cangkang kerang hijau $= \frac{4.444,444\ kg/jam}{302,53\ kg/jam} x1000$ = 14.690,921 kg/jam

Tabel A.1 Spesifikasi Bahan Baku Cangkang Kerang Hijau

No	Spesifikasi	
1.	Wujud	Padat
2.	Warna	Hijau, Kecokelatan
3.	Bau	Amis
2.	Komposisi (%)	
	▪ Protein	14,50
	▪ $CaCO_3$	49,48
	▪ Kitin	35
	▪ Air	1,02

Sumber : Wikipedia

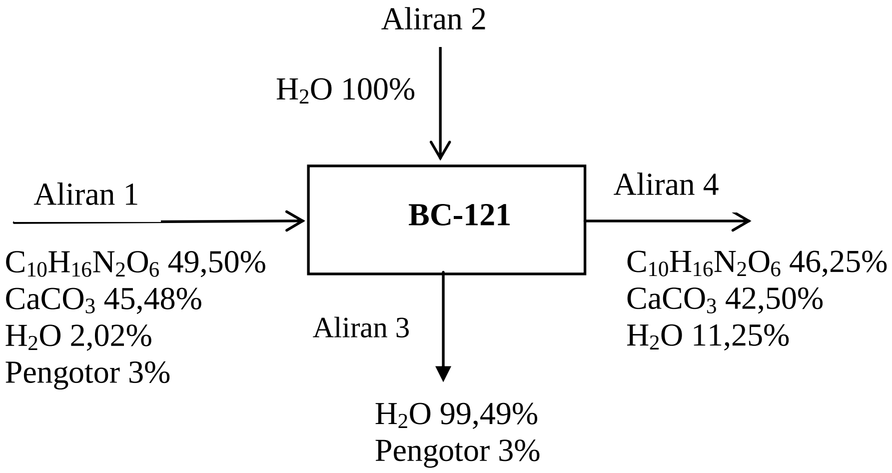
Tabel A.2 Spesifikasi Produk Nano Kitosan

No	Spesifikasi	
1.	Fasa	Serbuk Halus
2.	Deasetilasi	≥ 70% jenis teknis, dan ≥ 95% jenis pharmasikal
3.	Warna	Putih sampai kuning pucat
4.	Kadar air	2-10%
5.	Kelarutan	Hanya pada pH ≤ 6
6.	Ukuran partikel	850 nm

(Sumber: Wikipedia)

1. Pencucian (BC-121)

Fungsi: Sebagai tempat untuk mencuci dan membersihkan kotoran cangkang kerang hijau dengan menambahkan air proses



Kondisi Operasi:

- Temperatur : 30˚C
- Tekanan : 1 atm

Aliran 1 :

- Kitin-Protein ($C_{10}H_{16}N_2O_6$) = 7.272,006 kg/jam
- $CaCO_3$ = 6.681,431 kg/jam
- Air = 296,757 kg/jam
- Pengotor = 440,728 kg/jam

Aliran 2

- Air = 88.145,528 kg/jam

Aliran 3

- Air = 86.673,439 kg/jam
- Pengotor = 440,728 kg/jam

Aliran 4

- Kitin-Protein ($C_{10}H_{16}N_2O_6$) = 7.272,006 kg/jam
- $CaCO_3$ = 6.681,431 kg/jam
- Air = 1.768,846 kg/jam

Neraca massa total : Aliran 1 + Aliran 2 = Aliran 3 + Aliran 4

Neraca massa komponen :

- **Input**

- **Aliran 1**

- $C_{10}H_{16}N_2O_6$ = 49,50% x 14.690,921 $\frac{kg}{jam}$ = 7.272,006 $\frac{kg}{jam}$
- $CaCO_3$ = 45,48% x 14.690,921 $\frac{kg}{jam}$ = 6.681,431 $\frac{kg}{jam}$
- H_2O = 2,02% x 14.690,921 $\frac{kg}{jam}$ = 296,757 $\frac{kg}{jam}$
- Pengotor = 3% x 14.690,921 $\frac{kg}{jam}$ = 440,728 $\frac{kg}{jam}$

- **Aliran 2**

  Penambahan air untuk pencucian cangkang kerang hijau. Perbandingan cangkang kerang hijau dengan air yaitu 1:6 maka:

  - H_2O = 6 x 296,757 $\frac{kg}{jam}$ = 88.145,528 $\frac{kg}{jam}$

➢ **Output**

- **Aliran 3**
  - Air (H_2O)

    Jumlah air yang keluar dari proses pencucian (Aliran 3) = 86.673,439 kg/jam
  - Pengotor

    Jumlah pengotor yang keluar dari proses pencucian cangkang kerang hijau = 440,728 kg/jam

    Neraca massa pengotor pada proses pencucian

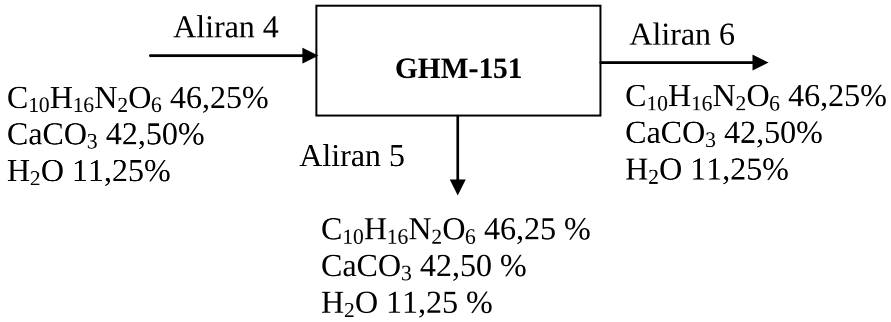
    Aliran 1 = Aliran 3 =440,728 kg/jam

- **Aliran 4**
  - $C_{10}H_{16}N_2O_6$ = 46,25% x 15.722,28 = 7.272,006 kg/jam
  - $CaCO_3$ = 42,50% x 15.722,28= 6.681,431 kg/jam
  - H_2O = 11,25% x15.722,28 = 1.768,846 kg/jam

Tabel A.3 Neraca Massa Proses Pencucian (BC-121)

Komponen	Masuk (kg/jam)		Keluar (kg/jam)	
	Aliran 1	Aliran 2	Aliran 3	Aliran 4
$C_{10}H_{16}N_2O_6$	7.272,006			7.272,006
$CaCO_3$	6.681,431			6.681,431
H_2O	296,757	88.145,528	86.673,439	1.768,846
Pengotor	440,728		440,728	
Sub Total	14.690,921	88.145,528	87.114,167	15.722,283
Total	102.836,450		102.836,450	

2. *Grinding Hammer Mill (GHM-151)*



Kondisi Operasi:

- Temperatur : 90˚C
- Tekanan : 1 atm (Walas, Tabel 11.18)
- Efisiensi alat : 99%
- Reject : 1% (mc.cabe 970)
- Feed : 150-450 mm
- Out : 25 mm – 20 mesh (mc.cabe 155)

Neraca massa total : Aliran 4 = Aliran 5 + Aliran 6

Neraca massa komponen :

➢ **Input**

- **Aliran 4**

  Pengecilan ukuran cangkang kerang hijau menggunakan Grinding Hammer Mill (Perry's, Hal. 96)

  - $C_{10}H_{16}N_2O_6$ = 46,25% x 15.722,28 = 7.272,006 kg/jam
  - $CaCO_3$ = 42,50% x 15.722,28= 6.681,431 kg/jam
  - H_2O = 11,25% x15.722,28 = 1.768,846 kg/jam

➢ **Output**

- **Aliran 5**

  Reject = 1%

  Maka untuk keluaran F5 yaitu

  - $C_{10}H_{16}N_2O_6$ = 1% x 7.272,006 = 72,720 kg/jam
  - $CaCO_3$ = 1% x 6.681,431 = 66,814 kg/jam
  - H_2O = 1% x 1.768,846 = 17,688 kg/jam

- **Aliran 6**

  Efisiensi alat = 99%

  Maka untuk keluaran F6 yaitu:

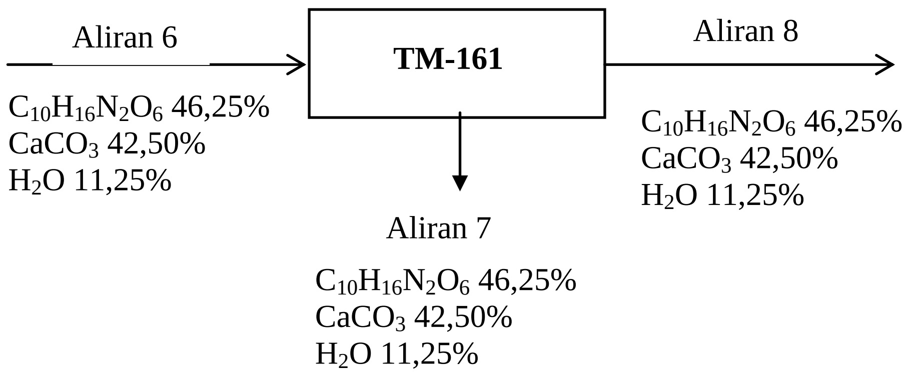
  - $C_{10}H_{16}N_2O_6$ = 99% x 7.272,006 = 7.199,286 kg/jam
  - $CaCO_3$ = 99% x 6.681,431 = 6.614,617 kg/jam
  - H_2O = 99% x 1.768,846 = 1.751,157 kg/jam

Tabel A.4 Neraca Massa *Grinding Hammer Mill-151*

Komponen	Masuk (kg/jam)	Keluar (kg/jam)	
	Aliran 4	Aliran 5	Aliran 6
$C_{10}H_{16}N_2O_6$	7.272,006	72,720	7.199,286
$CaCO_3$	6.681,431	66,814	6.614,617
H_2O	1.768,846	17,688	1.751,157
Sub Total	15.722,283	157,223	15.565,060
Total	15.722,283	15.722,283	

3. *Tumbling Mill* (TM-161)

Fungsi: sebagai tempat untuk menghaluskan cangkang kerang menjadi tepung 200 mesh



Kondisi Operasi:

- Temperatur : 90˚C
- Tekanan : 1 atm (Walas, Tabel 11.18)
- Efisiensi alat : 99%
- Reject : 1% (mc.cabe 970)
- Feed : 10 mesh
- Out : 200 mesh (mc.cabe 155)

Neraca massa total : Aliran 6 = Aliran 7 + Aliran 8

Neraca massa komponen :

- **Input**
- **Aliran 6**

Pengecilan ukuran cangkang kerang hijau menggunakan Tumbling Mill sampai ukurannya menjadi 200 mesh (Perry's, Hal. 96)

- $C_{10}H_{16}N_2O_6$ = 46,25% x 15.565,060 = 7.199,286 kg/jam
- $CaCO_3$ = 42,50 x 15.565,060 = 6.614,617 kg/jam
- H_2O = 11,25% x 15.565,060 = 1.751,157 kg/jam

- **Output**
- **Aliran 7**

Reject = 1%

Maka untuk keluaran F5 yaitu

- $C_{10}H_{16}N_2O_6$ = 1% x 7.199,286 = 71,993 kg/jam
- $CaCO_3$ = 1% x 6.614,617= 66,146 kg/jam
- H_2O = 1% x 1.751,157 = 17,512 kg/jam

- **Aliran 8**

Efisiensi alat = 99%

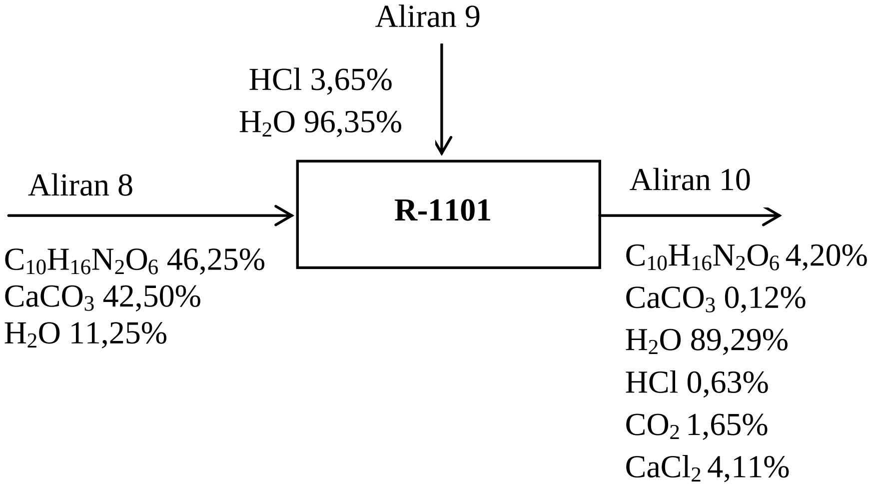
Maka untuk keluaran F6 yaitu:

- $C_{10}H_{16}N_2O_6$ = 99% x 7.199,286 = 7.127,293 kg/jam
- $CaCO_3$ = 99% x 6.614,617= 6.548,471 kg/jam
- H_2O = 99% x 1.751,157 = 1.733,646 kg/jam

Tabel A.5 Neraca Massa *Tumbling Mill (TM-161)*

Komponen	**Masuk (kg/jam)**	**Keluar (kg/jam)**	
	Aliran 6	**Aliran 7**	**Aliran 8**
$C_{10}H_{16}N_2O_6$	7.199,286	71,993	7.127,293
$CaCO_3$	6.614,617	66,146	6.548,471
H_2O	1.751,157	17,512	1.733,646
Sub Total	15.565,060	155,651	15.409,409
Total	15.565,060	15.565,060	

4. Reaktor Demineralisasi (R-1101)



Kondisi operasi :

Temperatur : 75˚C

Tekanan : 1 atm

Waktu : 180 menit

Konversi reaksi : 97% (Smith van Ness, Pers. 13.5)

➢ **Input**

- **Aliran 8**
  - $C_{10}H_{16}N_2O_6$ = 46,25% x 15.409,409 = 7.127,293 kg/jam
  - $CaCO_3$ = 42,50 x 15.409,409 = 6.548,471 kg/jam
  - H_2O = 11,25% x 15.409,4090 = 1.733,646 kg/jam

- **Aliran 9**
  - HCl = 3,65% x 154.094,094 kg/jam = 5.624,434 kg/jam
  - H_2O = 96,35% x 154.094,094 kg/jam = 148.469,660 kg/jam

Jumlah HCl yang ditambahkan sebanyak 3,65% dengan perbandingan umpan dan pelarut yaitu 1:10. (Najafpour, *et. al*, 2002)

Jumlah Pelarut pada aliran 9 yaitu: 10 x 15.409,4090 = 154.094,094 kg/jam

Jumlah HCl pada Aliran 9 = 3,65% x 154.094,094 kg/jam = 5.624,434 kg/jam

Reaksi yang terjadi dalam reaktor Demineralisasi yaitu:

	$CaCO_3$	+ $2HCl$	$\longrightarrow$ $CaCl_2$	+ CO_2	+ H_2O	
Mula[2]	65,48	156,23				
Berex	63,38	126,76	63,38	63,38	63,38	-
Produk	2,11	29,47	63,38	63,38	63,38	

- **Output**

- **Aliran 10**

  Aliran 10 = Aliran 8 + Aliran 9

  $$= 15.409,409 \frac{\text{kg}}{\text{jam}} + 154.094,094 \frac{\text{kg}}{\text{jam}} = 165.503,503 \frac{\text{kg}}{\text{jam}}$$

  - Kitin-Protein ($C_{10}H_{16}N_2O_6$)

    Jumlah kitin-protein yang keluar dari reaktor demineralisasi :

    $= 4,20\% \times 165.503,503 \frac{\text{kg}}{\text{jam}} = 7.127,293 \frac{\text{kg}}{\text{jam}}$

  - Air (H_2O)

    Jumlah air yang keluar dari reaktor demineralisasi :

    $= 89,29\% \times 165.503,503 \frac{\text{kg}}{\text{jam}} = 151.344,139 \frac{\text{kg}}{\text{jam}}$

  - Asam Klorida (HCl)

    Jumlah HCl yang keluar dari reaktor demineralisasi

    $= 0,63\% \times 165.503,503 \frac{\text{kg}}{\text{jam}} = 1.061,099 \frac{\text{kg}}{\text{jam}}$

  - $CaCO_3$

    Jumlah $CaCO_3$ yang keluar dari reaktor demineralisasi

    $= 0,12\% \times 165.503,503 \frac{\text{kg}}{\text{jam}} = 210,505 \frac{\text{kg}}{\text{jam}}$

  - CO_2

    Jumlah CO_2 yang keluar dari reaktor demineralisasi

    $= 1,65\% \times 165.503,503 \frac{\text{kg}}{\text{jam}} = 2.788,705 \frac{\text{kg}}{\text{jam}}$

  - $CaCl_2$

    Jumlah $CaCl_2$ yang keluar dari reaktor demineralisasi

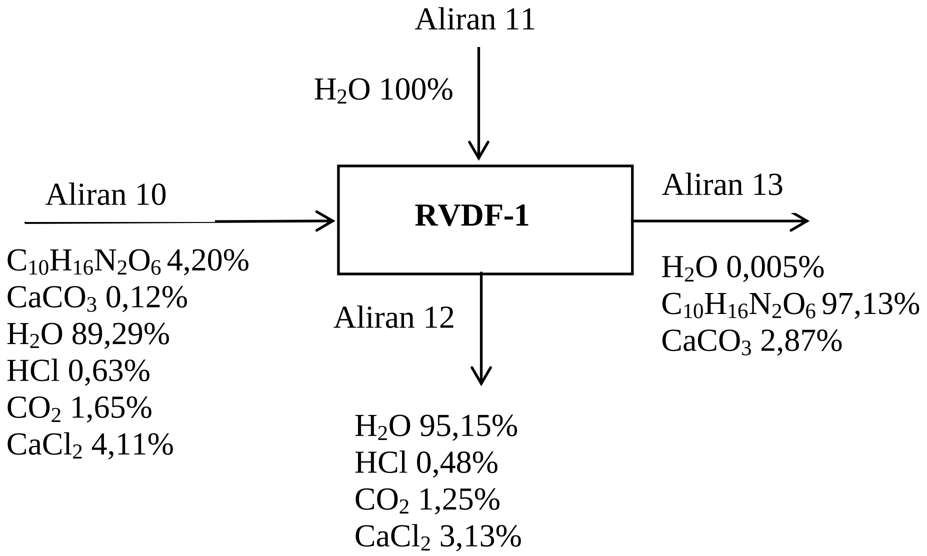
    $= 4,11\% \times 165.503,503 \frac{\text{kg}}{\text{jam}} = 6.971,762 \frac{\text{kg}}{\text{jam}}$

Tabel A.6 Neraca Massa Reaktor Demineralisasi (R-1101)

Komponen	Masuk (kg/jam)		Keluar (kg/jam)
	Aliran 8	Aliran 9	Aliran 10
$C_{10}H_{16}N_2O_6$	7.127,293		7.127,293
$CaCO_3$	6,548,471		210,505
H2O	1.733,646	148.469,660	151.344,139
HCl		5.624,434	1.061,099
CO_2			2.788,705
$CaCl_2$			6.971,762
Sub Total	15.409,409	154.094,09	169.503,503
Total	169.503,503		169.503,503

5. *Rotary Vacum Drum Filter* (RVDF-1111)

Fungsi: sebagai tempat untuk memisahkan padatan dan larutan secara vaccum berdasarkan kelarutan di dalam air.



Kondisi operasi :

- Temperatur : 30°C
- Tekanan : <1 atm (Smith van Ness, Pers. 13.5)

Neraca massa total : Aliran 10 +Aliran 11 = Aliran 12 + Aliran 13

Neraca massa komponen :

➢ **Input**

- Aliran 10
  - $C_{10}H_{16}N_2O_6$ = 4,20% x 169.503,503 = 7.127,293 kg/jam
  - $CaCO_3$ = 0,12% x 169.503,503 = 210,505 kg/jam
  - $CaCl_2$ = 4,11% x 169.503,503 = 6.971,762 kg/jam

- H_2O = 89,29% x 169.503,503 = 151.344,139 kg/jam
- HCl = 0,63% x 169.503,503 = 1.061,099 kg/jam
- CO_2 = 1,65% x 169.503,503 = 2.788,705 kg/jam

- Aliran 11

  Penyaringan menggunakan *rotary vacuum filter* untuk memisahkan padatan dan larutan secara vacuum, padatan yang ingin dipisahkan yaitu $CaCl_2$ dengan kelarutan = 114,44 g/100 ml, (Perry's, Hal. 96)

  Maka untuk penambahan air di aliran 11 = 114,44 / 1000 = 0,11

  Aliran 11 (H_2O) = 6.971,762 kg/jam / 0,11 = 60.920,677 kg/jam

➢ **Output**

- Aliran 12

  Jumlah partikel yang keluar di *rotary vacuum filter* yaitu :

  - $CaCl_2$ = Aliran 10 = 6.971,762 kg/jam
  - HCl = Aliran 10 = 1.061,099 kg/jam
  - CO_2 = Aliran 10 = 2.788,705 kg/jam
  - H2O = (Aliran 10 + Aliran 11) – Aliran 13 = 212.264,484 kg/jam

- Aliran 13

  Jumlah partikel yang tertahan di *rotary vacuum filter* yaitu :

  - $C_{10}H_{16}N_2O_6$ = Aliran 10 = 7.127,293 kg/jam
  - $CaCO_3$ = Aliran 10 = 210,505 kg/jam
  - H_2O = 89,29% x M = 89,29% x 0,37 kg/jam = 0,332 kg/jam

  Kelembaban pada *cake* ditentukan dengan persamaan berikut.

  $$M = S(\frac{\rho}{\rho_s}) \left(\frac{X}{1-X}\right)$$

  Berdasarkan perhitungan spesifikasi alat (Lampiran C), didapat:

  S = 0,03 kg/m^3 (brown, pers 179)

  ρ_f = 930,15 kg/m^3 (walas, tabel 11.6)

  ρ_s = 145,79 kg/m^3

  X = 0,7

  Maka, kelembaban cake:

  $$M = S(\frac{\rho}{\rho_s}) \left(\frac{X}{1-X}\right)$$ (Brown, Hal 225)

$$M = 0{,}03\left(\frac{930{,}15\ kg/m^3}{145{,}79\ kg/m^3}\right)\left(\frac{0{,}7}{1-0{,}7}\right)$$

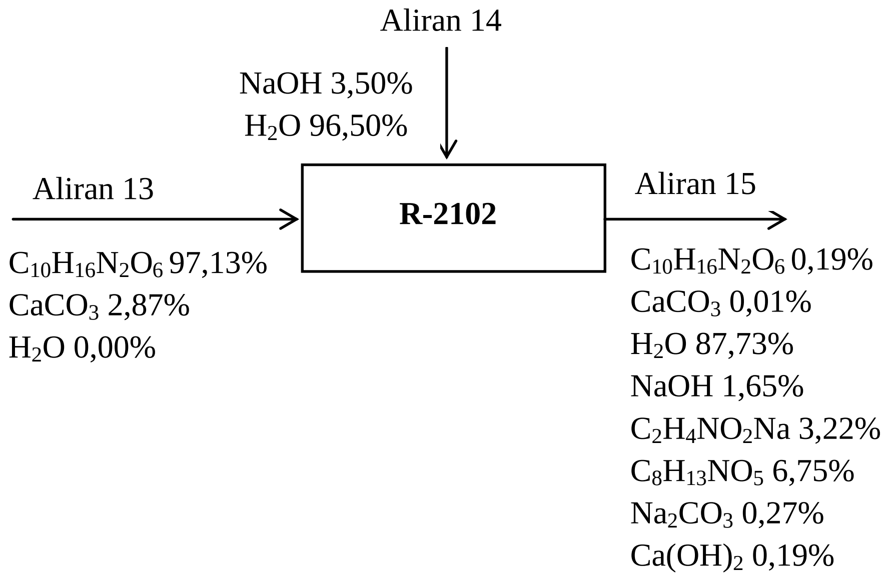
$$M = 0{,}37\ \text{kg/jam}$$

Tabel A.7 Neraca Massa pada *Rotary Vaccum Drum Filter-1111*

Komponen	Masuk (Kg/jam)		Keluar (Kg/jam)	
	Aliran 10	Aliran 11	Aliran 12	Aliran 13
$C_{10}H_{16}N_2O_6$	7.127,293			7.127,293
$CaCO_3$	210,505	60.920,677		210,505
$CaCl_2$	6.971,762		6.971,762	
H_2O	151.344,139		212.264,484	0,332
HCl	1.061,099		1.061,099	
CO_2	2.788,705		2.788,705	
Sub total	169.503,503	60.920,677	223.086,050	7.338,130
Total	**230.424,181**		**230.424,181**	

6. Reaktor Deproteinasi (R-2102)

Fungsi: sebagai tempat untuk memisahkan protein yang terkandung di cangkang kerang dengan menambahkan NaOH



Kondisi operasi :

- Temperatur : 70°C
- Tekanan : 1 atm
- Konversi reaksi : 98% (Ramlah,2010)
- Waktu : 1 jam

Reaksi yang terjadi di dalam reaktor deproteinasi yaitu :

- Reaksi 1

	$C_{10}H_{16}N_2O_6$	+	NaOH	→	$C_8H_{13}NO_5$	+	CH_3COONa
m:	27,41		64,21				
b:	26,83		26,83		26,83		26,83
s:	0,59		37,28		26,83		26,83

- Reaksi 2

	$CaCO_3$	+	2NaOH	→	Na_2CO_3	+	$Ca(OH)_2$
m:	2,11		37,38				
b:	2,06		4,12		2,06		2,06
s:	0,04		33,26		2,06		2,06

➢ **Input**

- **Aliran 13**
  - $C_{10}H_{16}N_2O_6$ = 7.127,293 kg/jam
  - $CaCO_3$ = 210,505 kg/jam
  - H_2O = 0,332 kg/jam
- **Aliran 14**

  Penambahan NaOH sebanyak 3,50% pada reaktor deproteinasi, dengan perbandingan NaOH dengan pelarut yaitu 1:10 **(**ISSN 2407-8476**)**

  Pelarut = 10 x 7.338,130 kg/jam = 73.381,303 kg/jam

  - NaOH = 3,50% x $73.381,303\ \frac{kg}{jam} = 2.568,346\frac{kg}{jam}$
  - H_2O = 96,50% x $73.381,303\frac{kg}{jam} = 70.812,957\frac{kg}{jam}$

- **Output**

- **Aliran 15**

  Aliran 13 + Aliran 14 = Aliran 15

  7.338,130 kg/jam + 73.381,303 kg/jam = 80.719,43 kg/jam

  - $C_{10}H_{16}N_2O_6$ = 0,19% x 80.719,43 kg/jam $= 152{,}207\,\frac{kg}{jam}$
  - $CaCO_3$ = 0,01% x 80.719,43 kg/jam $= 4{,}494\,\frac{kg}{jam}$
  - H_2O = = 87,73% x 80.719,43 kg/jam $= 70.813{,}290\,\frac{kg}{jam}$
  - NaOH = 1,65% x 80.719,43 kg/jam $= 1.330{,}446\,\frac{kg}{jam}$
  - $C_2H_4NO_2Na$ = 3,22% x 80.719,43 kg/jam $= 2.602{,}244\,\frac{kg}{jam}$
  - $C_8H_{13}NO_5$ = 6,75% x 80.719,43 kg/jam $= 5.445{,}933\,\frac{kg}{jam}$
  - Na_2CO_3 = 0,27% x 80.719,43 kg/jam $= 218{,}372\,\frac{kg}{jam}$
  - $Ca(OH)_2$ = = 0,19% x 80.719,43 kg/jam $= 152{,}448\,\frac{kg}{jam}$

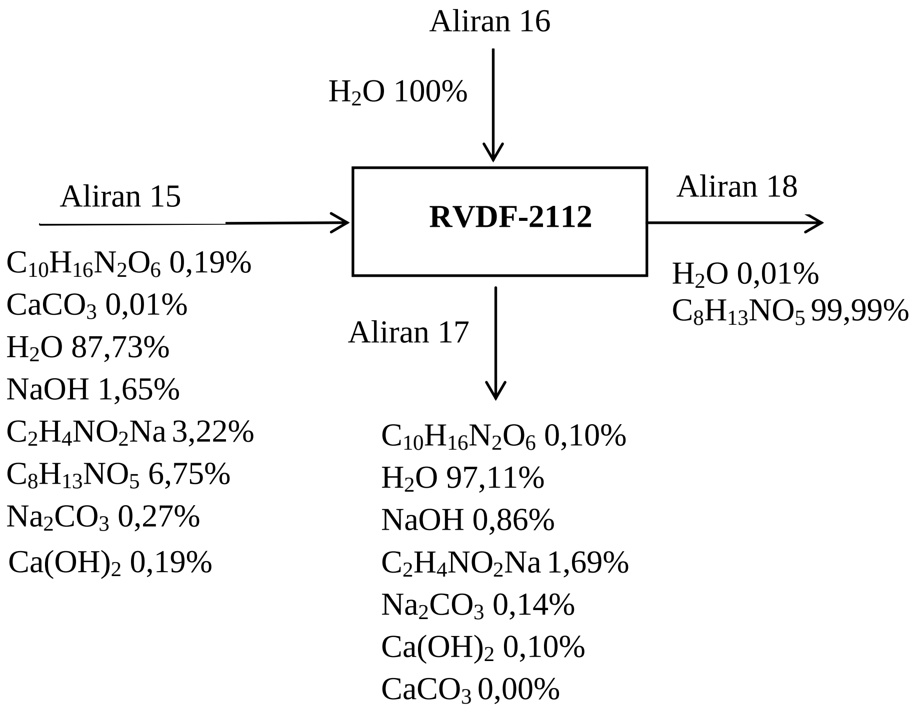
Tabel A.8 Neraca Massa Reaktor Deproteinasi (R-2102)

Komponen	**Masuk (kg/jam)**		**Keluar (kg/jam)**
	Aliran 13	**Aliran 14**	**Aliran 15**
$C_{10}H_{16}N_2O_6$	7.127,293		152,207
$CaCO_3$	210,505		4,494
H_2O	0,332	70.812,957	70.813,290
NaOH		2.568,346	1.330,446
$C_2H_4NO_2Na$			2.602,244
$C_8H_{13}NO_5$			5.445,933
Na_2CO_3			218,372
$Ca(OH)_2$			152,448
Sub total	7.338,130	73.381,303	80.719,43
Total	80.719,43		80.719,43

7. ***Rotary Vacum Drum Filter* (RVDF-2112)**

Fungsi: sebagai tempat untuk memisahkan padatan dan larutan secara vaccum berdasarkan kelarutan di dalam air.

Fungsi: sebagai tempat untuk memisahkan padatan dan larutan secara vaccum.



Kondisi operasi :

- Temperatur : 30°C
- Tekanan : <1 atm (Smith van Ness, Pers. 13.5)

Neraca massa total : Aliran 15 +Aliran 16 = Aliran 17 + Aliran 18

Neraca massa komponen :

➢ **Input**

- Aliran 15
  - $C_{10}H_{16}N_2O_6$ = 0,19% x 80.719,43 kg/jam $= 152{,}207 \frac{\text{kg}}{\text{jam}}$
  - $CaCO_3$ = 0,01% x 80.719,43 kg/jam $= 4{,}494 \frac{\text{kg}}{\text{jam}}$
  - H_2O = 87,73% x 80.719,43 kg/jam $= 70.813{,}290 \frac{\text{kg}}{\text{jam}}$
  - NaOH = 1,65% x 80.719,43 kg/jam $= 1.330{,}446 \frac{\text{kg}}{\text{jam}}$
  - $C_2H_4NO_2Na$ = 3,22% x 80.719,43 kg/jam $= 2.602{,}244 \frac{\text{kg}}{\text{jam}}$
  - $C_8H_{13}NO_5$ = 6,75% x 80.719,43 kg/jam $= 5.445{,}933 \frac{\text{kg}}{\text{jam}}$
  - Na_2CO_3 = 0,27% x 80.719,43 kg/jam $= 218{,}372 \frac{\text{kg}}{\text{jam}}$
  - $Ca(OH)_2$ = = 0,19% x 80.719,43 kg/jam $= 152{,}448 \frac{\text{kg}}{\text{jam}}$

- Aliran 16

  Penyaringan menggunakan *rotary vacuum filter* untuk memisahkan padatan dan larutan secara vacuum, padatan yang ingin dipisahkan yaitu $C_2H_4NO_2Na$ dengan kelarutan = 33 g/100 ml, (Perry's, Hal. 96)

  Maka untuk penambahan air di aliran 16 = 33 / 1000 = 0,033

  Aliran 16 (H_2O) = 2.602,244 kg/jam / 0,033 = 78.855,873 kg/jam

➢ **Output**

- Aliran 17

  Jumlah partikel yang keluar di *rotary vacuum filter* yaitu :

  - $C_{10}H_{16}N_2O_6$ = Aliran 15 = $152{,}207\ \frac{kg}{jam}$
  - $CaCO_3$ = Aliran 15 = $4{,}494\ \frac{kg}{jam}$
  - NaOH = Aliran 15 = $1.330{,}446\ \frac{kg}{jam}$
  - $C_2H_4NO_2Na$ = Aliran 15 = $2.602{,}244\ \frac{kg}{jam}$
  - Na_2CO_3 = Aliran 15 = $218{,}372\ \frac{kg}{jam}$
  - $Ca(OH)_2$ = Aliran 15 = $152{,}448\ \frac{kg}{jam}$
  - H2O = (Aliran 15 + Aliran 16) – Aliran 18 = 149.668,523 kg/jam

- Aliran 18

  Jumlah partikel yang tertahan di *rotary vacuum filter* yaitu :

  - $C_8H_{13}NO_5$ = 6,75% x 80.719,43 kg/jam = $5.445{,}933\ \frac{kg}{jam}$
  - H_2O = 94,27% x M = 94,27% x 0,68 kg/jam = 0,640 kg/jam

  Kelembaban pada *cake* ditentukan dengan persamaan berikut.

  $$M = S(\frac{\rho}{\rho_s})\left(\frac{X}{1-X}\right)$$

  Berdasarkan perhitungan spesifikasi alat (Lampiran C), didapat:

  S = 0,03 kg/m^3 (brown, pers 179)

  ρ_f = 972,76 kg/m^3 (walas, tabel 11.6)

  ρ_s = 83,56 kg/m^3

  X = 0,7

  Maka, kelembaban cake:

$$M = S\left(\frac{\rho}{\rho_s}\right)\left(\frac{X}{1-X}\right) \qquad \text{(Brown, Hal 225)}$$

$$M = 0{,}03\left(\frac{972{,}76\ kg/m^3}{83{,}56\ kg/m^3}\right)\left(\frac{0{,}7}{1-0{,}7}\right)$$

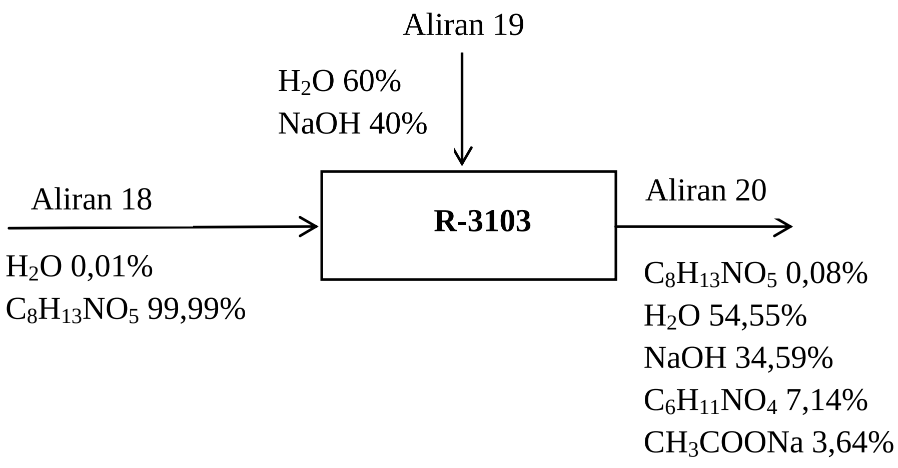
$$M = 0{,}68 \text{ kg/jam}$$

Tabel A.9 Neraca Massa pada *Rotary Vaccum Drum Filter-2112*

Komponen	Masuk (Kg/jam)		Keluar (Kg/jam)	
	Aliran 15	Aliran 16	Aliran 17	Aliran 18
$C_{10}H_{16}N_2O_6$	152,207		152,207	
$CaCO_3$	4,494		4,494	
H_2O	70.813,290	78.855,873	149.668,523	0,640
NaOH	1.330,446		1.330,446	
$C_2H_4NO_2Na$	2.602,244		2.602,244	
$C_8H_{13}NO_5$	5.445,933			5.445,933
Na_2CO_3	218,372		218,372	
$Ca(OH)_2$	152,448		152,448	
Sub total	80.719,433	78.855,873	154.128,733	5.446,573
Total	**159.575,306**		**159.575,306**	

8. Reaktor Deasetilasi (R-3103)

Fungsi: sebagai tempat untuk mengkonversi kitin menjadi kitosan.



Kondisi operasi :

- Temperatur : 90°C
- Tekanan : 1 atm
- konversi reaksi : 99% (Ramlah,2010)

	$C_8H_{13}NO_5$	+	NaOH	→	$C_6H_{11}NO_4$	+	CH_3COONa
m:	26,83		544,66				
b:	26,58		26,558		26,58		26,58
s:	0,24		518,07		26,58		26,58

➢ **Input**

- **Aliran 18**
  - Kitin ($C_8H_{13}NO_5$) = 99,99% x 5.446,573 kg/jam $= 5.445,933 \frac{kg}{jam}$
  - Air (H_2O) = 0,01% x 5.446,573 kg/jam $= 0,640 \frac{kg}{jam}$
- **Aliran 19**

  Penambahan NaOH sebanyak 40% pada reaktor deasetilasi, dengan perbandingan NaOH dengan pelarut yaitu 1:10 **(**ISSN 2407-8476**)**
  - NaOH = 40% x $54.465,73 \frac{kg}{jam} = 21.786,292 \frac{kg}{jam}$
  - H_2O = 60% x $54.465,73 \frac{kg}{jam} = 32.679,438 \frac{kg}{jam}$

➢ **Output**

- **Aliran 20**

  Aliran 18 + Aliran 19 = Aliran 20

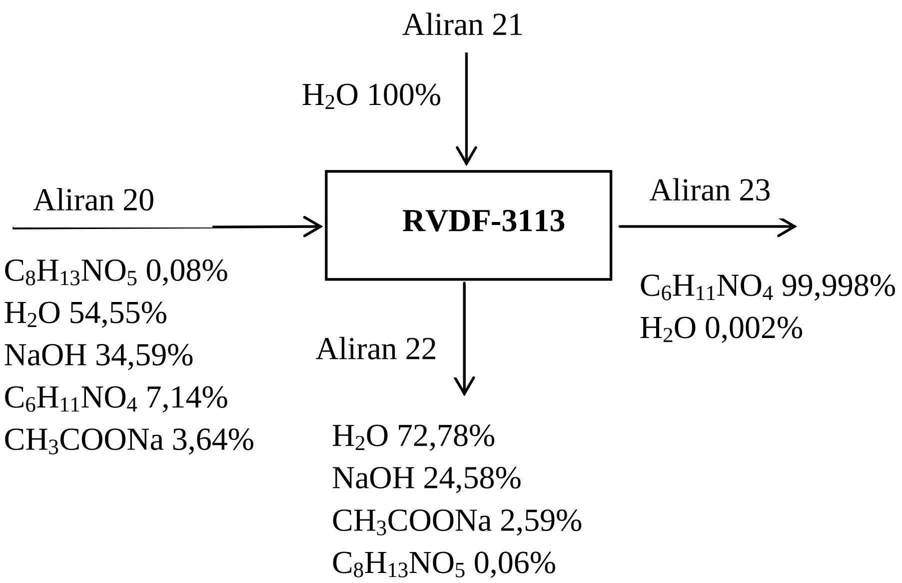
  5.446,573 kg/jam + 54.465,731 kg/jam = 59.912,304 kg/jam
  - $C_8H_{13}NO_5$ = 0,08% x 59.912,304 kg/jam $= 49,558 \frac{kg}{jam}$
  - H_2O = 54,55% x 59.912,304 kg/jam $= 32.680,079 \frac{kg}{jam}$
  - NaOH = 34,59% x 59.912,304 kg/jam $= 20.722,967 \frac{kg}{jam}$
  - $C_6H_{11}NO_4$ = 7,14% x 59.912,304 kg/jam $= 4.279,884 \frac{kg}{jam}$
  - CH_3COONa = 3,64% x 59.912,304 kg/jam $= 2.179,816 \frac{kg}{jam}$

Tabel A.10 Neraca Massa Reaktor Deasetilasi (R-3103)

Komponen	**Masuk (kg/jam)**		**Keluar (kg/jam)**
	Aliran 18	**Aliran 19**	**Aliran 20**
$C_8H_{13}NO_5$	5.445,933		49,558
H_2O	0,640	32.679,438	32.680,079
NaOH		21.786,292	20.722,967
$C_6H_{11}NO_4$			4.279,884
CH_3COONa			2.179,816
Sub total	5.446,573	54.465,731	59.912,304
Total	59.912,304		59.912,304

9. ***Rotary Vacum Drum Filter*** **(RVDF-3113)**

Fungsi: sebagai tempat untuk memisahkan padatan dan larutan secara vaccum.



Kondisi operasi :

- Temperatur : 30°C
- Tekanan : <1 atm (Smith van Ness, Pers. 13.5)

Neraca massa total : Aliran 20 +Aliran 21 = Aliran 22 + Aliran 23

Neraca massa komponen :

➢ **Input**

- Aliran 20
  - $C_8H_{13}NO_5$ = 0,08% x 59.912,304 kg/jam = 49,558 $\frac{\text{kg}}{\text{jam}}$
  - H_2O = 54,55% x 59.912,304 kg/jam = 32.680,079 $\frac{\text{kg}}{\text{jam}}$

- NaOH = 34,59% x 59.912,304 kg/jam = $20.722,967 \frac{kg}{jam}$
- $C_6H_{11}NO_4$ = 7,14% x 59.912,304 kg/jam = $4.279,884 \frac{kg}{jam}$
- CH_3COONa = 3,64% x 59.912,304 kg/jam = $2.179,816 \frac{kg}{jam}$

- Aliran 21

Penyaringan menggunakan *rotary vacuum filter* untuk memisahkan padatan dan larutan secara vacuum, padatan yang ingin dipisahkan yaitu CH_3COONa dengan kelarutan = 76 g/100 ml, (Perry's, Hal. 96)

Maka untuk penambahan air di aliran 21 = 76/1000 = 0,076

- Aliran 16 (H_2O) = 2.179,816 kg/jam / 0,076 = 28.681,796 kg/jam

➢ **Output**

- Aliran 22

Jumlah partikel yang keluar di *rotary vacuum filter* yaitu :

- NaOH = Aliran 20 = $20.722,967 \frac{kg}{jam}$
- CH_3COONa = Aliran 20 = $2.179,816 \frac{kg}{jam}$
- $C_8H_{13}NO_5$ = Aliran 20 = $49,558 \frac{kg}{jam}$
- H2O = (Aliran 20 + Aliran 21) – Aliran 23 = 61.361,804 kg/jam

- Aliran 23

Jumlah partikel yang tertahan di *rotary vacuum filter* yaitu :

- $C_6H_{11}NO_4$ = 100% x 4.279,884 kg/jam = $4.279,884 \frac{kg}{jam}$
- H_2O = 55,54% x M = 55,54% x 0,12 kg/jam = 0,070 kg/jam

Kelembaban pada *cake* ditentukan dengan persamaan berikut.

$$M = S(\frac{\rho}{\rho_s}) \left(\frac{X}{1-X}\right)$$

Berdasarkan perhitungan spesifikasi alat (Lampiran C), didapat:

S = 0,03 kg/m^3 (brown, pers 179)

ρ_f = 882,31 kg/m^3 (walas, tabel 11.6)

ρ_s = 431,91 kg/m^3

X = 0,7

Maka, kelembaban cake:

M $= S(\frac{\rho}{\rho_s})\left(\frac{X}{1-X}\right)$ (Brown, Hal 225)

M $= 0{,}03\ (\frac{882{,}31\ kg/m^3}{431{,}91\ kg/m^3})\left(\frac{0{,}7}{1-0{,}7}\right)$

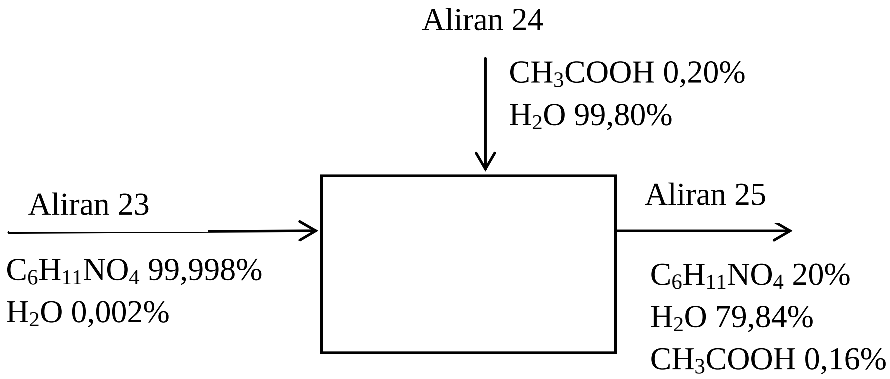
M = 0,12 kg/jam

Tabel A.11 Neraca Massa pada *Rotary Vaccum Drum Filter 3113*

Komponen	Masuk (Kg/jam)		Keluar (Kg/jam)	
	Aliran 20	Aliran 21	Aliran 22	Aliran 23
$C_8H_{13}NO_5$	49,558		49,558	
$C_6H_{11}NO_4$	4.279,884			4.279,884
H_2O	32.680,079	28.681,796	61.361,804	0,070
NaOH	20.722,967		20.722,967	
CH_3COONa	2.179,816		2.179,816	
Sub total	59.912,304	28.681,796	84.314,146	4.279,954
Total	**88.594,100**		**88.594,100**	

10. Tangki Pelarutan dengan CH3COOH (MT-3121)

Fungsi: sebagai tempat untuk melarutkan Kitosan



Kondisi Operasi:

- Temperatur : 30˚C
- Tekanan : 1 atm

Neraca massa total : Aliran 23 + Aliran 25 = Aliran 26

Neraca massa komponen :

➢ **Input**

- **Aliran 23**
  - $C_6H_{11}NO_4 = 4.279{,}884 \frac{kg}{jam}$
  - H_2O = 0,070 kg/jam
- **Aliran 25**

Penambahan CH_3COOH sebanyak 0,20% pada *Mixing Tank*, dengan perbandingan $C_6H_{11}NO_4$ dengan pelarut yaitu 1:4 (jurnal gelasi ionik)

Maka pelarut pada aliran 25 = 4 x 4.279,884 = 17.119,534 kg/jam

  - CH_3COOH = 0,20% x 17.119,534 kg/jam = $34{,}239 \frac{kg}{jam}$
  - H_2O = 99,80% x 17.119,534 kg/jam = $17.085{,}295 \frac{kg}{jam}$

➢ **Output**

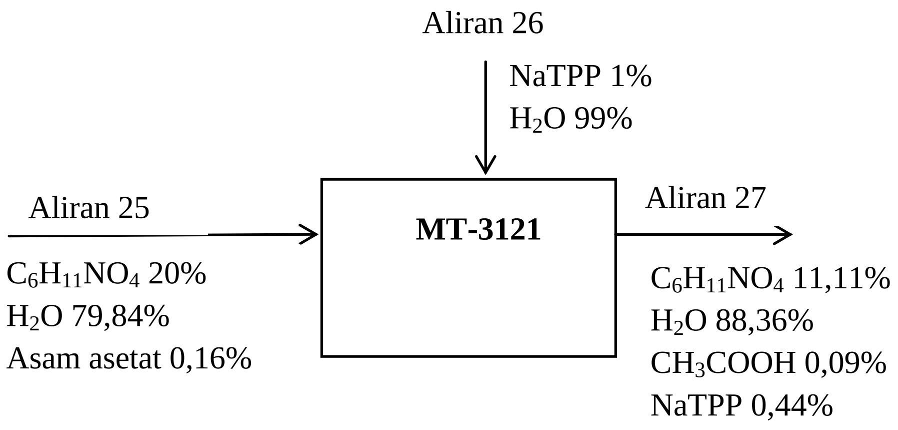
- **Aliran 26**
  - CH_3COOH = 100% x 34,239 kg/jam = $34{,}239 \frac{kg}{jam}$
  - $C_6H_{11}NO_4$ =100% x 4.279,884 kg/jam = $4.279{,}884 \frac{kg}{jam}$
  - H_2O = Aliran 23 + Aliran 25 = 17.085,365 kg/jam

Tabel A.12 Neraca Massa Mixing Tank CH_3COOH (MT-3121)

Komponen	**Masuk**		**Keluar (kg/jam)**
	Aliran 23	**Aliran 24**	**Aliran 25**
$C_6H_{11}NO_4$	4.279,884		4.279,884
H2O	0,070	17.085,295	17.085,365
Asam asetat		34,239	34,239
Sub Total	4.279,954	17.119,534	21.399,488
Total	21.399,488		21.399,488

11. Tangki Pelarutan dengan NaTPP (MT-3122)

Fungsi: sebagai tempat untuk melarutkan Kitosan



Kondisi Operasi:

- Temperatur : 30˚C
- Tekanan : 1 atm

Neraca massa total : Aliran 23 + Aliran 24 = Aliran 26

Neraca massa komponen :

➢ **Input**

- **Aliran 23**
  - $C_6H_{11}NO_4 = 4.279,884 \frac{kg}{jam}$
  - H_2O = 17.085,365 kg/jam
  - CH_3COOH = 34,239 kg/jam
- **Aliran 24**

  Penambahan NaTPP sebanyak 1% pada *Mixing Tank*, dengan perbandingan $C_6H_{11}NO_4$ dengan pelarut yaitu 1:4 (jurnal gelasi ionik)

  Maka pelarut pada aliran 24 = 4 x 4.279,884 = 17.119,534 kg/jam

  - NaTPP = 1% x 17.119,534 kg/jam $= 171,195 \frac{kg}{jam}$
  - H_2O = 99% x 17.119,534 kg/jam $= 16.948,339 \frac{kg}{jam}$

➢ **Output**

- **Aliran 26**
  - CH_3COOH = 100% x 34,239 kg/jam $= 34,239 \frac{kg}{jam}$
  - $C_6H_{11}NO_4$ =100% x 4.279,884 kg/jam $= 4.279,884 \frac{kg}{jam}$

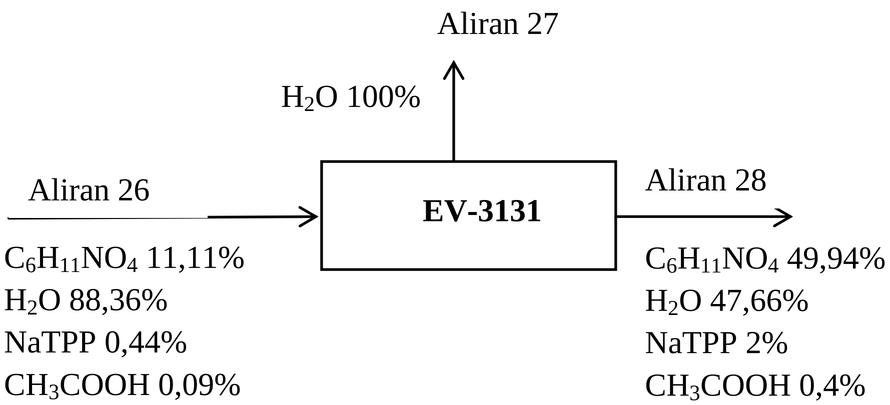
- NaTPP = 100% x 171,195 = 171,195 kg/jam
- H_2O = Aliran 23 + Aliran 26 = 34.033,704 kg/jam

Tabel A.13 Neraca Massa Mixing Tank NaTPP (MT-3122)

Komponen	**Masuk**		**Keluar (kg/jam)**
	Aliran 25	**Aliran 26**	**Aliran 27**
$C_6H_{11}NO_4$	4.279,884		4.279,884
H2O	17.085,365	16.948,339	34.033,704
Asam asetat	34,239		34,239
NaTPP		171,195	171,195
Sub Total	21.399,488	17.119,534	38.519,022
Total	38.519,022		38.519,022

12. Evaporator (EV-3131)

Fungsi: sebagai tempat untuk pemisahan antara padatan dan cairan.



Kondisi operasi :

- Temperatur : 90°C
- Tekanan : 1 atm
- Efisiensi alat : 88%

Neraca massa total : Aliran 26 = Aliran 27 + Aliran 28

Aliran 26 = 38.519,022 kg/jam

Neraca massa komponen :

- **Input :**
- **Aliran 26**
- $C_6H_{11}NO_4$ = 11,11% x 38.519,022 kg/jam $= 4.279,884 \frac{kg}{jam}$
- H_2O = 88,36% x 38.519,022 kg/jam $= 34.033,704 \frac{kg}{jam}$

- NaTPP = 0,043% x 38.519,022 kg/jam $= 171{,}195 \frac{\text{kg}}{\text{jam}}$

- CH_3COOH = 0,09% x 238.519,022 kg/jam $= 34{,}239 \frac{\text{kg}}{\text{jam}}$

➢ **Output**

- **Aliran 27**

  karena efisiensi alat evaporator 88%, Maka jumlah H_2O pada aliran 27 :

- $H_2O = \frac{88}{100} \times 34.033{,}704 \frac{\text{kg}}{\text{jam}} = 29.949{,}660$ kg/jam

- **Aliran 28**

- $C_6H_{11}NO_4$ = Aliran 26 $= 4.279{,}884 \frac{\text{kg}}{\text{jam}}$

- H_2O = Aliran 26 – Aliran 27 $= 4.084{,}045 \frac{\text{kg}}{\text{jam}}$

- NaTPP = Aliran 26 $= 171{,}195 \frac{\text{kg}}{\text{jam}}$

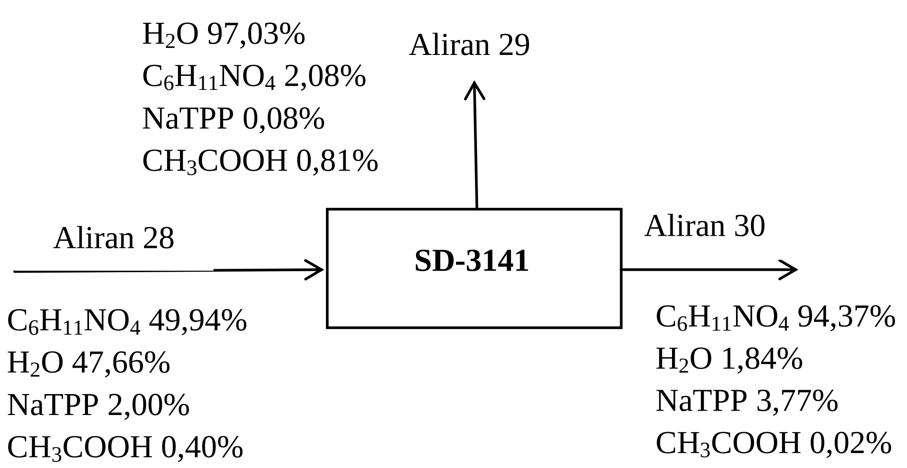
- CH_3COOH = Aliran 26 $= 34{,}239 \frac{\text{kg}}{\text{jam}}$

Tabel A.14 Neraca Massa Evaporator (EV-3131)

Komponen	Masuk (kg/jam)	Keluar (kg/jam)	
	Aliran 26	Aliran 27	Aliran 28
$C_6H_{11}NO_4$	4.279,884		4.279,884
H2O	34.033,704	29.949,660	4.084,045
NaTPP	171,195		171,195
Asam Asetat	34,239		34,239
Subtotal	38.519,022	29.949,660	8.569,362
Total	38.519,022	38.519,022	

13. Spray Dryer (SD-3141)

Fungsi : sebagai tempat untuk pemisahan antara padatan Cairan dan gas .



Kondisi operasi:

- Temperatur : 120°C
- Tekanan : 1 atm
- Efisiensi alat : 98%
- Reject : 2%

Neraca massa total : Aliran 28 = Aliran 29 + Aliran 30

Aliran 28 = 8.569,362 kg/jam

Neraca Massa Komponen :

➢ **Input**

- **Aliran 28**

- Kitosan ($C_6H_{11}NO_4$) $= 49{,}94\%$ x $8.569{,}362$ kg/jam $= 4.279{,}884 \frac{kg}{jam}$
- H_2O $= 47{,}66\%$ x $8.569{,}362$ kg/jam $= 4.084{,}045 \frac{kg}{jam}$
- NaTPP $= 2\%$ x $8.569{,}362$ kg/jam $= 171{,}195 \frac{kg}{jam}$
- CH_3COOH $= 0{,}40\%$ x $8.569{,}362$ kg/jam $= 34{,}239 \frac{kg}{jam}$

➢ **Output**

- **Aliran 29**

  - $C_6H_{11}NO_4$ $= 2\%$ x $4.279{,}884$ kg/jam $= 85{,}598 \frac{kg}{jam}$
  - H_2O $= 98\%$ x $4.084{,}045$ kg/jam $= 4.002{,}364 \frac{kg}{jam}$
  - NaTPP $= 2\%$ x $171{,}195$ kg/jam $= 3{,}424 \frac{kg}{jam}$
  - CH_3COOH $= 98\%$ x $34{,}239 \frac{kg}{jam} = 33{,}554 \frac{kg}{jam}$

- **Aliran 30**

  - $C_6H_{11}NO_4$ $= 98\%$ x $4.279{,}884$ kg/jam $= 4.194{,}286 \frac{kg}{jam}$
  - H_2O $= 2\%$ x $4.084{,}045$ kg/jam $= 81{,}681 \frac{kg}{jam}$
  - NaTPP $= 98\%$ x $171{,}195$ kg/jam $= 167{,}771 \frac{kg}{jam}$
  - CH_3COOH $= 2\%$ x $34{,}239 \frac{kg}{jam} = 0{,}685 \frac{kg}{jam}$

Tabel A.15 Neraca Massa Spray Dryer-3141

Komponen	Masuk (kg/jam)	Keluar (kg/jam)	
	Aliran 28	Aliran 29	Aliran 30
$C_6H_{11}NO_4$	4.279,884	85,598	4.194,286
H2O	4.084,045	4.002,364	81,681
NaTPP	171,195	3,424	167,771
Asam Asetat	34,239	33,554	0,685
Subtotal	8.569,362	4.124,939	4.444,42
Total	8.569,362		8.569,362

LAMPIRAN B
NERACA ENERGI

➢ Persamaan yang digunakan untuk menghitung nilai panas (Q)

- Menggunakan data Cp dalam bentuk konstanta

  $Q = m\ Cp\ \Delta T$ **(Himmelblau, Pers. 23.12, Hal. 693)**

  Data Cp konstanta dapat diperoleh dari Perry's *Chemichal Handbook* Vol.7 hal 354. Sedangkan data Cp konstanta untuk bahan yang dihitung berdasarkan gugus fungsi dapat dilihat pada buku Perry's *Chemical Handbook* Vol.7 hal 354.

➢ Persamaan yang digunakan untuk menghitung panas reaksi (Qr)

$Q_R = -\Delta H_R$ **(Himmelblau, Pers. 25.1, Hal.770)**

- $\Delta H_R = \Delta H_R^o + (\Delta H\ produk - \Delta H\ reaktan)$
- $\Delta H_R^o = \Delta H_f^o\ produk - \Delta H_f^o\ reaktan$
- $\Delta H\ produk = \sum(m \, . \, C_p \, . \, \Delta T)\ produk$
- $\Delta H\ reaktan = \sum(m \, . \, C_p \, . \, \Delta T)\ reaktan$

Nilai data ΔH_f dapat diperoleh dari Perry's *Chemical Engineers*' Ed. 8^{th} hal 2-185 dan David M. Himmelblau Ed.5^{th} hal 1049.

Tabel B.1 Nilai Kapasitas Panas Komponen Padat

Komponen	**Cp (kkal/kg.K)**
$C_{10}H_{16}N_2O_6$	0,286580
$CaCO_3$	0,189771
H_2O	0,378957
NaOH	0,281848
$C_2H_4NO_2Na$	0,335118
$C_8H_{13}NO_5$	0,249338
Na_2CO_3	0,233436
$Ca(OH)_2$	0,226765
CH_3COONa	0,284036
$C_6H_{11}NO_4$	0,243323
$Na_5P_3O_{10}$	0,224094
CH_3COOH	0,314133

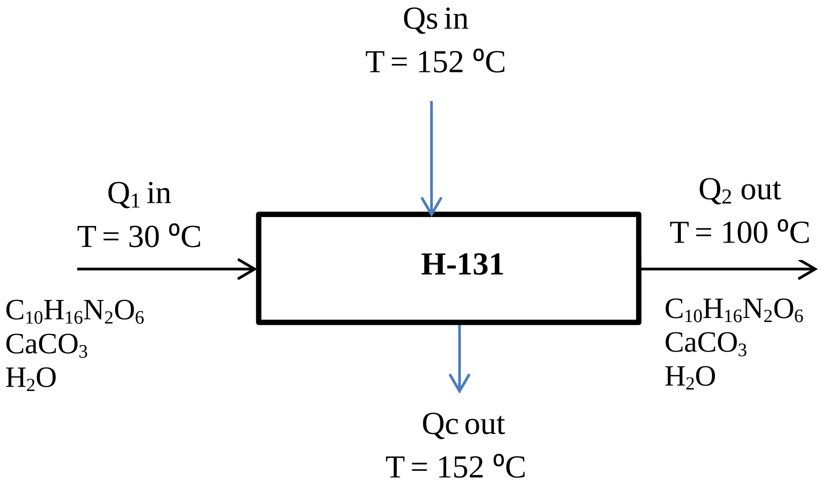
Sumber: The Properties of Gases & Liquids, Fourth Edition . Robert C. Reid John M.Prausnitz Bruce E. Poling

Tabel B.2 Nilai Panas Pembentukan Komponen

Komponen	**Kondisi**	**ΔHf**	**ΔHf (kkal/kmol)**
NaOH	c	-101,7200	-101720,00
H2O	l	-68,3150	-68315,00
O2	g	0,0000	0,00
CO2	g	-94,0510	-94051,00
Na2CO3	c	-269,8	-269800,00
Ca(OH)2	c	-235,5800	-235580,00
CaCO3	c	-289,5	-289500,00

Sumber: The Properties of Gases & Liquids, Fourth Edition . Robert C. Reid John M.Prausnitz Bruce E. Poling

1. *Heater* (H-131)



Kondisi operasi

- Tekanan : 1 atm
- Temperatur : 100°C
- T_{in} : 30˚C = 303˚K
- T_{out} : 100˚C = 373˚K
- T_{steam} : 152˚C = 425˚K

➢ **Input**

- **Q_1**

T_{in} = 30°C (303°K)

T_{ref} = 25°C (298°K)

Tabel B.3 Energi pada Q_1 *Heater* (H-332)

Komponen	m (kg/jam)	cP (kkal/kg.K)	dT	Q1 (kkal/jam)
$C_{10}H_{16}N_2O_6$	7.272,0061	0,3252	5	11.822,7588
$CaCO_3$	6.681,4310	0,1898	5	6.339,6944
H_2O	1.768,8457	0,3790	5	3.351,5812
Total	**15.722,2828**			**21.514,0344**

- **Output**
  - **Q_2**

    T_{in} = 100°C (373°K)

    T_{ref} = 25°C (298°K)

Tabel B.4 Energi pada Q_2 *Heater* (H-332)

Komponen	m (kg/jam)	cP (kkal/kg.K)	dT	Q2 (kkal/jam)
$C_{10}H_{16}N_2O_6$	7.272,0061	0,3252	75	177.341,3823
$CaCO_3$	6.681,4310	0,1898	75	95.095,4155
H_2O	1.768,8457	0,3790	75	50.273,7175
Total	**15.722,2828**			**322.710,5154**

Beban Panas

Masuk = Keluar

$\Delta Q = Q_2 - Q_1$

= 322.710,5154 – 21.514,0344 kkal/jam

= 301.196,48 kkal/jam

(ΔQ = +, membutuhkan steam)

- **Panas *Steam***

  Medium pemanas adalah *saturated steam* pada T = 152°C, Sehingga:

  H_l = 640,8 kkal/kg

  H_v = 2.747,7 kkal/kg

  λ_s = 2.106,9 kkal /kg

  (Smith van Ness, Appendix F.1 *Saturated Steam*, Hal. 669)

Jumlah *steam* yang dibutuhkan (m_s):

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{301.196,48\ \frac{kkal}{jam}}{2.106,9\ \frac{kkal}{kg}} = 142,96\ \frac{kg}{jam}$$

Panas *steam* masuk ($Q_{s\ in}$):

$$Q_{s\ in} = m_s\ x\ H_v$$

$$Q_{s\ in} = 142,96\ \frac{kg}{jam}\ x\ 2.747,7\ \frac{kkal}{kg} = 392.803,44\ \frac{kkal}{jam}$$

Panas *steam* keluar ($Q_{s\ out}$):

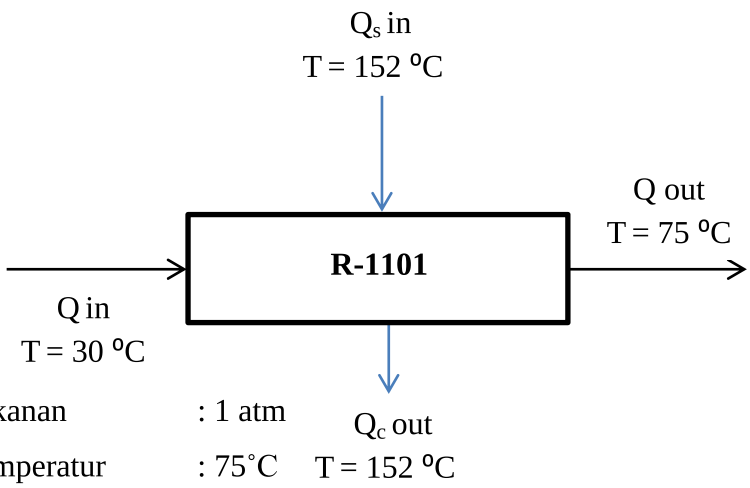
$$Q_{s\ out} = m_s\ x\ H_l$$

$$Q_{s\ out} = 142,96\ \frac{kg}{jam}\ x\ \ 640,8\ \frac{kkal}{kg} = 91.606,96\ \frac{\text{Kkal}}{\text{jam}}$$

Tabel B.5 Neraca Energi *Heater Heater* (H-131)

Komponen	Panas Masuk (kkal/jam)	Panas Keluar (kkal/jam)
Q_1	21.514,0344	
Q_2		322.710,5154
$Q_{s\ in}$	392.803,4415	
$Q_{c\ out}$		91.606,9605
Total	**414.317,4759**	**414.317,4759**

2. Reaktor Demineralisasi (R-1101)



Kondisi op

- Tekanan : 1 atm
- Temperatur : 75˚C
- T_{in} : 30˚C = 303˚K
- T_{out} : 75˚C = 348˚K
- T_{ref} : 25 ˚C = 298˚K
- pH : 11
- waktu : 3 jam

➢ **Input**

- **Q_3**

T_{in} = 30˚C = 303˚K

T_{ref} = 25°C = 298˚K

Tabel B.6 Energi pada Q_3 Reaktor Demineralisasi (R-1101)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	ΔT (K)	Q3 (Kkal/Kg.K)
$C_{10}H_{16}N_2O_6$	260	7.127,2932	27,4127	0,3252	5	44,5673
$CaCO_3$	100	6.548,4706	65,4847	0,1898	5	62,1353
H_2O	18	1.733,6457	96,3136	0,3790	5	182,4936
Total		15.409,4094	189,2110	0,8939		289,1962

- **Q_4**

T_{in} = 30°C (303°K)

T_{ref} = 25°C (298°K)

Tabel B.7 Energi pada Q_4 Reaktor Demineralisasi (R-1101)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	ΔT (K)	Q4 (Kkal/Kg.K)
HCl	36	5.624,4344	156,2343	0,2140	5	167,1443
H2O	18	148.469,6595	63,3797	0,3790	5	120,0908
Total		154.094,0939	219,6139	0,5929		287,2351

➢ **Output**

- **Q_5**

T_{in} = 75°C (348°K)

T_{ref} = 25°C (298°K)

Tabel B.8 Energi pada Q_5 Reaktor Demineralisasi (R-1101)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/Kg.K)	ΔT (K)	Q5 (kkal/jam)
$C_{10}H_{16}N_2O_6$	260	7.127,2932	27,4127	0,3252	50	445,6725
$CaCO_3$	100	210,5048	2,1050	0,1898	50	19,9738
H_2O	18	151.344,1390	8.408,0077	0,3790	50	159.313,6156
HCl	36	1.061,0991	29,4750	0,2140	50	315,3324
CO_2	44	2.788,7049	63,3797	0,2048	50	649,0408

$CaCl_2$	110,98	6.971,7623	62,8200	0,1671	50	524,7720
Total		169.503,5033		1,4797		161.268,4072

Reaksi 1:

Konversi 99% **(Smith van Ness, Pers. 13.5, hal 467)**

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$

$\Delta H_R°$ = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan **(Himmelblau, Pers. 25.1, hal 770)**

$\Delta H_R°$ = [{n x $\Delta H_f°(CO_2)$}] + [{n x $\Delta H_f°(H_2O)$}] + {n x $\Delta H_f°(CaCl_2)$}] - [{n x $\Delta H_f°(CaCO_3)$} + {n x $\Delta H_f°(HCl)$}]

$\Delta H_R°$ = [{63,3797 x (100,1386 kkal/kmol)}] + [{63,3797 x (68,2717 kkal/kmol)}] + [{63,3797 x (269,8960 kkal/kmol)}] – [{63,3797 x (340,1000 kkal/kmol)} + [{126,7593 x (399,3505 kkal/kmol)}

$\Delta H_R°$ = $44.397,1150 \ \frac{kkal}{jam}$

Maka:

ΔH_R = $\Delta H_R°$ + ($Q_{produk} - Q_{reaktan}$)

ΔH_R = [44.397,1150 kkal/jam + (2.379,3959 kkal/jam – 1.957,4901 kkal/jam)]

ΔH_R = 44.819,0208 kkal/jam

Q_R = $-\Delta H_R$

Q_{R1} = -44.819,0208 kkal/jam

- **Beban Panas Tangki**

  ΔQ = $Q_{out} - Q_{in}$

  ΔQ = $Q_5 - (Q_4+Q_3+Qr\ total)$

  ΔQ = 161.268,4072 kkal/jam – (287,2351 kkal/jam + 289,1962 kkal/jam + (-44.819,0208 kkal/jam)

  ΔQ = 205.510,9968 kkal/jam

- **Panas *Steam***

  Medium pemanas adalah *saturated steam* pada T = 152°C

  Sehingga:

H_l = 640,8 kkal/kg

H_v = 2.747,7 kkal/kg

λ_s = 2.106,9 kkal /kg

(Smith van Ness, Appendix F.1 *Saturated Steam*, Hal. 669)

Jumlah *steam* yang dibutuhkan (m_s):

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{205.510,9968 \frac{kkal}{jam}}{2.106,9 \frac{kkal}{kg}} = 97,5419 \frac{kg}{jam}$$

Panas *steam* masuk ($Q_{s\ in}$):

$$Q_{s\ in} = m_s\ x\ H_v$$

$$Q_{s\ in} = 97,5419\ \frac{kg}{jam} x\ 2.747,7\ \frac{kkal}{kg} = 268.015,8365\ \frac{kkal}{jam}$$

Panas *steam* keluar ($Q_{s\ out}$):

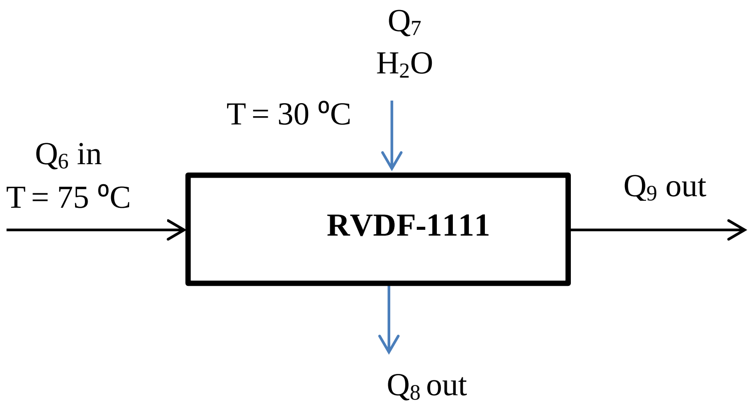
$$Q_{s\ out} = m_s\ x\ Hl$$

$$Q_{s\ out} = 97,5419\ \frac{kg}{jam} x\ 640,8 \frac{kkal}{kg} = 62.504,8397 \frac{kkal}{jam}$$

Tabel B.9 Neraca Energi Reaktor Demineralisasi (R-1101)

Komponen	Panas Masuk (kkal/jam)	Panas Keluar (kkal/jam)
Q_3	289,1962	
Q_4	287,2351	
Q_5		161.268,4072
Qr		44.819,0208
Qs in	268.015,8365	
Qc out		62.504,8397
Total	268.592,2677	268.592,2677

3. Rotary Vacum Drum Filter 1 (RVDF-1111)



Kondisi operasi

- Tekanan : 1 atm
- T_{in} : 75°C = 348°K
- T_{out} : ? °C

➢ **Input**

- **Q_6**

T_{in} = 75 °C (348 °K)

T_{ref} = 25 °C (298 °K)

Tabel B.10 Energi pada Q_6 *Rotary Vacuum Drum Filter* (RVDF-1111)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q6 (Kkal/jam)
$C_{10}H_{16}N_2O_6$	260	7.127,2932	27,4127	0,3252	50	445,6725
$CaCO_3$	100	210,5048	2,1050	0,1898	50	19,9738
H_2O	18	151.344,1390	8.408,0077	0,3790	50	159.313,6156
HCl	36	1.061,0991	29,4750	0,2140	50	315,3324
CO_2	44	2.788,7049	63,3797	0,2048	50	649,0408
$CaCl_2$	110,98	6.971,7623	62,8200	0,1671	50	524,7720
Total		169.503,5033				160.743,6352

- **Q_7**

T_{out} = 30°C (363 °K)

T_{ref} = 25°C (298 °K)

Tabel B.11 Energi pada Q_5 *Rotary Vacuum Drum Filter* (RVDF-1111)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	ΔT (K)	Q7 (Kkal/jam)
H2O	18	60.920,6773	3.384,4821	0,3790	5	6.412,8637
Total						6.412,8637

➢ **Output**

- **Q_8**

T_{out} = T°C (T°K)

T_{ref} = 25°C (298 °K)

Tabel B.12 Energi pada Q_8 *Rotary Vacuum Drum Filter* (RVDF-1111)

Komponen	BM	Massa (Kg/jam)	n(kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q8 (Kkal/jam)
$C_{10}H_{16}N_2O_6$	260			0,3252	T-298ºK	
$CaCO_3$	100			0,1898	T-298ºK	
H_2O	18	212.264,4841	11.792,4713	0,3790	T-298ºK	4.468,8381
HCL	36	1.061,0991	29,4750	0,2140	T-298ºK	6,3066
CO_2	44	2.788,7049	63,3797	0,2048	T-298ºK	12,9808
$CaCl_2$	110,98	6.971,7623	62,8200	0,1671	T-298ºK	10,4954
Total		223.086,0504				4.498,6210

- **Q_9**

T_{out} = T°C (T K)

T_{ref} = 25°C (298,15 K)

Tabel B.13 Energi pada Q_9 *Rotary Vacuum Drum Filter* (RVDF-1111)

Komponen	BM	Massa (Kg/jam)	n(kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q9 (Kkal/jam)
H_2O	18	0,3323	0,0185	0,3790	T-298ºK	0,0070
$C_{10}H_{16}N_2O_6$	260	7.127,2932	27,4127	0,3252	T-298ºK	8,9135
$CaCO_3$	100	210,5048	2,1050	0,1898	T-298ºK	0,3995
Total		7.338,1303				9,3199

Neraca Energi :

$Q_{in} = Q_{out}$

Q6 + Q7 = Q8 + Q9

160.743,6453 Kkal/jam + 6.412,8637 Kkal/jam = 4.498,6210 Kkal/jam (T-298ºK)

\+ 9,3199 Kkal/jam (T-298ºK)

167.156,4989 Kkal/jam = 4.507,9409 (T-298ºK)

T-298ºK = 37,0805 Kkal/jam

T = 335,2305 ºK

T = 62,2305 ºC

Sehingga :

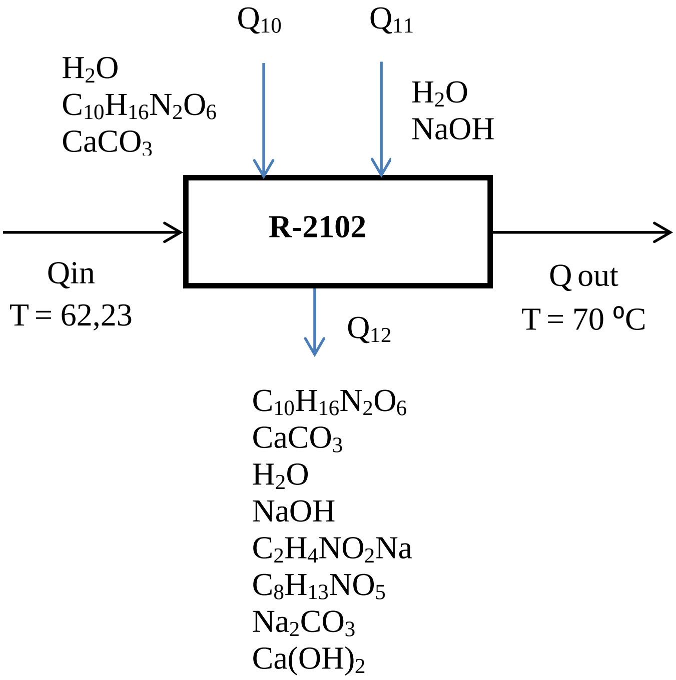
Q8 = 4.498,6210 x (335,2305 ºK - 298ºK) = 166.810,9119 Kkal/jam

Q9 = 9,3199 x (335,2305 ºK - 298ºK) = 345,5870 Kkal/jam

Tabel B.14 Neraca Energi *Rotary Vacuum Drum Filter* (RVDF-1111)

Komponen	Masuk (Kkal/Jam)	Keluar (Kkal/jam)
Q6	160.743,6352	
Q7	6.412,8637	
Q8		166.810,9119
Q9		345,5870
Total	167.156,4989	167.156,4989

4. Reaktor Deproteinasi (R-2102)



Kondisi operasi :

- Tekanan : 1 atm
- Temperatur : 70˚C
- T_{in} : 30˚C = 303˚K
- T_{out} : 70˚C = 343˚K
- pH : 11
- waktu : 1 jam

➢ **Input**

- **Q_{10}**

T_{in} = 62,23 ˚C = 335,23˚K

T_{ref} = 25 °C = 298˚K

Tabel B.15 Energi pada Q_{10} Reaktor Deproteinasi (R-2102)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	ΔT (K)	Q10 (Kkal/Kg.K)
$C_{10}H_{16}N_2O_6$	260	7.127,2932	27,4127	0,3252	37,23	331,8518
$CaCO_3$	100	210,5048	2,1050	0,1898	37,23	14,8727
H_2O	18	0,3323	0,0185	0,3790	37,23	0,2605
Total		7.338,1303				346,9850

- **Q_{11}**

T_{in} = 62,23 ˚C = 335,23˚K

T_{ref} = 25°C (298,15 K)

Tabel B.16 Energi pada Q_{11} Reaktor Deproteinasi (R-2102)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	ΔT (K)	Q11 (Kkal/Kg.K)
NaOH	40	2.568,3456	64,2086	0,2818	37,23	673,7612
H_2O	18	70.812,9573	3.934,0532	0,3790	37,23	55.504,5208
Total		73.381,3029	3.998,2618			56.178,2821

➢ **Output**

- **Q_{12}**

T_{in} = 70°C (343 °K)

T_{ref} = 25°C (298 °K)

Tabel B.17 Energi pada Q_{12} Reaktor Deproteinasi (R-2102)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/Kg.K)	ΔT (K)	Q12 (kkal/jam)
$C_{10}H_{16}N_2O_6$	260	152,2067	0,5854	0,3252	45	8,5658
$CaCO_3$	100	4,4935	0,0449	0,1898	45	0,3837
H_2O	18	70.813,2896	3.934,0716	0,37890	45	67.087,9570
NaOH	40	1.330,4463	33,2612	0,2818	45	421,8559
$C_2H_4NO_2Na$	97	2.602,2438	26,8273	0,3351	45	404,5632
$C_8H_{13}NO_5$	203	5.445,9329	26,8273	0,2493	45	301,0076
Na_2CO_3	106	218,3720	2,0601	0,2334	45	21,6407
$Ca(OH)_2$	74	152,4484	2,0601	0,2268	45	21,0222
Total		80.719,4332				68.266,9962

Reaksi 1:

Konversi 98% **(Smith van Ness, Pers. 13.5, hal 467)**

$$C_{10}H_{16}N_2O_6 + NaOH \longrightarrow C_8H_{13}NO_5 + C_2H_4NO_2Na$$

$\Delta H_R°$ = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan **(Himmelblau, Pers. 25.1, hal 770)**

$\Delta H_R°$ = [{n x $\Delta H_f°(C_8H_{13}NO_5)$}] + [{n x $\Delta H_f°(C_2H_4NO_2Na)$}] – [{n x $\Delta H_f°(C_{10}H_{16}N_2O_6)$} + {n x $\Delta H_f°(NaOH)$}]

$\Delta H_R°$ = [{26,237 x (189,8205 kkal/kmol)}] + [{26,8273 x (87,9097 kkal/kmol)}] – [{26,8273 x (340,1000 kkal/kmol)} + {26,8273 x (112,0546 kkal/kmol)}]

$\Delta H_R°$ = $4.679{,}3295\ \frac{kkal}{jam}$

Maka:

ΔH_R = $\Delta H_R°$ + (Q_{produk} – $Q_{reaktan}$)

ΔH_R = [4.679,3295 kkal/jam + (705,5708 kkal/jam – 732,7933 kkal/jam)]

ΔH_R = 4.652,1071 kkal/jam

Reaksi 2:

Konversi 99% **(Smith van Ness, Pers. 13.5, hal 467)**

$$CaCO_3 + 2NaOH \longrightarrow Na_2CO_3 + Ca(OH)_2$$

$\Delta H_R°$ = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan **(Himmelblau, Pers. 25.1, hal 770)**

$\Delta H_R°$ = [{n x $\Delta H_f°(Ca(OH)_2)$}] + [{n x $\Delta H_f°(Na_2CO_3)$}] – [{n x $\Delta H_f°(CaCO_3)$} + {n x $\Delta H_f°(NaOH)$}]

$\Delta H_R°$ = [{2,0601 x (235,6359 kkal/kmol)}] + [{2,0601 x (269,8960 kkal/kmol)}] – [{2,0601 x (288,2632 kkal/kmol)} + {4,1202 x (112,0546 kkal/kmol)}]

$\Delta H_R°$ = $14{,}0923\ \frac{kkal}{jam}$

Maka:

ΔH_R = $\Delta H_R°$ + (Q_{produk} – $Q_{reaktan}$)

ΔH_R =[14,0923 kkal/jam + (42,6630 kkal/jam – 69,8501 kkal/jam)]

ΔH_R = -13,0948 kkal/jam

ΔH_R total = $\Delta H_{R1} + \Delta H_{R2}$ = 4.639,0123

Qr = -ΔHr = -4.639,0123 kkal/jam

- **Beban Panas Tangki**

  ΔQ = $Q_{out} - Q_{in}$

  ΔQ = $Q_{12} - (Q_{10} + Q_{11} +$ Qr total)

  ΔQ = 68.266,9962 kkal/jam – (346,9850 kkal/jam + 56.178,2821 kkal/jam + (-4.639,0123 kkal/jam)

  ΔQ = 16.380,7414 kkal/jam

- **Panas *Steam***

  Medium pemanas adalah *saturated steam* pada T = 152°C, Sehingga:

  H_l = 640,8 kkal/kg

  H_v = 2.747,7 kkal/kg

  λ_s = 2.106,9 kkal /kg

  (Smith van Ness, Appendix F.1 *Saturated Steam*, Hal. 669)

Jumlah *steam* yang dibutuhkan (m_s):

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{16.380,7414\ \frac{kkal}{jam}}{2.106,9\ \frac{kkal}{kg}} = 7,7748\ \frac{kg}{jam}$$

Panas *steam* masuk ($Q_{s\ in}$):

$$Q_{s\ in} = m_s\ x\ H_v$$

$$Q_{s\ in} = 7,7748\ \frac{kg}{jam}\ x\ 2.747,7\ \frac{kkal}{kg} = 21.362,8379\ \frac{kkal}{jam}$$

Panas *steam* keluar ($Q_{s\ out}$):

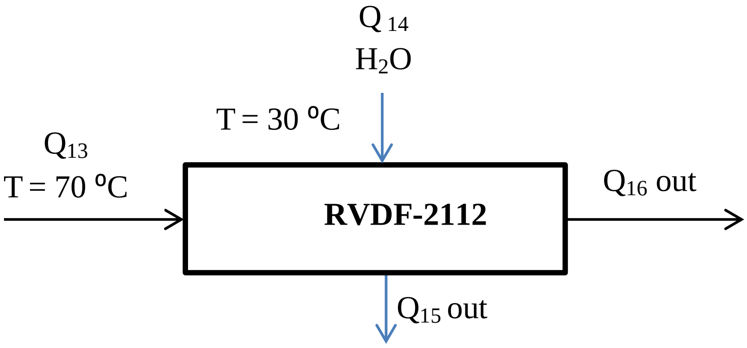
$$Q_{s\ out} = m_s\ x\ H_l$$

$$Q_{s\ out} = 7,7748\ \frac{kg}{jam}\ x\ 640,8\ \frac{kkal}{kg} = 4.982,0965\ \frac{\text{Kkal}}{\text{jam}}$$

Tabel B.18 Neraca Energi Reaktor Deproteinasi (R-2102)

Komponen	Panas Masuk (kkal/jam)	Panas Keluar (kkal/jam)
Q10	346,9850	
Q11	56.178,2821	
Q12		68.266,9962
Qr		4.639,0123
Qin	21.362,8379	
Q out		4.982,0965
Total	77.888,1050	77.888,1050

5. Rotary Vacum Drum Filter 2 (RVDF-2112)



Kondisi operasi

- Tekanan : 1 atm
- T_{in} : 70 °C = 343 °K
- T_{out} : ? °C = ? °K

➤ **Input**

- **Q_{13}**

T_{in} = 70°C (343°K)

T_{ref} = 25°C (298°K)

Tabel B.19 Energi pada Q_{13} *Rotary Vacuum Drum Filter* (RVDF-2112)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q13 (Kkal/jam)
$C_{10}H_{16}N_2O_6$	260	152,2067	0,5854	0,3252	45	8,5658
$CaCO_3$	100	4,4935	0,0449	0,1898	45	0,3837
H_2O	18	70.813,2896	3.934,0716	0,3790	45	67.087,9570
NaOH	40	1.330,4463	33,2612	0,2818	45	421,8559
$C_2H_4NO_2Na$	97	2.602,2438	26,8273	0,3351	45	404,5632
$C_8H_{13}NO_5$	203	5.445,9329	26,8273	0,2493	45	301,0076
Na_2CO_3	106	218,3720	2,0601	0,2334	45	21,6407
$Ca(OH)_2$	74	152,4484	2,0601	0,2268	45	21,0222
Total		80.719,4332				68.266,9962

- **Q_{14}**

T_{out} = 30°C (363°K)

T_{ref} = 25°C (298°K)

Tabel B.20 Energi pada Q_{14} *Rotary Vacuum Drum Filter* (RVDF-2112)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	ΔT (K)	Q14 (Kkal/jam)
H_2O	18	78.855,8730	4.380,8818	0,3790	5	8.300,8264
Total		78.855,8730				8.300,8264

- **Output**
  - **Q_{15}**

T_{out} = T °C (T °K)

T_{ref} = 25°C (298,15 °K)

Tabel B.21 Energi pada Q_{15} *Rotary Vacuum Drum Filter* (RVDF-2112)

Komponen	**BM**	**Massa (Kg/jam)**	**n(kmol/jam)**	**Cp (Kkal/kg.K)**	**ΔT (K)**	**Q15 (Kkal/jam)**
$C_{10}H_{16}N_2O_6$	260	152,2067	0,5854	0,3252	T-298K	0,1904
H_2O	18	149.668,5225	0,2496	0,3790	T-298K	3.150,9953
NaOH	40	1.330,4463	3.741,7131	0,2818	T-298K	9,3746
$C_2H_4NO_2Na$	97	2.602,2438	13,7159	0,3351	T-298K	8,9903
Na_2CO_3	106	218,3720	24,5495	0,2334	T-298K	0,3809
$Ca(OH)_2$	74	152,4484	-	0,2268	T-298K	0,4672
$CaCO_3$	100	4,4935	2,1837	0,1898	T-298K	0,0085
Total		**154.128,7332**				**3.170,5071**

- **Q_{16}**

T_{out} = T °C (T °K)

T_{ref} = 25°C (298,15 °K)

Tabel B.22 Energi pada Q_{16} *Rotary Vacuum Drum Filter* (RVDF-2112)

Komponen	BM	Massa (Kg/jam)	n(kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q16 (Kkal/jam)
H_2O	18	0,6402	0,0356	0,3790	T-298K	0,0135
$C_8H_{13}NO_5$	23	5.445,9329	26,8273	0,2493	T-298K	6,6891
Total						6,7025

Neraca Energi :

$Q_{in} = Q_{out}$

Q13 + Q14 = Q15 + Q16

68.266,9962 Kkal/jam + 8.300,8264 Kkal/jam = 3.170,5071 Kkal/jam (T-298ºK) + 6,7025 Kkal/jam (T-298ºK)

76.567,8226 Kkal/jam = 1.072,3216 (T-298ºK)

T-298ºK = 71,4038 Kkal/jam

T = 322,2491 ºK = 49,2491 ºC

Sehingga :

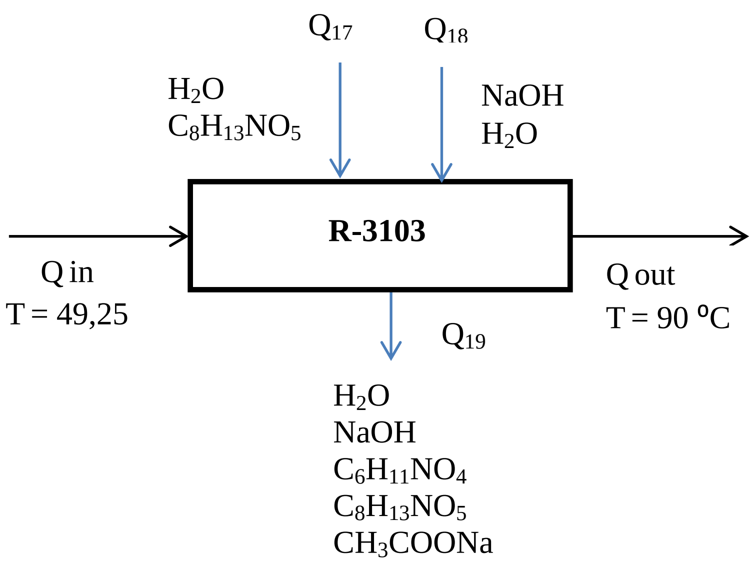
Q16 = 6,7025 x (322,2491 ºK - 298ºK) = 161,5249 Kkal/jam

Q15 = 3.170,5071 x (322,2491 ºK - 298ºK) = 76.089,2362 Kkal/jam

Tabel B.23 Neraca Energi *Rotary Vacuum Drum Filter* (RVDF-2112)

Komponen	Masuk (Kkal/Jam)	Keluar (Kkal/jam)
Q13	68.266,9962	
Q14	8.300,8264	
Q15		76.406,2977
Q16		161,5249
Total	76.567,8226	76.567,8226

6. **Reaktor Deasetilasi (R-3103)**



Kondisi operasi :

- Tekanan : 1 atm
- Temperatur : 90˚C
- T_{in} : 49,25˚C = 303,15 K
- T_{out} : 90˚C = 363,15 K
- pH : 11
- waktu : 1 jam

➢ **Input**

- **Q17**

T_{in} = 49,25 ˚C = 322,25˚K

T_{ref} = 25°C = 298˚K

Tabel B.24 Energi pada Q_{17} Reaktor Deasetilasi (R-3103)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	∆T (K)	Q17 (Kkal/Kg.K)
C8H13NO5	203	5.445,9329	26,8273	0,2493	24,25	162,2097
Air	18	0,6402	0,0356	0,3790	24,25	0,3268
Total		5.473,0095				162,5365

- **Q_{18}**

T_{in} = 49,25 ˚C = 322,25˚K

T_{ref} = 25°C = 298˚K

Tabel B.25 Energi pada Q_{18} Reaktor Deasetilasi (R-3103)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (kkal/kg.K)	∆T (K)	Q18 (Kkal/Kg.K)
NaOH	40	21.786,2923	544,6573	0,2818	24,25	767,5515
H_2O	18	32.679,4385	1.815,5244	0,3790	24,25	3.440,0272
Total		21.786,2923				4.207,5787

➢ **Output**

- **Q_{19}**

T_{in} = 90°C (303°K)

T_{ref} = 25°C (298°K)

Tabel B.26 Energi pada Q_{19} Reaktor Deasetilasi (R-3103)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/Kg.K)	ΔT (K)	Q19 (kkal/jam)
H_2O	18	32.680,0786	1.815,5599	0,3790	65	44.721,2292
NaOH	40	20.722,9672	518,0742	0,2818	65	9.491,1648
$C_8H_{13}NO_5$	203	49,5580	0,2441	0,2493	65	3,9566
$C_6H_{11}NO_4$	161	4.279,8836	26,5831	0,2433	65	420,4391
CH_3COONa	82	2.179,8165	26,5831	0,2840	65	490,7862
Total		59.912,3038				55.127,5758

Reaksi :

Konversi 99% **(Smith van Ness, Pers. 13.5, hal 467)**

$C_8H_{13}NO_5$ + NaOH → $C_6H_{11}NO_4$ + CH_3COONa

$\Delta H_R°$ = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan **(Himmelblau, Pers. 25.1, hal 770)**

$\Delta H_R°$ = [{n x $\Delta H_f°$(CH_3COONa)}] + [{n x $\Delta H_f°$($C_6H_{11}NO_4$)}] – [{n x $\Delta H_f°$($C_8H_{13}NO_5$)} + {n x $\Delta H_f°$(NaOH)}]

$\Delta H_R°$ = [{26,5831 x (169,4182 kkal/kmol)}] + [{26,5831 x (91,6309 kkal/kmol)}] – [{26,5831 x (189,8205 kkal/kmol)} + {26,5831 x (112,0545 kkal/kmol)}]

$\Delta H_R°$ = $1.085,2814 \frac{kkal}{jam}$

Maka:

ΔH_R = $\Delta H_R°$ + (Q_{produk} – $Q_{reaktan}$)

ΔH_R = [1.085,2814 kkal/jam + (911,2253 kkal/jam – (917,8374 kkal/jam)]

ΔH_R = 1.078,6692 kkal/jam

Q_R = -ΔH_R

Q_R = -1.078,6692 kkal/jam

- **Beban Panas Reaktor**

  ΔQ = Q_{out} – Q_{in}

  ΔQ = Q_{19} – (Q_{18}+Q_{17} + Qr)

  ΔQ = 55.127,5758 kkal/jam – (20.406,7567 kkal/jam + 162,5365 kkal/jam + (-1.078,6692 kkal/jam)

  ΔQ = 35.636,9518 kkal/jam

- **Panas *Steam***

Medium pemanas adalah *saturated steam* pada T = 152°C

Sehingga:

H_l = 640,8 kkal/kg

H_v = 2.747,7 kkal/kg

λ_s = 2.106,9 kkal /kg

(Smith van Ness, Appendix F.1 *Saturated Steam*, Hal. 683)

Jumlah *steam* yang dibutuhkan (m_s):

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{35.636,9518\ \frac{kkal}{jam}}{2.106,9\frac{kkal}{kg}} = 16,9144\ \frac{kg}{jam}$$

Panas *steam* masuk ($Q_{s\ in}$):

$$Q_{s\ in} = m_s\ x\ H_v$$

$$Q_{s\ in} = 16,9144\ \frac{kg}{jam} x\ 2.747,7\frac{kkal}{kg} = 46.475,7001\ \frac{kkal}{jam}$$

Panas *steam* keluar ($Q_{s\ out}$):

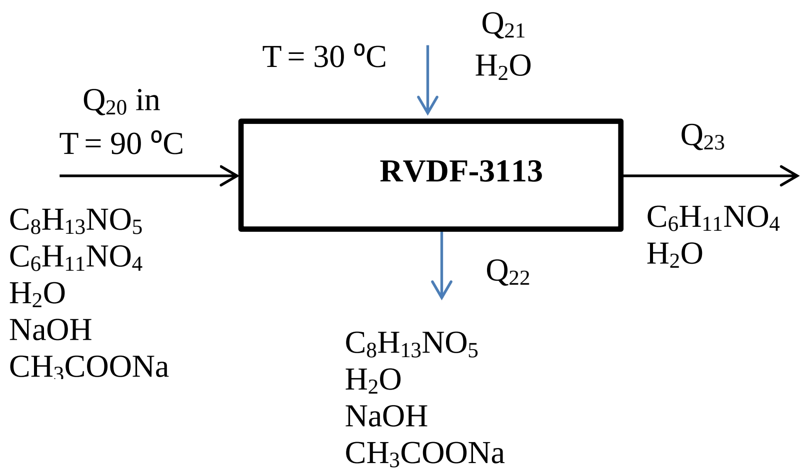
$$Q_{s\ out} = m_s\ x\ H_l$$

$$Q_{s\ out} = 16,9144\frac{kg}{jam} x\ 640,8\ \frac{kkal}{kg} = 10.838,7483\frac{kkal}{jam}$$

Tabel B.27 Neraca Energi Reaktor Deasetilasi (R-3103)

Komponen	**Masuk (kkal/Jam)**	**Keluar (kkal/jam)**
Q_{17}	162,5365	
Q_{18}	20.406,7567	
Q_{19}		55.127,5758
Qr		1.078,6692
Qs in	46.475,7001	
Qc out		10.838,7483
Total	67.044,9933	67.044,9933

7. Rotary Vacum Drum Filter 3 (RVDF-3113)



Kondisi operasi

- Tekanan : 1 atm
- T_{in} : 90°C = 363°K
- T_{out} : ?°C = ?°K

➢ **Input**

- **Q_{20}**

T_{in} = 90°C (363°K)

T_{ref} = 25°C (298°K)

Tabel B.28 Energi pada Q_{20} *Rotary Vacuum Drum Filter* (RVDF-3113)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q20 (Kkal/jam)
$C_8H_{13}NO_5$	203	49,5580	0,2441	0,2493	65	3,9566
$C_6H_{11}NO_4$	161	4.279,8836	26,5831	0,2433	65	420,4391
H_2O	18	32.680,0786	1.815,5599	0,3790	65	44.721,2292
NaOH	40	20.722,9672	518,0742	0,2818	65	9.491,1648
CH_3COONa	82	2.179,8165	26,5831	0,2840	65	490,7862
Total		59.912,3038				55.127,5758

- **Q_{21}**

T_{in} = 30°C (303°K)

T_{ref} = 25°C (298°K)

Tabel B.29 Energi pada Q_{21} *Rotary Vacuum Drum Filter* (RVDF-3113)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q21 (Kkal/jam)
H_2O	18	28.681,7957	1.593,4331	0,3790	5	3.019,2121
Total						3.019,2121

➢ **Output**

- **Q_{22}**

T_{out} = ?°C

T_{ref} = 25°C (298,15 K)

Tabel B.30 Energi pada Q_{22} *Rotary Vacuum Drum Filter* (RVDF-3113)

Komponen	BM	Massa	n (kmol/jam)	Cp	ΔT (K)	Q_{22}

		(Kg/jam)		(Kkal/kg.K)		(Kkal/jam)
$C_8H_{13}NO_5$	203	49,5580	0,2442	0,2493	T-298K	0,0609
$C_6H_{11}NO_4$	161	-	-	0,2433	T-298K	-
H_2O	18	61.361,8043	3.408,9891	0,3790	T-298K	1.291,8599
NaOH	40	20.722,9672	518,0742	0,2818	T-298K	146,0179
CH_3COONa	82	2.179,8165	26,5831	0,2840	T-298K	7,5506
Total		84.314,1459				1.445,4892

- **Q_{23}**

T_{out} = ?°C

T_{ref} = 25°C (298,15 K)

Tabel B.31 Energi pada Q_{23} *Rotary Vacuum Drum Filter* (RVDF-3113)

Komponen	BM	Massa (Kg/jam)	n(kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q23 (Kkal/jam)
H_2O	18	0,0701	0,0039	0,3790	T-298K	0,0015
$C_6H_{11}NO_4$	161	4.279,8836	26,5831	0,2433	T-298K	6,4683
Total						6,4698

Neraca Energi :

$Q_{in} = Q_{out}$

Q20 + Q21 = Q22 + Q23

55.127,5758 Kkal/jam + 3.019,2121 Kkal/jam = 1.445,4892 Kkal/jam (T-298ºK) + 6,4698 Kkal/jam (T-298ºK)

58.146,7880 Kkal/jam = 1.445,4892 (T-298ºK) + 6,4698 Kkal/jam (T-298ºK)

T-298ºK = 40,0471 Kkal/jam

T = 338,1971 ºK = 65,1971 ºC

Sehingga :

Q22 = 1.445,4892 x (338,1971 ºK - 298ºK) = 57.887,6923 Kkal/jam

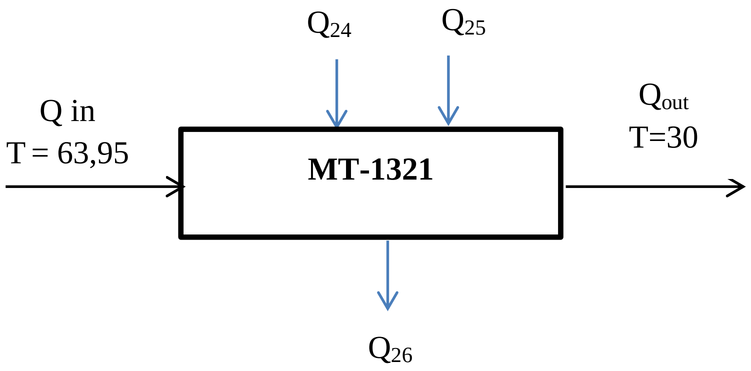
Q23 = 6.4698 x (338,1971 ºK - 298ºK) = 259,0956 Kkal/jam

Tabel B.32 Neraca Energi *Rotary Vacuum Drum Filter* (RVDF-3113)

Komponen	Masuk (Kkal/Jam)	Keluar (Kkal/jam)
Q_{20}	55.127,5758	
Q_{21}	1.207,6848	

Q_{22}		56.084,2370
Q_{23}		251,0237
Total	56.335,2607	56.335,2607

8. Mixing Tank



Kondisi operasi

- Tekanan : 1 atm
- T_{in} : 63,95°C = 336,95°K
- T_{out} : 30°C = 303°K

➢ **Input**

- **Q_{30}**

T_{in} = 63,95°C (336.95°K)

T_{ref} = 25°C (298°K)

Tabel B.33 Energi pada Q_{24} *Mixing Tank* (MT-1321)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q24 (Kkal/jam)
$C_6H_{11}NO_4$	161	4.279,8836	26,5831	0,2433	38,95	251,9367
H_2O	18	0,0701	0,0039	0,3790	38,95	0,0575
Total		59.912,3038				251,9941

- **Q_{25}**

T_{in} = 63,95°C (336.95°K)

T_{ref} = 25°C (298°K)

Tabel B.34 Energi pada Q_{25} *Mixing Tank* (MT-1321)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q25 (Kkal/jam)
H_2O	18	34,2391	0,8560	0,2818	38,95	9,3968
CH3COOH	40	17.085,2952	949,1831	0,3790	38,95	14.010,1083
Total						14.019,5050

- **Output**
  - **Q_{26}**

T_{out} = 30°C = 303°K

T_{ref} = 25°C = 298°K

Tabel B.35 Energi pada Q_{26} *Mixing Tank* (MT-1321)

Komponen	BM	Massa (Kg/jam)	n (kmol/jam)	Cp (Kkal/kg.K)	ΔT (K)	Q_{26} (Kkal/jam)
$C_6H_{11}NO_4$	161	4.279,8836	26,5831	0,2433	5	32,3415
H_2O	18	17.085,3653	949,1870	0,3790	5	1.798,5046
CH3COOH	82	34,2391	0,5707	0,2840	5	0,8963
Total		84.314,1459				1.831,7424

CP air = 0,3790 Kkal/jam

ΔT in

T in = 50°C = 323 °K

T ref = 25°C = 298 °K

ΔT out

T out = 30°C = 303 °K

T ref = 25°C = 298 °K

ΔT = (323-298) - (303-298) = 20°K

Beban Reaktor

ΔQ = Qout-Qin

= 1.831,7424 – 14.271,4992

= - 12.439,7568 Kkal/jam

= 12.439,7568 Kkal/jam

Jumlah air yang dibutuhkan :

ΔQ = m x cp x ΔT

m = ΔQ/(cp x ΔT)

= 12.439,7568 / 0,3790 x 20°K

= 1.641,3156 Kkal/jam

QW in = m (air pendingin) x cp (air)

= 621,9878 Kkal/jam

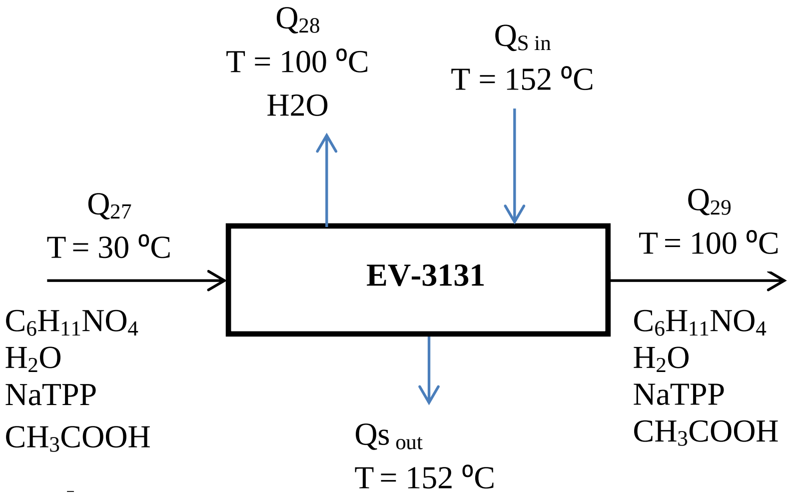
QW out = (Q in + Qw in) – (Q out)

= 13.061,7446

Tabel B.37 Neraca Energi *Mixing Tank* (MT-1321)

Komponen	Masuk (Kkal/Jam)	Keluar (Kkal/jam)
Q_{30}	251,9941	
Q_{31}	14.019,5050	
Q_{32}		1.831,7424
Q_w in	621,9878	
Q_w out		13.061,7446
Total	14.893,4870	14.893,4870

9. Evaporator (EV-3131)



Koı

- Tekanan : 1 atm
- Temperatur :100°C
- Tin : 30 °C : 303°K
- Tout : 100°C : 373°K

➢ **Input**

- **Q_{24}**

T_{in} = 30°C (363°K)

T_{ref} = 25°C (298°K)

Tabel B.38 Energi pada Q_{27} Evaporator (EV-3131)

Komponen	**Massa (kg)**	**Cp kkal/kg.K**	**dT**	**Q24**
$C_6H_{11}NO_4$	4.279,8836	0,2433	5,00	5.206,9761
H_2O	34.033,7042	0,3790	5,00	64.486,5305
NaTPP	171,1953	0,2241	5,00	191,8191
Asam Asetat	34,2391	0,3141	5,00	53,7781
Total	38.519,0222			69.939,1039

- **Output**
  - **Q_{25}**

T_{out} = 100°C (373°K)

T_{ref} = 25°C (298°K)

Tabel B.39 Energi pada Q_{28} Evaporator (EV-3131)

Komponen	Massa (kg)	Cp kkal/kg.K	dT	Q25
H2O	29.949,6597	0,3790	75,00	851.222,2031
Total				851.222,2031

- **Q_{26}**

T_{out} = 100°C (373°K)

T_{ref} = 25°C (298°K)

Tabel B.40 Energi pada Q_{29} Evaporator (EV-3131)

Komponen	**Massa (kg)**	**Cp kkal/kg.K**	**dT**	**Q26**
$C_6H_{11}NO_4$	4.279,8836	0,2433	75,00	78.104,6414
H_2O	4.084,0445	0,3790	75,00	116.075,7550
NaTPP	171,1953	0,2241	75,00	2.877,2868
Asam Asetat	34,2391	0,3141	75,00	806,6721
Total				**197.864,3553**

- **Beban Evaporator**

ΔQ = $Q_{out} - Q_{in}$

ΔQ = $(Q_{26} + Q_{25}) - Q_{24}$

ΔQ = (197.864,3553 kkal/jam + 851.222,2031 kkal/jam) – 69.939,1039 kkal/jam

ΔQ = 979.147,4545 kkal/jam

- **Panas Steam**

Medium pemanas adalah *saturated steam* pada T = 152°C, Sehingga:

H_f = 640,8 kkal/kg

H_v = 2.747,7 kkal/kg

λ_s = 2.106,9 kkal /kg

(Smith van Ness, Appendix F.1 *Saturated Steam*, Hal. 669)

Jumlah *steam* yang dibutuhkan (m_s):

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{979.147,4545 \frac{kkal}{jam}}{2.106,9 \frac{kkal}{kg}} = 464,7337 \frac{kg}{jam}$$

Panas *steam* masuk ($Q_{s\ in}$):

$$Q_{s\ in} = m_s\ x\ H_v$$

$$Q_{s\ in} = 464,7337 \frac{kg}{jam} x\ 2.747,7 \frac{kkal}{kg} = 1.276.948,8162 \frac{kkal}{jam}$$

Panas *steam* keluar ($Q_{s\ out}$):

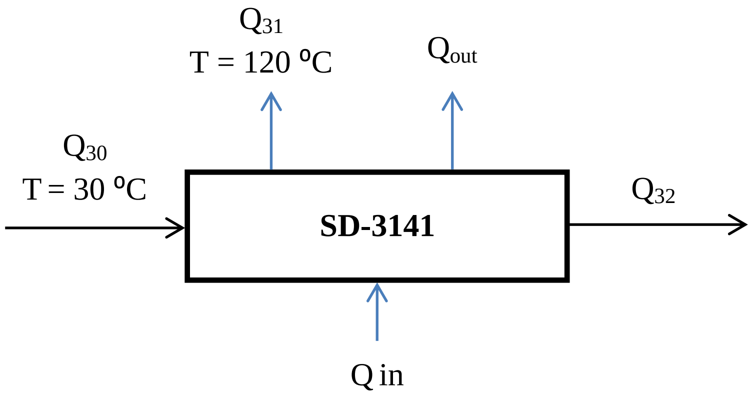
$$Q_{s\ out} = m_s\ x\ H_f$$

$$Q_{s\ out} = 464,7337 \frac{kg}{jam} x\ 640,8\ \frac{kkal}{kg} = 297.801,3616 \frac{kkal}{jam}$$

Tabel B.41 Neraca Energi Evaporator (EV-3131)

Komponen	Panas Masuk (Kkkal/jam)	Panas Keluar (Kkkal/jam)
Q24	69.939,1039	
Q25		851.222,2031
Q26		197.864,3553
Qs in	1.276.948,8162	
Qs out		297.801,3616
	1.346.887,9201	1.346.887,9201

10. Spray Dryer (SD-3141)



Kondisi operasi

- Tekanan : 1 atm
- Temperatur :120°C
- Tin : 30 °C : 303°K
- Tout : 120°C : 393°K

➢ **Input**

- **Q_{24}**

T_{in} = 100°C (373°K)

T_{ref} = 25°C (298°K)

Tabel B.42 Energi pada Q_{30} *Spray Dryer* (SD-3141)

Komponen	BM	CP (Kkal/Kg K)	Massa (Kg/Jam)	ΔT (K)	Q30 (kkal/jam)
$C_6H_{11}NO_4$	161	0,2433	4.279,8836	75	78.104,6414
H2O	18	0,3790	4.084,0445	75	116.075,7550
NaTPP	98	0,2241	171,1953	75	2.877,2868
asam asetat	60,05	0,3141	34,2391	75	806.6721
Total		65,9884	8.569,3625		197.864,3553

➢ **Output**

- **Q_{31}**

T_{out} = 120°C (393°K)

T_{ref} = 25°C (298°K)

Tabel B.43 Energi pada Q_{31} Spray *Dryer* (SD-3141)

Komponen	BM	CP (Kkal/Kg K)	Massa (Kg/Jam)	ΔT (K)	Q31 (kkal/jam)
H2O	18	0,3790	4.002,3636	95	114.088,7038
NaTPP	98	0,2241	3,4239	95	72,8913
Asam asetat	60,05	0,3141	33,5543	95	1.001,3490
$C_6H_{11}NO_4$	161	0,2433	85,5977	95	1.978,6509
Total			4.124,9395		147.141,59950

- **Q_{32}**

T_{out} = 120°C (393°K)

T_{ref} = 25°C (298°K)

Tabel B.44 Energi pada Q_{32} *Dryer* (SD-3141)

Komponen	BM	CP (Kkal/Kg K)	Massa (Kg/Jam)	ΔT (K)	Q32 (kkal/jam)
$C_6H_{11}NO_4$	161	0,2433	4.194,2859	95	96.953,8948
H_2O	18	0,3790	81,6809	95	2.940,5858
NaTPP	98	0,2241	167,7714	95	3.571,6721
Asam asetat	60,05	0,3141	0,6848	95	20,4357
Total					103.486,5884

- **Kebutuhan Pemanas Spray Dryer**

Masuk = Keluar

Q24 = (Q25 + Q26 + ΔQ

197.864,3553 = 147.141,59950 + 103.486,5884 + ΔQ

197.864,3553 = 250.628,1834 + ΔQ

ΔQ = 52.763,8281 Kkal/jam

➢ Udara Panas

T_{in} = 150°C

T_{out} = 120°C

Cp udara = 0,24 Kkal/KgK

ΔT = 30°C

Cp Udara = 79% cp N2 + 21% cp O2

Cp Udara = 0,1975 + 0,0483

Cp Udara = 0,2458 Kkal/KgK

- Massa Udara yang dibutuhkan

M udara = ΔQ / (Cp udara * ΔT)

= 52.763,8281 Kkal/jam / (0,24 kkal/kg.K x 30°C)

= 7.328,,3095 Kg/jam

- **Input udara**

  Tin = 150°C = 423°K

  Tref = 25°C = 298°K

Komponen	**Massa (Kg/jam)**	**cP (kkal/kg.K)**	**dT**	**Qum (kkal/jam)**
Udara	7.328,3095	0,2400	125	219.849,2837

- **Output udara**

  Tin = 120°C = 393°K

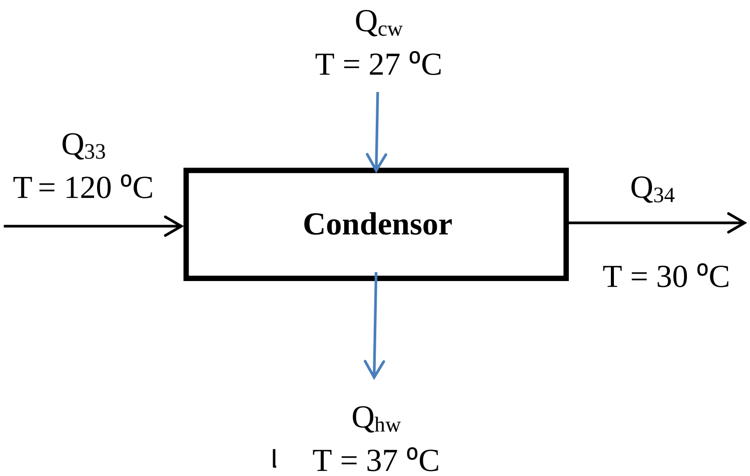
  Tref = 25°C = 298°K

Komponen	**Massa (Kg/jam)**	**cP (kkal/kg.K)**	**dT**	**Quk (kkal/jam)**
Udara	7.328,3095	0,2400	95	167.085,4556

Tabel B.45 Neraca Energi Spray *Dryer* (SD-3141)

Komponen	Panas Masuk (kkal/jam)	Panas Keluar (kkal/jam)
Q_{24}	197.864,3553	
Q_{25}		147.141,5950
Q^{26}		103.486,5884
Qin	219.849,2837	
Qout		167.085,4556
TOTAL	417.713,6390	417.713,6390

11. Condensor



Beban panas kondensor = 26.381,91 Kkal/jam

Jumlah air yang dibutuhkan : 27 ^oC

T air pendingin : 37 ^oC

Q = m x cp x dt

m = Q / cp x dt

= 26.381,91 / 1 x (37^{o}C – 27^{o}C)

= 2.638,19 Kkal/jam

Panas sensibel air pendingin masuk (Qin)

Qcw (in) = m x cp x dT

= 5.276,38 Kkal/jam

Panas Sensibel air keluar (Qout)

Qhw (out) = m x cp x dt

= 31. 658,29 Kkal/jam

Tabel B.46 Neraca Energi Condensor

Komponen	Panas Masuk (kkal/jam)	Panas Keluar (kkal/jam)
Q_c	26.381,91	
Q_{cw} in	5.276,38	
Qhc out		31. 658,29
Total	31. 658,29	31. 658,29

LAMPIRAN C
SPESIFIKASI PERALATAN

A. Spesifikasi Peralatan Utama

1. Gudang *Bahan Baku* (WH-111)

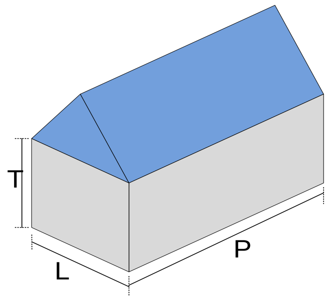
Fungsi : Tempat menyimpan cangkang kerang Hijau

Tipe : *Werehouse*

Bahan konstruksi : Beton

Jumlah : 1 unit

Gambar :



Data :

- Jumlah umpan, m : 14.253,45 kg/jam
- Lama penyimpanan, t : 7 hari = 168 jam
- Densitas cangkang kerang ρ : 2610 kg/m^3
- Tekanan : 1 atm
- Temperatur : 30°C

Volume gudang, Vg

$$V_g = \frac{m \: x \: t}{\rho}$$

$$= \frac{14.253,45 \; {}^{kg}/_{jam} \; x \; 168 \; jam}{2610 \; {}^{kg}/_{m^3}}$$

$$= 345,99 \; m^3$$

$Ruang\ kosong = 20\ \%$

$$V_g = \frac{245{,}99\ m^3}{0.8}$$

$$= 432{,}48\ m^3$$

Dimensi gudang, Dg

$$V_g = P\ x\ L\ x\ T$$

$$P\ x\ L\ x\ T = 3 : 2 : 1$$

$$V_g = 3T\ x\ 2T\ x\ T$$

$$V_g = 6T^3$$

$$T = \sqrt[3]{\frac{V_g}{6}}$$

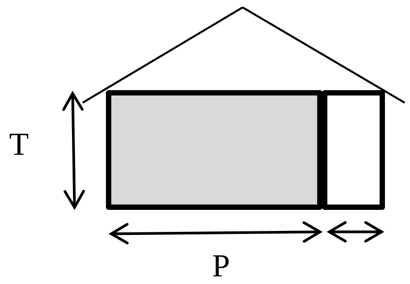
$$= \sqrt[3]{\frac{432{,}48\ m^3}{6}}$$

$$= 4{,}10\ m\ \approx 5\ m$$

Maka,

$$P = 3T = 12{,}31\ m$$

$$L = 2T = 8{,}21\ m$$



Gudang penyimpanan cangkang kerang hijau memiliki bagian kosong untuk jalan dan tempat pemeriksaan. Bagian kosong ini memiliki lebar 4 m. Maka :

$$P = 14\ m$$

$L = 12,21\ m$

$T = 5\ m$

2. *Conveyor* (BC-121)

Fungsi : Transportasi cangkang kerang menuju pengeringan

Tipe : *Conveyor* tertutup

Bahan : *Carbon Steel*

Jumlah : 1 unit

Gambar :

Data :

- Laju alir umpan, m : 15.565,06 kg/jam
- Faktor keamanan 10%

Kapasitas *conveyor*, W

$$W = \frac{m}{0.9}$$

$$W = \frac{15.565,06\ kg/jam}{0.9}$$

$$= 17.294,51\ kg/jam$$

$$= 17,29\ ton/jam$$

Ukuran *conveyor*

Dengan kapasitas di atas, dipilih *continuos flow conveyor* dengan spesifikasi sebagai berikut (Perry's 7^{th} Ed, Tabel 21-11 Hal 21-19)

Lebar *conveyor* : 18 in = 0.46 m

Kecepatan : 10 ft/menit

Horizontal : 3 m = 9.8425 ft

Daya *conveyor*

$$P = 0.001\left[\left({L_1}/{30} + 5\right)u + \left({L_2}/{16} + 2L_3\right)T\right] \qquad (Walas, Pers\ 5.26)$$

u : kecepatan = 10 ft/menit

T : kapasitas conveyor 17,29ton/jam

L_1 : panjang total conveyor = 3 m = 9.8425 ft

L_2 : jarak horizoltal yang ditempuh = 3 m = 9.8425 ft

L_3 : jarak vertical yang ditempuh = 0 m = 0 ft

$$P = 0.001 \left[\left({}^{9.84\ \text{ft}}/_{30} + 5\right) 10 \frac{\text{ft}}{\text{mnt}} + \left({}^{9.84}/_{16} + 2.0\right) 17{,}29 \frac{\text{ton}}{\text{jam}}\right]$$

$$= 95{,}22\ hp \quad \approx 1\ HP$$

3. *Grinding Hammer mill* (GHM-151)

Fugsi : mengecilkan ukuran cangkang kerang hijau masuk

Jumlah : 1 buah

Bahan :Stainless steal

Gambar :

Data : 15.722,283 kg/jam = 15,72 Ton/jam

Temperatur : 30◦C

Tekanan :1 atm

Ukuran *Output* :25 mm – 20 mesh

Kapasitas : 50-75 kg /jam

Daya Motor : 10 Hp

Bahan : Stainless steal

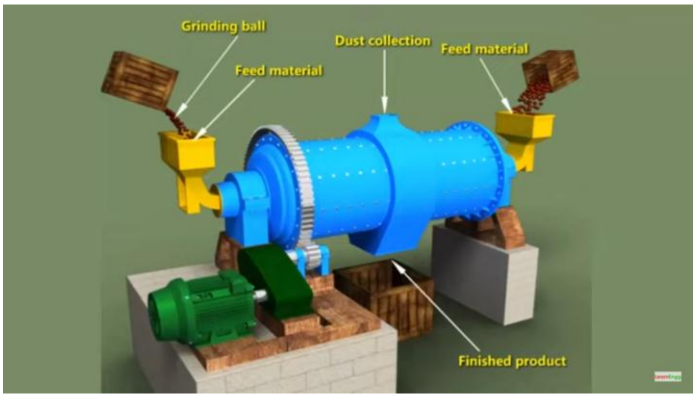
4. *Tumbling mill* (TM-161)

Fungsi :mengecilkan ukuran cangkang kerang hijau masuk

Jumlah : 1 buah

Bahan : Stailess steal

Gambar :



Data : 15.565,060 kg/jam = 15,57 Ton/jam

Temperatur : 30◦C

Tekanan :1 atm

Ukuran *Output* : 200 mesh

Kapasitas :up to 36 Ton/jam

Daya Motor :155 kW = 207,86 Hp

5. *Continuous Flow Conveyor* (CC-1181)

Fungsi : Mengangkut NaOH ke *Bin* NaOH

Tipe : *Continuous Flow Conveyor*

Bahan : *Carbon Steel*

Jumlah : 1 unit

Gambar :

Data :

- Laju alir umpan, m : 898,88 kg/jam
- Faktor keamanan 10%

Kapasitas *conveyor*, W

$$W = \frac{m}{0,9}$$

$= \frac{898,88\ kg/jam}{0,9}$

= 34.335,33 kg/jam

= 34,3353ton/jam

Ukuran *conveyor*

Dengan kapasitas di atas, dipilih *continuos flow conveyor* dengan spesifikasi sebagai berikut (Perry's 7^{th} Ed, Tabel 21-11 Hal 21-19)

Lebar *conveyor*	: 5,37 in = 1,56 ft
Panjang *conveyor*	: 3,37 m = 52,5 ft
Kecepatan	: 10 ft/menit

Daya *conveyor*

$$P = 0.001\left[\left({}^{L_1}/_{30} + 5\right)u + \left({}^{L_2}/_{16} + 2L_3\right)T\right]$$ (Walas, Pers 5.26)

u	: kecepatan = 10 ft/menit
T	: kapasitas conveyor = 34,3353 ton/jam
L_1	: panjang total conveyor = 11,06 ft
L_2	: jarak horizoltal yang ditempuh = 7,63 m = 25,05 ft
L_3	: jarak vertical yang ditempuh = 5 m = 16,4 ft

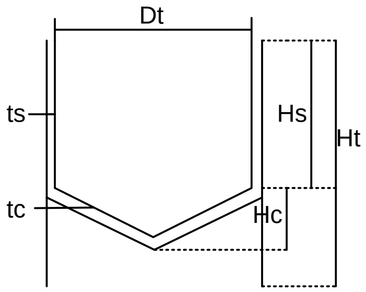
$$P = 0,001\left[\begin{array}{c}\left(11.06\ {}^{ft}/_{30} + 5\right)10\ {}^{ft}/_{menit} + \\ \left(25,05\ {}^{ft}/_{16} + 2 \times 16,4\ ft\right)34,3353\ {}^{ton}/_{jam}\end{array}\right]$$

= 1,18145 HP

≈ 0,5 HP

6. Bin Feeder (TT-1192)

Fungsi	: Tempat penimbangan dan pengaturan NaOH masuk ke dalam tangki pelarutan
Tipe	: Silinder vertikal dengan alas *conical* (kerucut)
Bahan	: *Carbon steel*
Jumlah	: 1 unit
Gambar	:



Data :

- Laju alir massa : 898,88 kg/jam
- Densitas NaOH : 2107,40 kg/m^3
- Temperatur : 30°C
- Tekanan : 1 atm

Setiap unit *bin feeder* menimbang sebanyak 1 kali, sehingga jumlah massa setiap kali unit per 1 kali penimbangan :

$$\frac{898{,}88\ kg/jam}{1} = 898{,}88 \text{ kg/jam}$$

Kapasitas *bin feeder*, V_t

$$V_b = \frac{m}{\rho}$$

$$= \frac{898{,}88\ ^{kg}/_{jam}}{2107{,}4\ ^{kg}/_{m^3}} = 0{,}43 \text{ m}^3$$

Faktor keamanan 10%

Maka,

$$V_b = 0{,}9\ V_t$$

$$V_t = \frac{V_b}{0{,}9}$$

$$= \frac{0{,}43\ m^3}{0{,}9} = 0{,}47 \text{ m}^3$$

Dimensi *bin feeder*

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4} \times D_b^2 \times H_s \qquad H_s = D_b$$

Maka,

$V_s \quad = \frac{\pi}{4} \times D_b^3$

- **Volume *conical*, V_c**

$V_c \quad = \frac{\pi}{12} \times D_b^2 \times H_c$ $\qquad\qquad H_c = ½\ D_b \tan 30°$

Maka,

$V_c \quad = \frac{\pi}{24} \times D_b^3 \tan 30^o$

- **Diameter *bin feeder*, D_b**

$V_t \quad = V_s + V_c$

$= \left(\frac{\pi}{4} \times D_b^3\right) + \left(\frac{\pi}{12} \times D_b^3 \tan 30^o\right)$

$D_b^3 \quad = \frac{V_t}{0{,}9369}$

$D_b \quad = \sqrt[3]{\frac{0{,}47\ m^3}{0{,}9369}}$

= 0,80 m = 31,37 in

- **Tinggi *bin feeder*, H_b**

Tinggi silinder, $H_s = D_b$ = 0,80 m

Tinggi *conical*, $H_c = ½\ D_t \tan 30°$ = 0,23 m

Bin Feeder diletakan diatas kaki setinggi 1 m

Tinggi total *bin feeder* = (0,80 + 0,23+ (1-0,23) m

= 1,80 m

- **Tebal dinding *bin feeder*, t_b**

$t_b \quad = \frac{PR}{SE - 0{,}6P} + C$ (Walas, Tabel 18.3)

- Tekanan desain, P : 14,695 psi
- Diameter,D : 0,80 m = 31,37 in
- Jari-jari tangki, R : 0,40 m = 15,68 in
- *Allowable stress*, S : 13.700 psi (Walas, Tabel 18.4)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)
- Faktor korosi yang diizinkan : 0,002 in/thn (Perry's Tabel 23-2)

Maka,

t_b $= \frac{14,695\ psi \times 15,68\ in}{(13.700\ psi \times 0,85)-(0,6 \times 14,696\ psi)} + 0,002 \frac{in}{tahun} \times 10 tahun$

= 0,04 in

= 1,01 mm

Tebal dinding alas *conical*, t_c

t_c $= \frac{PD_b}{2(SE-0,6P)\cos 30^o} + C$ (Walas, Tabel 18.3)

$= \frac{14,696\ psi \times 31,37\ in}{2(13.700\ psi \times 0,85-0,6 \times 14,696\ psi)\cos 30^o} + 0,002 \frac{in}{tahun} \times 10 tahun$

= 0,04 in

= 1,09 mm

Dengan cara yang sama, maka diperoleh dimensi pada *bin feeder* lainnya pada peralatan proses seperti pada Tabel C.2 di bawah ini :

Tabel C.2 Dimensi *Bin Feeder* pada Peralatan Proses

Kode Alat	**Kapasitas (m^3)**	**Diameter (m)**	**Tinggi (m)**	**Tebal Dinding (mm)**	**Tebal Dinding Alas *Conical* (m)**
TT-1061	0,23	0,63	0,63	0,91	0,97

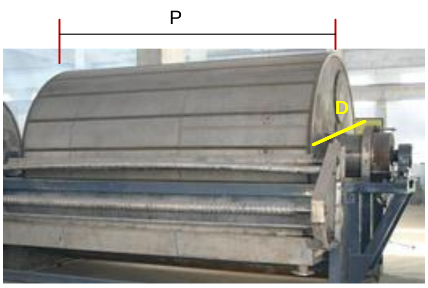
7. *Rotary Vacuum Drum Filter* (RVDF-1111)

Fungsi : Memisahkan residu dari filtrat

Bahan konstruksi : *Stainless steel*

Jumlah : 1

Gambar :



Data Slurry:

- Laju alir massa, ṁ = 1.303,64 kg/jam = 0,80 lb/s
- Densitas filtrat, ρ_f = 10.301 kg/m^3 = 643,08 lb/ft^3
- Densitas padatan, ρ_s = 1.611,1 kg/m^3 = 100,58 lb/ft^3
- Viskositas udara, μ_a = 0,018 cP = 0,000012 lb/ft.s

- Viskositas filtrat, μ_f = 1.694,76 cP = 0,001138 lb/ft.s

Data Cake:

-	$\frac{Total\ volume\ wash}{Volume\ filtrat}$	= 0,00010	(Brown, Fig. 259a)
-	% *final staturated cake*	= 0,85	(Superpro)
-	Porosity, X	= 0,4	(Superpro)
-	Sphericity, ψ	= 1	(Brown, Tabel 26)
-	Diameter partikel, D_p	= 0,0015 in = 0,00012 ft	(Brown, Fig. 259a)
-	Tebal cake, L	= 2 in = 0,16 ft	(Brown, Hal 224)
-	*Pressure drop*, ΔP	= 500 torr = 1.392,2 lb/ft^2	(Walas, Tabel 11.18)

Konstanta Filtrasi (C_L, C_t, C_a)

Berdasarkan nilai *porosity* dan *sphericity*, maka didapat *friction factor* dan *Reynold number factor*:

-	*Reynold number factor*, F_{Re}	= 41	(Brown, Fig. 219)
-	*Friction factor*, F_l	= 1500	(Brown, Fig. 220)

- Permeabilitas, K :

$$K = \frac{g_c D_p^2 F_{Re}}{32 F_f}$$ (Brown, Pers. 172)

$$K = \frac{32{,}2\ x\ (0{,}00012\ ft)^2\ x\ 41}{32\ x\ 1500} = 1{,}96x\ 10^{-8}\ \frac{ft^3}{sec^2}$$

- *Surface tension*, ɣ

$$ɣ = \frac{K\Delta P}{L g_c cos\theta}$$ (Brown, Hal 223)

$$ɣ = \frac{1{,}96x\ 10^{-8}\ \frac{ft^3}{sec^2}\ x\ 1.392{,}2 \frac{lb}{ft^2}}{0{,}166\ ft\ x\ 32{,}2\ x\ 1} = 1{,}11\ x\ 10^{-5}\ \frac{lb}{ft}$$

Maka, konstanta filtrasi, C_L, C_t, C_a

$$C_L = \frac{\mu_f[\rho_S(1-x)(1-X)-\rho x X]}{2K\rho x}$$ (Brown, Pers. 196)

$$C_L = \frac{0{,}001 \frac{lb}{ft.s}\ x\ [100{,}58\ \frac{lb}{ft^3}\ x\ (1-0{,}088)(1-0{,}4)-100{,}58\ \frac{lb}{ft^3}\ x\ 0{,}088\ x\ 0{,}4]}{2\ x\ (4{,}2\ x\ 10^{-10}\ \frac{ft^3}{sec^2})\ x\ 100{,}58\ \frac{lb}{ft^3}\ x\ 0{,}088}$$

C_L =12767646 lb.s/ft^4

$C_t = \frac{\mu_f X L^2}{K \Delta P}$ (Brown, Pers. 219)

$C_t = \frac{0{,}001 \frac{lb}{ft.s} \ x \ 0{,}4 \ x \ (0{,}166 \ ft)^2}{4{,}2 \ x \ 10^{-10} \ \frac{ft^3}{sec^2} \ x \ 1.392{,}2 \frac{lb}{ft^2}} = 3{,}9546 \text{ sec}$

$C_a = \frac{X L \mu_f}{\mu_a}$ (Brown, Pers. 223)

$C_a = \frac{0{,}4 \ x \ 0{,}166 \ ft \ x \ 0{,}001 \frac{lb}{ft}.s}{0{,}000012 \frac{lb}{ft}.s} = 5{,}86 \frac{ft^3}{ft^2}$

Kecepatan udara, v_a :

$v_a = \frac{K \Delta P}{L \mu_a}$ (Brown, Pers. 170)

$v_a = \frac{4{,}2 \ x \ 10^{-10} \frac{ft^3}{sec^2} \ x \ 1.392{,}2 \frac{lb}{ft^2}}{0{,}166 \ ft \ x \ 1{,}2 \ x \ 10^{-5} \frac{lb}{ft.s}} = 0{,}2966 \frac{ft}{s}$

Kecepatan filtrat, v_f :

$v_f = \frac{K \Delta P}{L \mu_f}$ (Brown, Pers. 170)

$v_f = \frac{4{,}2 \ x \ 10^{-10} \frac{ft^3}{sec^2} \ x \ 1.392{,}2 \frac{lb}{ft^2}}{0{,}166 \ ft \ x \ 0{,}001 \frac{lb}{ft.s}} = 0{,}0034 \frac{ft}{s}$

***Residual Saturation*, S_r** :

$S_r = 0{,}025 [\frac{K \Delta P}{g_c L \gamma \cos \theta}]$ (Brown, Pers. 179)

$S_r = 0{,}025 \left[\frac{4{,}2 \ x \ 10^{-8} \frac{ft^3}{sec^2} \ x \ 1{,}392{,}2 \frac{lb}{ft^2}}{32{,}2 \ x \ 0{,}166 \ ft \ x \ 0{,}00452 \frac{lb}{ft} \ x \ 1} \right] = 0{,}025$

Pembentukan Cake

Waktu pembentukan cake :

$t_1 = \frac{C_L L^2}{\Delta P}$ (Brown, Pers. 198)

$t_1 = \frac{300000 \text{ lb.} \frac{\text{s}}{\text{ft}^4} \text{ x } (0{,}166 \text{ ft})^2}{1.392{,}2 \frac{lb}{ft^2}} = 5{,}98 \ detik$

Daerah pembentukan cake :

$\theta_1 = \frac{360° t_1}{60 \ detik} = \frac{360° \ x \ 5{,}98 \ detik}{60 \ detik} = 20{,}89°$

Dewatering Pertama, V_2 :

$\theta_1 = 150° - 20{,}88° = 129{,}119°$

$t_2 = \frac{\theta_2}{360°} x\ 60\ detik = \frac{1129{,}11°\ x\ 60\ detik}{360°} = 21{,}52\ detik$

$$\frac{t_2}{C_t} = \frac{21{,}52\ detik}{3{,}95\ detik} = 5{,}44$$

Dari Fig. 255, Brown, dengan Sr = 0,025 dan $\frac{t_2}{C_t}$ = 4,03 didapat:

S_2 = 0,25 $\frac{V_2}{C_a} = 1$

Maka,

V_2 = 5,87 ft x 1 = 5,87 ft^3 udara/ft^2 (*cycle*)

Washing :

$$v_l' = \frac{v_l'}{v_l} x v_l$$

$$V_l' = 0{,}1\ x\ 0{,}0037 \frac{ft}{s} = 0{,}00037 \frac{ft}{s}$$

Dari Fig. 259d, Brown, dengan Sr = 0,025 dan $\frac{v_l'}{v_l}$ = 0,1 didapat:

$\frac{v_a'}{v_a} = 0{,}15$ S3 = 0,4

$$v_a' = \frac{v_a'}{v_a} x v_a$$

$$v_a' = 0{,}15\ x\ 0{,}296 \frac{ft}{s} = 0{,}044 \frac{ft}{s}$$

$t_3 = \frac{60°}{360°}\ x\ 60\ detik = 10\ detik$

Maka,

$V_3 = v_a'$ x t_3

= 0,044 ft/s x 10 detik = 0,45 ft^3/ft^2 (cycle)

Dewatering **Kedua**

$t_4 = \frac{90°}{360°}\ x\ 60\ detik = 15\ detik$

Koreksi viskositas pada saat pencucian

$C_t' = C_t \frac{1}{\mu_f} = 3{,}95 \left(\frac{1}{1{,}58}\right) = 2{,}49$ detik

$C_a' = C_a \frac{1}{\mu_f} = 5{,}85 \left(\frac{1}{1{,}58}\right) = 3{,}7$ ft

$\frac{t_4}{C_t'} = \frac{15\ detik}{2{,}49\ detik} = 6$

Dari Fig. 255, Brown, dengan S_r = 0,025 dan $\frac{t_4}{C_t'}$ = 4,25, didapat:

S_4 = 0,22 $\frac{V_4}{C_a'} = 1{,}5$

Maka,

V_4 =1,5 x C_a = 1,5 x 5,85 = 5,55 ft^3/ft^2 (cycle)

Area Filtrasi

$C_v = \frac{\mu_f \rho_f x}{2K[\rho_S(1-x)(1-X)-\rho_f xX]}$ (Brown, Pers. 192)

$C_v = \frac{0{,}001\,\frac{lb}{ft.s}\,x\,85{,}75\,\frac{lb}{ft^3}\,x\,0{,}088}{2\,x\,4{,}2\,x\,10^{-10}\frac{ft^3}{sec^2}\,x\,[159{,}05\frac{lb}{ft^3}\,x\,(1-0{,}088)(1-0{,}4)-85{,}88\frac{lb}{ft^3}\,x\,0{,}088\,x\,0{,}4]}$

C_v = 113751,6242 lb.s/ft^4

Faktor keamanan 20%

Jumlah Alat = 2 bauh

V_{umpan} = (1,2 x 26,164 m^3)/2

= 15,6980 m^3 = 554,37 ft^3

A = $\sqrt{\frac{C_v V^2}{t\Delta P}}$ (Brown, Pers. 193)

A = $\sqrt{\frac{113751{,}6242\ lb.\frac{s}{ft^4}\,x\,(554{,}37\ ft^3)^2}{52{,}5\ detik\ x\ 1.392{,}2\frac{lb}{ft^2}}}$

A = 524,9345 ft^2

Berdasarkan Tabel 11.12b, Walas, maka didapat diameter dan panjang alat:

Diameter, D = 10 ft = 3,05 m

Panjang, L = 17 ft = 5,16 m

Final Moisture **pada cake**

FM = $S\left(\frac{\rho_f}{\rho_s}\right)\left(\frac{X}{1-X}\right)$ (Brown, Hal 225)

FM = $0{,}22\left(\frac{1.375{,}7\,\frac{kg}{m^3}}{2.547{,}77\,\frac{kg}{m^3}}\right)\left(\frac{0{,}4}{1-0{,}4}\right) = 0{,}079$ kg air

Sehingga air yang ikut bersama cake sebesar 0,079 kg

Kapasitas *Blower*

V = $V_2 + V_3 + V_4$ (Brown, Hal 255)

V = (5,86 + 0,44 + 5,55) ft^3/ft^2 (cycle)

V = 11,86 ft^3/ft^2 (*cycle*)

Dari Fig. 258, Brown dengan :

Permeabilitas, K = 4,2 x 10^{-10} ft^3/sec^2

ΔP/L = 9,75

Maka :

Turbulance correction factor, F_t = 0,9

Q_a = $\frac{V\ x\ F_t x\ P_2}{60\ \min x\ \Delta P}$ (Peter's, Hal. 554)

Q_a = $\frac{(11{,}85\frac{ft^3}{ft^2(cycle)}\ x\ 0{,}9\ x\ 1392{,}2\frac{lb}{ft^2})}{60\ \min x\ 1.392\frac{lb}{ft^2}}$

Q_a = 0,27 ft3/min pada 500 torr (9,5 psi)

Data:

Rasio kapasitas panas gas, k = 1,4 (Peter's, Hal. 553)

Tekanan masuk, P_1 = 500 torr = 9,5 psi

Tekanan keluar, P_2 = 760 torr = 14,7 psi

HP = $\frac{3{,}03\ x\ 10^{-5}k}{k-1} P_1 Q_a \left[\left(\frac{P_1}{P_2}\right)^{(k-1)/k} - 1\right]$ (Peter's, Pers. 24)

HP = $\frac{3{,}03\ x\ 10^{-5} x\ 1{,}4}{1{,}4-1} 14{,}7\ psi\ x\ 16{,}61\ ft^3/min\left[\left(\frac{14{,}7\ psi}{9{,}5\ psi}\right)^{(1{,}4-1)/1{,}4} - 1\right]$

HP = 0,054 HP ≈ 0,5 HP

8. *Heater* (H-131)

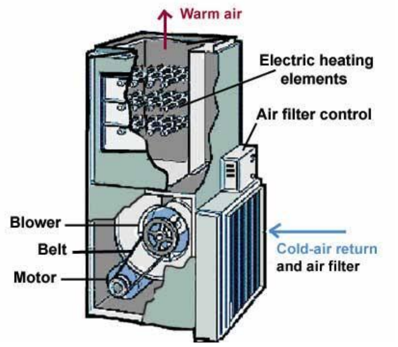
Fungsi : Untuk memanaskan udara sebelum digunakan untuk mengeringkan bahan baku

Tipe : *Electric Air Heater*

Jumlah : 1 unit

Fasa : gas

Gambar :



Gambar C.7 *Heater* (H-131)

Data:

m = laju alir massa= 62.749,2668 kg/jam = 17,43035 kg/s

Cu = Spesifik panas udara = 1.005 kJ/kg°C

Δt = Perbedaan temperatur (°C)

Ca = Spesifik panas air = 4.18 kJ/kg°C

ΔT_1= 100°C -25°C= 85°C

ΔT_2= 120°C -25°C= 95°C

U = Koefisien perpindahan panas keseluruhan

= 50 w / m^2°C (Sebagaimana tabel per standar)

Analisis Desain:

a. Perpindahan Panas

Q = m x c x Δt

Q = 62.749,2668 kg/s x 1.005 kJ/kg°C x 75°C

Q = 1.313.812,77539 kW

b. Panas Hilang

Q = m x c x Δt

= 62.749,2668 x 1.005 x (95)

= 1.664.162,84882 kW

c. LMTD

LMTD = ((Th1-Tc2)-(Th2-Tc1))/ln((Th1-Tc2)- (Th2-Tc1))

= ((120-100)-(25-25))/ln ((120-110)/(30-25))

LMTD = 28,85°C

d. Total Flow Area

$Q = U \times A \times \Delta T_m \times F$

Dimana:

A = Luas Air Heater (m^2)

F = Correction factor

$A = Q / U\ \Delta T_m \times F$

= (1.664.162,84882 x1000) / (50 x 0.94 x 28,85°)

= 968.793,21387 m2

m = ρAv

Dimana:

m = laju alir massa (kg/s)

A = Flow area tube (m^2)

v = Kecepatan aliran = 0.2m/s

ρ = 1.5 kg/m^3

Dari persamaan kontinuitas:

Q = A x v

17,43035 / 1000 = 3.14 x (0.04)2 x v

v = 0,06939 m/s

m = ρAv

A = m / (ρv)

A = 17,43035 / (1.5 x 0,06939)

= 167,46667 m^2

Jumlah tube:

167,46667 m^2 = n X π/4 X d2

n = 213 tube

Panjang tube untuk 2 pass

nπdL = 43.015m^2

L = 43.015 / (213 x 3.14 x 0.04)

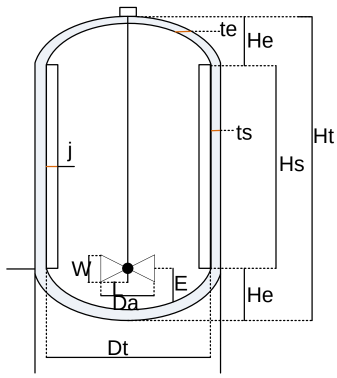
L = 1,6 m

Jumlah tube = 213

Jumlah pass = 2, panjang = 1,6 m

9. Tangki Pelarutan NaOH

Fungsi	: Tempat pelarutan bahan baku NaOH
Tipe	: Silinder vertikal dengan alas dan tutup *ellipsoidal*
Bahan	: *Carbon steel*
Jumlah	: 1 unit
Gambar	:



Data :

-	Laju alir NaOH	: 2.568,3456 kg/jam
-	Laju alir air	: 70.812,9573 kg/jam
-	Laju alir total	: 73.381,3029 kg/jam
-	Densitas NaOH	: 2.130 kg/m^3
-	Densitas air	: 997 kg/m^3
-	Temperatur	: 30°C
-	Tekanan	: 1 atm
-	Densitas campuran	: 3.127 kg/m^3 = 195,22 lb/ft^3
-	Viskositas campuran	: 78,9 cP = 0,05 lb/ft.s

Kapasitas tangki, V_t

Pelarutan untuk 1 hari = 24 jam

$$Vc_{\text{(cairan)}} = \frac{m}{\rho}$$

$$= \frac{73.381,3029 \, {}^{kg}/_{jam} \, x \, 24 \, jam}{3.127 \, {}^{kg}/_{m^3}} = 563,2080 \text{ m}^3$$

Faktor keamanan 10%

VESSEL (TANGKI PENYIMPANAN)

1. Untuk yang kurang dari 1000 gal, gunakan tangki vertikal dengan kaki-kaki.
2. Antara 1000 dan 10,000 gal, gunakan tangki horisontal dengan *support* beton.
3. Diatas 10,000 gal, gunakan tangki vertikal dengan pondasi beton.
4. Cairan mengacu ke *breathing losses* dapat disimpan dalam tangki dengan atap mengapung atau mengembang untuk konservasi.
5. *Freeboard* adalah 15% dibawah kapasitas 500 gal dan 10% diatas kapasitas 500 gal.

Maka,

$V_c = 0,9 \, V_t$

$$V_t = \frac{V_c}{0,9}$$

$$= \frac{563,2080 \, m^3}{0,9} = 628,7866 \text{ m}^3$$

Dimensi tangki

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4} \times D_s^2 \times H_s \qquad H_s = D_s$$

Maka,

$$V_s = \frac{\pi}{4} \times D_s^3$$

- **Volume *ellipsoidal*, V_e**

$$V_e = \frac{\pi}{6} \times D_s^2 \times H_e \qquad H_e = \frac{1}{4} D_s$$

Maka,

$$V_e = \frac{\pi}{24} \times D_s^3$$

TABLE 4
Design equations and data for pressure vessels (Continued)

Properties of vessel heads (Include corrosion allowance in variables)	2:1 Ellipsoidal	Hemi-spherical	Standard ASME torispherical
Capacity as volume in head, in³	$\frac{\pi D_a^3}{24}$	$\frac{2}{3}\pi L_a^3$	$0.9\left[\frac{2\pi L_a^2}{3}(IDD)\right]$
IDD = inside depth of dish, in	$\frac{D_a}{4}$	L_a	$L_a - [(L_a - r)^2 - (L_a - t - r)^2]^{1/2}$
Approximate weight of dished portion of head, lbm	$\rho_m\left[\frac{\pi(nD_a + t)^2 t}{4}\right]$	$\rho_m[2\pi L_a^2 t]$	$\rho_m\left[\frac{\pi(OD + OD/24 + at)^2 t}{4}\right]$

- **Diameter tangki, D_t**

V_t $= V_s + 2V_e$

$$= \left(\frac{\pi}{4} \times D_S^3\right) + 2\left(\frac{\pi}{24} \times D_S^3\right)$$

$$= 4\,Vt/12\pi$$

$$D^3 = \frac{V_t}{3\pi}$$

$$= \frac{625{,}7866\ m^3}{3x3{,}14}$$

$$D = \sqrt[3]{\frac{625{,}7866\ m^3}{3x3{,}14}}$$

$= 4{,}05$ m $= 159{,}4498$ in

630 APPENDIX A. Conversion Factors and Values of the Gas Constant

Table A.1 Conversion Factors

Quantity	Conversion
Length	1 m = 100 cm = 3.280 84 (ft) = 39.3701 (in)
Mass	1 kg = 10^3 g = 2.204 62 (lb_m)
Force	1 N = 1 kg m s^{-2} = 10^5 (dyne) = 0.224 809 (lb_f)
Pressure	1 bar = 10^5 kg m^{-1} s^{-2} = 10^5 N m^{-2} = 10^5 Pa = 10^2 kPa = 10^6 dyne cm^{-2} = 0.986 923 atm = 14.5038 (psia) = 750.061 torr
Volume	1 m^3 = 10^6 cm^3 = 35.3147 $(ft)^3$ = 264.172 (gal)
Density	1 g cm^{-3} = 10^3 kg m^{-3} = 62.4278 (lb_m)$(ft)^{-3}$
Energy	1 J = 1 kg m^2 s^{-2} = 1 N m = 1 m^3 Pa = 10^{-5} m^3 bar = 10 cm^3 bar = 9.869 23 cm^3 atm = 10^7 dyne cm = 10^7 erg = 0.239 006 (cal) = 5.121 97 x $10^{-3}$$(ft)^3$(psia) = 0.737 562 (ft)($lb_f$) = 9.478 31 x 10^{-4} (Btu)
Power	1 kW = 10^3 W = 10^3 kg m^2 s^{-3} = 10^3 J s^{-1} = 239.006 (cal) s^{-1} = 737.562 (ft)(lb_f) s^{-1} = 0.947 831 (Btu) s^{-1} = 1.341 02 (hp)

Table A.2 Values of the Universal Gas Constant

R = 8.314 J mol^{-1} K^{-1} = 8.314 m^3 Pa mol^{-1} K^{-1}
= 83.14 cm^3 bar mol^{-1} K^{-1} = 8314 cm^3 kPa mol^{-1} K^{-1}
= 82.06 cm^3 atm mol^{-1} K^{-1} = 82 363.95 cm^3 torr mol^{-1} K^{-1} = 0.082 06 m^3 atm $kmol^{-1}$ K^{-1}
= 1.9872 (cal) mol^{-1} K^{-1} = 1.986 (Btu)(lb mole)$^{-1}$$(R)^{-1}$
= 0.7302 $(ft)^3$(atm)(lb mol)$^{-1}$$(R)^{-1}$ = 10.73 $(ft)^3$(psia)(lb mol)$^{-1}$$(R)^{-1}$
= 1545 (ft)(lb_f)(lb mol)$^{-1}$$(R)^{-1}$

(Smith Van Ness, Hal 630)

- **Tinggi tangki, H_s**

Tinggi silinder, H_s = D_s = 4,05 m = 159,4498 in

Tinggi *ellipsoidal*, H_e = ¼ D_s = 1,0125 m = 39,8624 in

Tangki direncanakan diletakkan di atas kaki penyangga yang terbuat dari besi dengan tinggi 2 m.

Tinggi total, (Ht) = tinggi silinder + 2 x tinggi *ellipsoidal* + (2 - tinggi *ellipsoidal*)

= 4,05 m + 2(1,0125 m) + (2 – 1,0125) m

= 7,0625 m = 23,1651 ft

- **Tinggi Cairan, H_c :**

$$Hc = \frac{V_c \text{ x } (H_s + 2H_e)}{V_t}$$

$$Hc = \frac{(563,2080 \text{ m}^3 \text{x } (4,05 \text{ m} + 1,0125 \text{m})}{625,7866 \text{m}^3} = 5,4675 \text{ m}$$

- Tekanan cairan dalam tangki, P_H :

$P_H \quad = \rho g H_c$

$P_H \quad = 3.127\ kg/m^3 \times 9{,}81\ m/s^2 \times 5{,}4575\ m$

$P_H \quad = 167.721{,}6448\ kg/m.s^2 = 1{,}6269\ atm = 23{,}9088\ psi$

- Tekanan desain, P_d :

$P_d \quad = P_{op} + P_H$

$P_d \quad = 1\ atm + 1{,}6269\ atm = 2{,}6269\ atm = 38{,}6047\ psi$

TABLE A.5 Pressure and Stress ($L^{-1}MT^{-2}$)

Pascal (Pa, $N\ m^{-2}$, $J\ m^{-3}$, $kg\ m^{-1}\ s^{-2}$)	Pound-force per inch² (psi, $lb_f\ in.^{-2}$)	Kilogram-force per metre² ($kg_f\ m^{-2}$)	Standard atmosphere (atm)	Dyne per cm² ($dyn\ cm^{-2}$)	Torr (Torr, mmHg)*	Inches of water** (in. H_2O)	Bar
1	1.450×10^{-4}	1.020×10^{-1}	9.869×10^{-6}	10^{1}	7.501×10^{-3}	4.015×10^{-3}	10^{-5}
6.895×10^{3}	1	7.031×10^{2}	6.805×10^{-2}	6.895×10^{4}	5.171×10^{1}	2.768×10^{1}	6.895×10^{-2}
9.807	1.422×10^{-3}	1	9.678×10^{-5}	9.807×10^{2}	7.356×10^{-2}	3.937×10^{-2}	9.807×10^{-5}
1.013×10^{5}	1.470×10^{1}	1.033×10^{4}	1	1.013×10^{6}	7.6×10^{2}	4.068×10^{2}	1.013
10^{-1}	1.450×10^{-5}	1.020×10^{-2}	9.869×10^{-7}	1	7.501×10^{-4}	4.015×10^{-4}	10^{-6}
1.333×10^{2}	1.934×10^{-2}	1.360×10^{1}	1.316×10^{-3}	1.333×10^{3}	1	5.352×10^{-1}	1.333×10^{-3}
2.491×10^{2}	3.613×10^{-2}	2.540×10^{1}	2.458×10^{-3}	2.491×10^{3}	1.868	1	2.491×10^{-3}
10^{5}	1.450×10^{1}	1.020×10^{4}	9.869×10^{-1}	10^{6}	7.501×10^{2}	4.015×10^{2}	1

*mmHg refers to Hg at 0°C; 1 Torr = 1.00000 mmHg.
**in. H_2O refers to water at 4°C.

(Pauline M Doran, Hal 856)

- **Tebal dinding tangki, t_d**

$$t_d = \frac{PR}{SE - 0{,}6P} + C$$ (Walas, Tabel 18.4)

- **Tebal tutup *ellipsoidal*, t_e**

$$t_e = \frac{PD_t}{2SE - 0{,}2P} + C$$ (Walas, Tabel 18.4)

TABLE 18.3. Formulas for Design of Vessels under Internal Pressure[a]

Item	Thickness t(in.)	Pressure P(psi)	Stress S(psi)	Notes
Cylindrical shell	$\frac{PR}{SE-0.6P}$	$\frac{SEt}{R+0.6t}$	$\frac{P(R+0.6t)}{t}$	$t \le 0.25D$, $P \le 0.385SE$
Flat flanged head (a)	$D\sqrt{0.3P/S}$	$t^2S/0.3D^2$	$0.3D^2P/t^2$	
Torispherical head (b)	$\frac{0.885PL}{SE-0.1P}$	$\frac{SEt}{0.885L+0.1t}$	$\frac{P(0.885L+0.1t)}{t}$	$r/L=0.06$, $L \le D+2t$
Torispherical head (b)	$\frac{PLM}{2SE-0.2P}$	$\frac{2SEt}{LM+0.2t}$	$\frac{P(LM+0.2t)}{2t}$	$M=\frac{3+(L/r)^{1/2}}{4}$
Ellipsoidal head (c)	$\frac{PD}{2SE-0.2P}$	$\frac{2SEt}{D+0.2t}$	$\frac{P(D+0.2t)}{2t}$	$h/D=4$
Ellipsoidal head (c)	$\frac{PDK}{2SE-0.2P}$	$\frac{2SEt}{DK+0.2t}$	$\frac{P(DK+0.2t)}{2Et}$	$K=[2+(D/2h)^2]/6$, $2 \le D/h \le 6$
Hemispherical head (d) or shell	$\frac{PR}{2SE-0.2P}$	$\frac{2SEt}{R+0.2t}$	$\frac{P(R+0.2t)}{2t}$	$t \le 0.178D$, $P \le 0.685SE$
Toriconical head (e)	$\frac{PD}{2(SE-0.6P)\cos\alpha}$	$\frac{2SEt\cos\alpha}{D+1.2t\cos\alpha}$	$\frac{P(D+1.2t\cos\alpha)}{2t\cos\alpha}$	$\alpha \le 30°$

[a]Nomenclature: D = diameter (in.), E = joint efficiency (0.6–1.0), L = crown radius (in.), P = pressure (psig), h = inside depth of ellipsoidal head (in.), r = knuckle radius (in.), R = radius (in.), S = allowable stress (psi), t = shell or head thickness (in.).
Note: Letters in parentheses in the first column refer to Figure 18.16.

Data :

- Tekanan desain, P : 2,6269 atm = 38,6047psi
- Diameter, D : 4,05 m = 159,4498 in
- Jari-jari tangki, R : 2,0250 m = 79,7249 in
- *Allowable stress*, S : 18.700 psi (Peter, Tabel 4 Hal 538)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)

TABLE 4
Design equations and data for pressure vessels (Continued)

Properties of vessel heads (Include corrosion allowance in variables)	2: 1 Ellipsoidal	Hemi-spherical	Standard ASME torispherical
Capacity as volume in head, in³	$\frac{\pi D_a^3}{24}$	$\frac{2}{3}\pi L_a^3$	$0.9\left[\frac{2\pi L_a^2}{3}(IDD)\right]$
IDD = inside depth of dish, in.	$\frac{D_a}{4}$	L_a	$L_a - [(L_a - r)^2 - (L_a - t - r)^2]^{1/2}$
Approximate weight of dished portion of head, lbm	$\rho_m\left[\frac{\pi(nD_a + t)^2 t}{4}\right]$	$\rho_m[2\pi L_a^2 t]$	$\rho_m\left[\frac{\pi(OD + OD/24 + at)^2 t}{4}\right]$

Joint efficiencies	Recommended stress values: Metal	Temp., °F	S, psi
For double-welded butt joints	Carbon steel	-20 to 650	13,700
if fully radiographed = 1.0	(SA-285, Cr. C)	750	12,000
if spot examined = 0.85		850	8,300
if not radiographed = 0.70	Low-alloy steel	-20 to 800	13,700
In general, for spot examined	for resistance to	950	11,000
if electric resistance weld = 0.85	H_2 and H_2S	1050	5,000
if lap welded = 0.80	(SA-387, Gr.12C1.1)	1200	1,000
if single-butt welded = 0.60	High-tensile steel	-20 to 750	20,000
	for heavy-wall	850	16,800
	vessels	950	10,000
	(SA-302, Gr.B)	1000	6,200
	High-alloy steel for cladding and	-20	18,700
	corrosion resistance	650	11,200
	Stainless 304	800	10,500
	(SA-240)	1000	9,700
	Stainless 316	-20	18,700
	(SA-240)	650	11,500
		800	11,000
		1000	10,600
	Nonferrous metals		
	Copper	100	6,700
	(SB-11)	400	3,000
	Aluminum	100	2,300
	(SB-209, 1100-0)	400	1,000

See the latest ASME Boiler and Pressure Vessel Code for further details.

- Faktor korosi yang diizinkan : 0,002 in/thn (Perry's Tabel 23-2)
- Waktu operasi pabrik : 10 tahun

Maka :

$$t_d = \frac{23,9088 psi \times 79,7249\ in}{(18.700\ psi \times 0,85) - (0,6 \times 23,9088 psi)} + 0,002 \frac{in}{tahun} \times 10\ tahun$$

= 0,14 in

= 3,53 mm

Plate Thickness (mm)	Weight (kg/m²)
1.6	12.6
2.0	15.7
2.5	19.6
3	23.6
3.2	25.1
4	31.4
5	39.3
6	47.1
8	62.8
10	78.5

(Sumber: Engineering toolbox)

- **Tebal tutup *ellipsoidal*, t_e**

t_e $= \frac{PD_t}{2SE-0,2P} + C$ (Walas, Tabel 18.3)

$= \frac{23,9088\ psi \times 159,4498\ in}{(2\times18700\times0,85)-(0,2\times23,9088\ psi)} + 0,002\frac{in}{tahun} \times 10\ tahun$

= 0,14 in

= 3,53 mm

Desain pengaduk

Untuk umpan dengan viskositas ≤ 4.000 cP, maka dipilih pengaduk jenis propeller berdaun tiga. Untuk mencegah vortex, maka pada tangki dipasang *baffle* (Walas, hal 288)

10.2. KINDS OF IMPELLERS

A rotating impeller in a fluid imparts flow and shear to it, the shear resulting from the flow of one portion of the fluid past another. Limiting cases of flow are in the axial or radial directions so that impellers are classified conveniently according to which of these flows is dominant. By reason of reflections from vessel surfaces and obstruction by baffles and other internals, however, flow patterns in most cases are mixed. When a close approach to axial flow is particularly desirable, as for suspension of the solids of a slurry, the impeller may be housed in a draft tube; and when radial flow is needed, a shrouded turbine consisting of a rotor and a stator may be employed.

Because the performance of a particular shape of impeller usually cannot be predicted quantitatively, impeller design is largely an exercise of judgment so a considerable variety has been put forth by various manufacturers. A few common types are illustrated on Figure 10.2 and are described as follows:

a. The three-bladed mixing propeller is modelled on the marine propeller but has a pitch selected for maximum turbulence. They are used at relatively high speeds (up to 1800 rpm) with low viscosity fluids, up to about 4000 cP. Many versions are available: with cutout or perforated blades for shredding and breaking up lumps, with sawtooth edges as on Figure 10.2(g) for cutting and tearing action, and with other than three blades. The stabilizing ring shown in the illustration sometimes is included to minimize shaft flutter and vibration particularly at low liquid levels.

"STANDARD" TURBINE DESIGN. The designer of an agitated vessel has an unusually large number of choices to make as to type and location of the impeller, the proportions of the vessel, the number and proportions of the baffles, and so forth.[37] Each of these decisions affects the circulation rate of the liquid, the velocity patterns, and the power consumed. As a starting point for design in ordinary agitation problems, a turbine agitator of the type shown in Fig. 9.7 is commonly

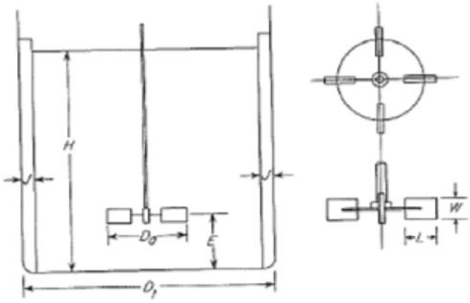


FIGURE 9.7
Measurements of turbine. (*After Rushton et al.*[42])

used. Typical proportions are

$$\frac{D_a}{D_t} = \frac{1}{3} \qquad \frac{H}{D_t} = 1 \qquad \frac{J}{D_t} = \frac{1}{12}$$

$$\frac{E}{D_t} = \frac{1}{3} \qquad \frac{W}{D_a} = \frac{1}{5} \qquad \frac{L}{D_a} = \frac{1}{4}$$

(Mc. Cabe, Hal 242 – 243)

- **Diameter pengaduk, d**

d $= {D_t}/{3}$

$= {4{,}05\ m}/{3} = 1{,}35$ m = 4,4280ft

- **Panjang daun pengaduk, L**

L $= {d}/{4}$

$= {1{,}35\ m}/{4} = 0{,}3375$ m = 1,1070 ft

- **Lebar daun pengaduk, W**

W $= {d}/{5}$

$= {1{,}35\ m}/{5} = 0{,}27$ m = 0,8856 ft

- **Tinggi pengaduk dari dasar tangki, E**

E $= {D}/{3}$

$= {}^{4,05\ m}/_{3} = 1,35\text{m} = 4,428 \text{ ft}$

- **Lebar *baffle*, J**

J $= {}^{D}/_{12}$

$= {}^{4,05\ m}/_{12} = 0,3375 \text{ m} = 1,107 \text{ ft}$

- **Kecepatan putar pengaduk, N**

$$\frac{N \times d}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1,22 + 1,25\left(\frac{D_t}{d}\right)$$ (Treybal, Pers 6.18)

Impellers

Both open and disk flat-blade turbines are used extensively, particularly because of the high discharge velocities normal to the flow of gas which they maintain. Especially in the larger sizes, the disk type is preferred.† They are best specified with $d_i/T = 0.25$ to 0.4 and set off the bottom of the vessel a distance equal to the impeller diameter. In some cases, especially designed impellers can be used to induce the gas flow from the space above the liquid down into the agitated mass [81, 115].

For production of effective gas dispersions with disk flat-blade turbines, the impeller speed should exceed that given by [122]

$$\frac{Nd_i}{(\sigma g g_c/\rho_L)^{0.25}} = 1.22 + 1.25\frac{T}{d_i} \qquad (6.18)$$

σ : 0,05 lb/ft (Mc. Cabe, Ed 5, hal.295)

For water the interfacial tension is 72.75 dyn/cm. The rise velocity of the bubbles may be assumed constant at 0.2 m/s.

g_c : 32,2 ft/dt^2

Maka,

$$N = \frac{\left(1,22+1,25\left(\frac{D_t}{d}\right)\left(\frac{\sigma g_c}{\rho}\right)^{0,25}\right)}{d}$$

= 0,3382 rps

- **Daya pengadukan, P**

$N_{Re} = \frac{\rho \times N \times d^2}{\mu}$ (Mc. Cabe Pers 9.17)

SIGNIFICANCE OF DIMENSIONLESS GROUPS.[23] The three dimensionless groups in Eq. (9.14) may be given simple interpretations. Consider the group $nD_a^2\rho/\mu$. Since the impeller tip speed u_2 equals $\pi D_a n$,

$$N_{Re} = \frac{nD_a^2\rho}{\mu} = \frac{(nD_a)D_a\rho}{\mu} \propto \frac{u_2 D_a \rho}{\mu} \quad (9.17)$$

$$= \frac{195{,}2186\,\frac{lb}{ft^3} \times 0{,}3382\ rps \times (4{,}428\,ft)^2}{0{,}05.dt} = 24.418{,}7845$$

Karena N_{Re} > 10.000, maka

$P = \frac{K_T N^3 d^5 \rho}{g_c}$ (Mc Cabe, Pers 9.24)

In baffled tanks at Reynolds numbers larger than about 10,000, the power number is independent of the Reynolds number, and viscosity is not a factor. In this range the flow is fully turbulent and Eq. (9.16) becomes

$$N_P = K_T \quad (9.23)$$

from which

$$P = \frac{K_T n^3 D_a^5 \rho}{g_c} \quad (9.24)$$

Magnitudes of the constants K_T and K_L for various types of impellers and tanks are shown in Table 9.3.

K_T = 0,87 (Mc Cabe, Tabel 9.3)

TABLE 9.3
Values of constants K_L and K_T in Eqs. (9.21) and (9.23) for baffled tanks having four baffles at tank wall, with width equal to 10 percent of the tank diameter

Type of impeller	K_L	K_T
Propeller, three blades		
Pitch 1.0[40]	41	0.32
Pitch 1.5[35]	55	0.87
Turbine		
Six-blade disk[35] ($S_3 = 0.25$, $S_4 = 0.2$)	65	5.75
Six curved blades[40] ($S_4 = 0.2$)	70	4.80
Six pitched blades[39] (45°, $S_4 = 0.2$)	—	1.63
Four pitched blades[35] (45°, $S_4 = 0.2$)	44.5	1.27
Flat paddle, two blades[40] ($S_4 = 0.2$)	36.5	1.70
Anchor[35]	300	0.35

$$P = \frac{K_T N^3 d^5 \rho}{g_c}$$

$$= \frac{0{,}87 \times (0{,}3382)^3 (4{,}428)^5 \times 195{,}2186}{32{,}2}$$

= 347,4596 lb.ft/s

= 0,6317 HP

10. Reaktor Demineralisasi (R-1101)

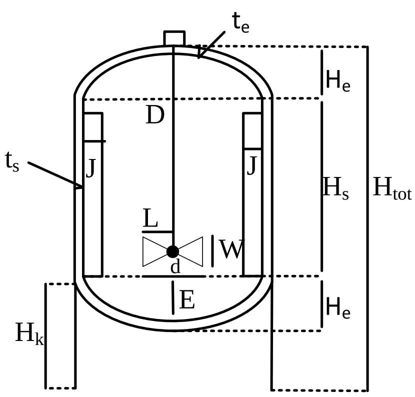
Fungsi : Tempat penguaraian mineral dari kitin

Tipe : Silinder vertikal dengan alas dan tutup *ellipsoidal*

Bahan : *Carbon steel*

Jumlah : 1 unit

Gambar :



Data :

- Temperatur, T = 75 ^{0}C
- Tekanan, P = 1,00 atm = 14,7 psi

- Laju Alir, m = 164.035,30 kg/jam = 100,45 lb/s
- Laju alir volumetrik,v = 158,75 m^3/jam = 5.606,27 ft^3/jam
- Viskositas, µ = 69,01 cP = 0,05 lb/ft.s
- Densitas, ρ = 6.171 kg/m^3 = 385,26 lb/ft^3
- Waktu reaksi demineralisasi = 3 jam

Kapasitas tangki, V_t

$$Vc_{\text{(cairan)}} = \frac{m}{\rho}$$

$$= \frac{164.035,30 \ {kg}/{jam} \ x \ 3 \ jam}{6.171 \ {kg}/{m^3}} = 79,74 \ m^3$$

Faktor keamanan 20%

VESSEL (TANGKI PENYIMPANAN)

1. Untuk yang kurang dari 1000 gal, gunakan tangki vertikal dengan kaki-kaki.
2. Antara 1000 dan 10,000 gal, gunakan tangki horisontal dengan *support* beton.
3. Diatas 10,000 gal, gunakan tangki vertikal dengan pondasi beton.
4. Cairan mengacu ke *breathing losses* dapat disimpan dalam tangki dengan atap mengapung atau mengembang untuk konservasi.
5. *Freeboard* adalah 15% dibawah kapasitas 500 gal dan 10% diatas kapasitas 500 gal.

Maka,

$$V_c = 0,8 \ V_t$$

$$V_t = \frac{V_c}{0,8}$$

$$= \frac{79,74 m^3}{0,8} = 99,68 \ m^3$$

Dimensi tangki

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4} \times D_s^2 \times H_s \qquad H_s = D_s$$

Maka,

$$V_s = \frac{\pi}{4} \times D_s^3$$

- **Volume *ellipsoidal*, V_e**

$$V_e = \frac{\pi}{6} \times D_s^2 \times H_e \qquad H_e = ¼ \ D_s$$

Maka,

$V_e \quad = \frac{\pi}{24} \times D_s^3$

TABLE 4
Design equations and data for pressure vessels (Continued)

Properties of vessel heads (Include corrosion allowance in variables)	2: 1 Ellipsoidal	Hemi-spherical	Standard ASME torispherical
Capacity as volume in head, in³	$\frac{\pi D_a^3}{24}$	$\frac{2}{3}\pi L_a^3$	$0.9\left[\frac{2\pi L_a^2}{3}(IDD)\right]$
IDD = inside depth of dish, in	$\frac{D_a}{4}$	L_a	$L_a - [(L_a - r)^2 - (L_a - t - r)^2]^{1/2}$
Approximate weight of dished portion of head, lbm	$\rho_m\left[\frac{\pi(nD_a + t)^2 t}{4}\right]$	$\rho_m[2\pi L_a^2 t]$	$\rho_m\left[\frac{\pi(OD + OD/24 + at)^2 t}{4}\right]$

- **Diameter tangki, D_t**

$V_t \quad = V_s + 2V_e$

$= \left(\frac{\pi}{4} \times D_s^3\right) + 2\left(\frac{\pi}{24} \times D_s^3\right)$

$= 4\,Vt/12\pi$

$D^3 \quad = \frac{V_t}{3\pi}$

$= \frac{99{,}68\ m^3}{3x3{,}14}$

$D \quad = \sqrt[3]{\frac{99{,}68\ m^3}{3x3{,}14}}$

$= 10{,}58$ m $= 86{,}43$ in

630 APPENDIX A Conversion Factors and Values of the Gas Constant

Table A.1 Conversion Factors

Quantity	Conversion
Length	1 m = 100 cm = 3.280 84 (ft) = 39.3701 (in)
Mass	1 kg = 10^3 g = 2.204 62 (lb_m)
Force	1 N = 1 kg m s^{-2} = 10^5 (dyne) = 0.224 809 (lb_f)
Pressure	1 bar = 10^5 kg m^{-1} s^{-2} = 10^5 N m^{-2} = 10^5 Pa = 10^2 kPa = 10^6 dyne cm^{-2} = 0.986 923 atm = 14.5038 (psia) = 750.061 torr
Volume	1 m^3 = 10^6 cm^3 = 35.3147 $(ft)^3$ = 264.172 (gal)
Density	1 g cm^{-3} = 10^3 kg m^{-3} = 62.4278 (lb_m)$(ft)^{-3}$
Energy	1 J = 1 kg m^2 s^{-2} = 1 N m = 1 m^3 Pa = 10^{-5} m^3 bar = 10 cm^3 bar = 9.869 23 cm^3 atm = 10^7 dyne cm = 10^7 erg = 0.239 006 (cal) = 5.121 97 x 10^{-3} $(ft)^3$(psia) = 0.737 562 (ft)(lb_f) = 9.478 31 x 10^{-4} (Btu)
Power	1 kW = 10^3 W = 10^3 kg m^2 s^{-3} = 10^3 J s^{-1} = 239.006 (cal) s^{-1} = 737.562 (ft)(lb_f) s^{-1} = 0.947 831 (Btu)s^{-1} = 1.341 02 (hp)

Table A.2 Values of the Universal Gas Constant

R = 8.314 J mol^{-1} K^{-1} = 8.314 m^3 Pa mol^{-1} K^{-1}
= 83.14 cm^3 bar mol^{-1} K^{-1} = 8314 cm^3 kPa mol^{-1} K^{-1}
= 82.06 cm^3 atm mol^{-1} K^{-1} = 82 363.95 cm^3 torr mol^{-1} K^{-1} = 0.082 06 m^3 atm $kmol^{-1}$ K^{-1}
= 1.9872 (cal) mol^{-1} K^{-1} = 1.986 (Btu)(lb mole)$^{-1}$$(R)^{-1}$
= 0.7302 $(ft)^3$(atm)(lb mol)$^{-1}$$(R)^{-1}$ = 10.73 $(ft)^3$(psia)(lb mol)$^{-1}$$(R)^{-1}$
= 1545 (ft)(lb_f)(lb mol)$^{-1}$$(R)^{-1}$

(Smith Van Ness, Hal 630)

- **Tinggi tangki, H_s**

  Tinggi silinder, H_s = D_s = 2,2 m 86,43 in

  Tinggi *ellipsoidal*, H_e = ¼ D_s = 0,55 m = 21,61 in

  Tangki direncanakan diletakkan di atas kaki penyangga yang terbuat dari besi dengan tinggi 2 m.

  Tinggi total, (Ht) = tinggi silinder + 2 x tinggi *ellipsoidal* + (2 - tinggi *ellipsoidal*)

  = 2,2 m + 2(0,55 m) + (2 – 0,55) m

  = 4,74 m = 15,56 ft

- **Tinggi Cairan, H_c :**

$$Hc = \frac{V_c \text{ x } (H_s + 2H_e)}{V_t}$$

$$Hc = \frac{(79{,}74 \text{ m}^3 \text{x } (2{,}2 \text{ m} + 0{,}55\text{m})}{99{,}68\text{m}^3} = 2{,}2 \text{ m}$$

- Tekanan cairan dalam tangki, P_H :

$P_H \quad = \rho g H_c$

$P_H \quad = 6.171\ kg/m^3 \times 9{,}81\ m/s^2 \times 2{,}2\ m$

$P_H \quad = 132.906{,}21\ kg/m.s^2 = 1{,}29\ atm = 18{,}95\ psi$

- Tekanan desain, P_d :

$P_d \quad = P_{op} + P_H$

$P_d \quad = 1\ atm + 1{,}29\ atm = 2{,}29\ atm = 33{,}64\ psi$

TABLE A.5 Pressure and Stress ($L^{-1}MT^{-2}$)

Pascal (Pa, $N\ m^{-2}$, $J\ m^{-3}$, $kg\ m^{-1}\ s^{-2}$)	Pound-force per inch^2 (psi, $lb_f\ in.^{-2}$)	Kilogram-force per metre^2 ($kg_f\ m^{-2}$)	Standard atmosphere (atm)	Dyne per cm^2 (dyn cm^{-2})	Torr (Torr, mm Hg)*	Inches of water** (in. H_2O)	Bar
1	1.450×10^{-4}	1.020×10^{-1}	9.869×10^{-6}	10^{1}	7.501×10^{-3}	4.015×10^{-3}	10^{-5}
6.895×10^{3}	1	7.031×10^{2}	6.805×10^{-2}	6.895×10^{4}	5.171×10^{1}	2.768×10^{1}	6.895×10^{-2}
9.807	1.422×10^{-3}	1	9.678×10^{-5}	9.807×10^{1}	7.356×10^{-2}	3.937×10^{-2}	9.807×10^{-5}
1.013×10^{5}	1.470×10^{1}	1.033×10^{4}	1	1.013×10^{6}	7.6×10^{2}	4.068×10^{2}	1.013
10^{-1}	1.450×10^{-5}	1.020×10^{-2}	9.869×10^{-7}	1	7.501×10^{-4}	4.015×10^{-4}	10^{-6}
1.333×10^{2}	1.934×10^{-2}	1.360×10^{1}	1.316×10^{-3}	1.333×10^{3}	1	5.352×10^{-1}	1.333×10^{-3}
2.491×10^{2}	3.613×10^{-2}	2.540×10^{1}	2.458×10^{-3}	2.491×10^{3}	1.868	1	2.491×10^{-3}
10^{5}	1.450×10^{1}	1.020×10^{4}	9.869×10^{-1}	10^{6}	7.501×10^{2}	4.015×10^{2}	1

*mmHg refers to Hg at 0°C; 1 Torr = 1.00000 mmHg.
**in. H_2O refers to water at 4°C.

(Pauline M Doran, Hal 856)

- **Tebal dinding tangki, t_d**

$t_d \quad = \frac{PR}{SE - 0{,}6P} + C$ (Walas, Tabel 18.4)

- **Tebal tutup *ellipsoidal*, t_e**

$t_e \quad = \frac{PD_t}{2SE - 0{,}2P} + C$ (Walas, Tabel 18.4)

TABLE 18.3. Formulas for Design of Vessels under Internal Pressure[a]

Item	Thickness t(in.)	Pressure P(psi)	Stress S(psi)	Notes
Cylindrical shell	$\frac{PR}{SE-0.6P}$	$\frac{SEt}{R+0.6t}$	$\frac{P(R+0.6t)}{t}$	$t \le 0.25D$, $P \le 0.385SE$
Flat flanged head (a)	$D\sqrt{0.3P/S}$	$t^2S/0.3D^2$	$0.3D^2P/t^2$	
Torispherical head (b)	$\frac{0.885PL}{SE-0.1P}$	$\frac{SEt}{0.885L+0.1t}$	$\frac{P(0.885L+0.1t)}{t}$	$r/L = 0.06$, $L \le D+2t$
Torispherical head (b)	$\frac{PLM}{2SE-0.2P}$	$\frac{2SEt}{LM+0.2t}$	$\frac{P(LM+0.2t)}{2t}$	$M = \frac{3+(L/r)^{1/2}}{4}$
Ellipsoidal head (c)	$\frac{PD}{2SE-0.2P}$	$\frac{2SEt}{D+0.2t}$	$\frac{P(D+0.2t)}{2t}$	$h/D = 4$
Ellipsoidal head (c)	$\frac{PDK}{2SE-0.2P}$	$\frac{2SEt}{DK+0.2t}$	$\frac{P(DK+0.2t)}{2Et}$	$K = [2+(D/2h)^2]/6$, $2 \le D/h \le 6$
Hemispherical head (d) or shell	$\frac{PR}{2SE-0.2P}$	$\frac{2SEt}{R+0.2t}$	$\frac{P(R+0.2t)}{2t}$	$t \le 0.178D$, $P \le 0.685SE$
Toriconical head (e)	$\frac{PD}{2(SE-0.6P)\cos\alpha}$	$\frac{2SEt\cos\alpha}{D+1.2t\cos\alpha}$	$\frac{P(D+1.2t\cos\alpha)}{2t\cos\alpha}$	$\alpha \le 30°$

[a] Nomenclature: D = diameter (in.), E = joint efficiency (0.6–1.0), L = crown radius (in.), P = pressure (psig), h = inside depth of ellipsoidal head (in.), r = knuckle radius (in.), R = radius (in.), S = allowable stress (psi), t = shell or head thickness (in.).
Note: Letters in parentheses in the first column refer to Figure 18.16.

Data :

- Tekanan desain, P : 2,29 atm = 33,64psi
- Diameter, D : 2,2 m = 86,43 in
- Jari-jari tangki, R : 1,1 m = 43,22 in
- *Allowable stress*, S : 18.700 psi (Peter, Tabel 4 Hal 538)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)

TABLE 4
Design equations and data for pressure vessels (Continued)

Properties of vessel heads (Include corrosion allowance in variables)	2: 1 Ellipsoidal	Hemi-spherical	Standard ASME torispherical
Capacity as volume in head, in?	$\frac{\pi D_a^3}{24}$	$\frac{2}{3}\pi L_a^3$	$0.9\left[\frac{2\pi L_a^2}{3}(IDD)\right]$
IDD = inside depth of dish, in	$\frac{D_a}{4}$	L_a	$L_a - [(L_a - r)^2 - (L_a - t - r)^2]^{1/2}$
Approximate weight of dished portion of head, lbm	$\rho_m\left[\frac{\pi(nD_a+t)^2 t}{4}\right]$	$\rho_m[2\pi L_a^2 t]$	$\rho_m\left[\frac{\pi(OD + OD/24 + at)^2 t}{4}\right]$

Joint efficiencies	Recommended stress values: Metal	Temp., °F	S, psi
For double-welded butt joints	Carbon steel	-20 to 650	13,700
if fully radiographed = 1.0	(SA-285, Cr. C)	750	12,000
if spot examined = 0.85		850	8,300
if not radiographed = 0.70	Low-alloy steel	-20 to 800	13,700
In general, for spot examined	for resistance to	950	11,000
if electric resistance weld = 0.85	H_2 and H_2S	1050	5,000
if lap welded = 0.80	(SA-387, Gr.12C1.1)	1200	1,000
if single-butt welded = 0.60	High-tensile steel	-20 to 750	20,000
	for heavy-wall	850	16,800
	vessels	950	10,000
	(SA-302, Gr.B)	1000	6,200
	High-alloy steel for		
	cladding and	-20	18,700
	corrosion resistance	650	11,200
	Stainless 304	800	10,500
	(SA-240)	1000	9,700
	Stainless 316	-20	18,700
	(SA-240)	650	11,500
		800	11,000
		1000	10,600
	Nonferrous metals		
	Copper	100	6,700
	(SB-11)	400	3,000
	Aluminum	100	2,300
	(SB-209, 1100-0)	400	1,000

See the latest ASME Boiler and Pressure Vessel Code for further details.

- Faktor korosi yang diizinkan : 0,002 in/thn (Perry's Tabel 23-2)
- Waktu operasi pabrik : 10 tahun

Maka :

$$t_d = \frac{18{,}95\ psi \times 43{,}22\ in}{(18.700\ psi \times 0{,}85) - (0{,}6 \times 18{,}95\ psi)} + 0{,}002\ \frac{in}{tahun} \times 10\ tahun$$

$= 0{,}07$ in

$= 1{,}82$ mm

Plate Thickness (mm)	Weight (kg/m²)
1.6	12.6
2.0	15.7
2.5	19.6
3	23.6
3.2	25.1
4	31.4
5	39.3
6	47.1
8	62.8
10	78.5

(Sumber: Engineering toolbox)

- **Tebal tutup *ellipsoidal*, t_e**

t_e $= \frac{PD_t}{2SE - 0{,}2P} + C$ (Walas, Tabel 18.3)

$= \frac{18{,}95\ psi \times 86{,}43\ in}{(2 \times 18700 \times 0{,}85) - (0{,}2 \times 18{,}95\ psi)} + 0{,}002\,\frac{in}{tahun} \times 10\ tahun$

= 0,07 in

= 1,82 mm

Desain pengaduk

Untuk umpan dengan viskositas ≤ 4.000 cP, maka dipilih pengaduk jenis propeller berdaun tiga. Untuk mencegah vortex, maka pada tangki dipasang *baffle* (Walas, hal 288)

10.2. KINDS OF IMPELLERS

A rotating impeller in a fluid imparts flow and shear to it, the shear resulting from the flow of one portion of the fluid past another. Limiting cases of flow are in the axial or radial directions so that impellers are classified conveniently according to which of these flows is dominant. By reason of reflections from vessel surfaces and obstruction by baffles and other internals, however, flow patterns in most cases are mixed. When a close approach to axial flow is particularly desirable, as for suspension of the solids of a slurry, the impeller may be housed in a draft tube; and when radial flow is needed, a shrouded turbine consisting of a rotor and a stator may be employed.

Because the performance of a particular shape of impeller usually cannot be predicted quantitatively, impeller design is largely an exercise of judgment so a considerable variety has been put forth by various manufacturers. A few common types are illustrated on Figure 10.2 and are described as follows:

1. The three-bladed mixing propeller is modelled on the marine propeller but has a pitch selected for maximum turbulence. They are used at relatively high speeds (up to 1800 rpm) with low viscosity fluids, up to about 4000 cP. Many versions are available: with cutout or perforated blades for shredding and breaking up lumps, with sawtooth edges as on Figure 10.2(g) for cutting and tearing action, and with other than three blades. The stabilizing ring shown in the illustration sometimes is included to minimize shaft flutter and vibration particularly at low liquid levels.

"STANDARD" TURBINE DESIGN. The designer of an agitated vessel has an unusually large number of choices to make as to type and location of the impeller, the proportions of the vessel, the number and proportions of the baffles, and so forth.[37] Each of these decisions affects the circulation rate of the liquid, the velocity patterns, and the power consumed. As a starting point for design in ordinary agitation problems, a turbine agitator of the type shown in Fig. 9.7 is commonly

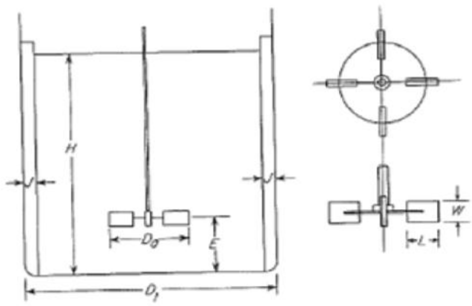


FIGURE 9.7
Measurements of turbine. (*After Rushton et al.*[42])

used. Typical proportions are

$$\frac{D_a}{D_t} = \frac{1}{} \qquad \frac{H}{D_t} = 1 \qquad \frac{J}{D_t} = \frac{1}{12}$$

$$\frac{E}{D_t} = \frac{1}{} \qquad \frac{W}{D_a} = \frac{1}{5} \qquad \frac{L}{D_a} = \frac{1}{4}$$

(Mc. Cabe, Hal 242 – 243)

- **Diameter pengaduk, d**

  d $= {}^{D_t}/_{3}$

  $= {}^{2,2m}/_{3}$ = 0,73 m = 2,40ft

- **Panjang daun pengaduk, L**

  L $= {}^{d}/_{4}$

  $= {}^{2,40\ m}/_{4}$ = 0,18 m = 0,60 ft

- **Lebar daun pengaduk, W**

  W $= {}^{d}/_{5}$

  $= {}^{2,4\ m}/_{5}$ = 0,15 m = 0,48 ft

- **Tinggi pengaduk dari dasar tangki, E**

  E $= {}^{D}/_{3}$

$= 2{,}2\ m/_3 = 0{,}73\ \text{m} = 2{,}40\ \text{ft}$

- **Lebar *baffle*, J**

J $= D/_{12}$

$= 2{,}2\ m/_{12} = 0{,}18\ \text{m} = 0{,}60\ \text{ft}$

- **Kecepatan putar pengaduk, N**

$$\frac{N \times d}{\left(\frac{\sigma g c}{\rho}\right)^{0.25}} = 1{,}22 + 1{,}25\left(\frac{D_t}{d}\right)$$ (Treybal, Pers 6.18)

Impellers

Both open and disk flat-blade turbines are used extensively, particularly because of the high discharge velocities normal to the flow of gas which they maintain. Especially in the larger sizes, the disk type is preferred.† They are best specified with $d_i/T = 0.25$ to 0.4 and set off the bottom of the vessel a distance equal to the impeller diameter. In some cases, especially designed impellers can be used to induce the gas flow from the space above the liquid down into the agitated mass [81, 115].

For production of effective gas dispersions with disk flat-blade turbines, the impeller speed should exceed that given by [122]

$$\frac{Nd_i}{(\sigma g g_c/\rho_L)^{0.25}} = 1.22 + 1.25\frac{T}{d_i} \quad (6.18)$$

σ : 0,05 lb/ft (Mc. Cabe, Ed 5, hal.295)

For water the interfacial tension is 72.75 dyn/cm. The rise velocity of the bubbles may be assumed constant at 0.2 m/s.

g_c : 32,2 ft/dt^2

Maka,

$$N = \frac{\left(1{,}22+1{,}25\left(\frac{D_t}{d}\right)\left(\frac{\sigma g c}{\rho}\right)^{0{,}25}\right)}{d}$$

= 0,53 rps

- **Daya pengadukan, P**

$$N_{Re} = \frac{\rho \times N \times d^2}{\mu}$$ (Mc. Cabe Pers 9.17)

SIGNIFICANCE OF DIMENSIONLESS GROUPS.[23] The three dimensionless groups in Eq. (9.14) may be given simple interpretations. Consider the group $nD_a^2\rho/\mu$. Since the impeller tip speed u_2 equals $\pi D_a n$,

$$N_{Re} = \frac{nD_a^2\rho}{\mu} = \frac{(nD_a)D_a\rho}{\mu} \propto \frac{u_2 D_a \rho}{\mu} \qquad (9.17)$$

$$= \frac{385{,}26\,\frac{lb}{ft^3}\times 0{,}53\ rps \times (2{,}4ft)^2}{0{,}05.dt} = 25.198{,}06$$

Karena N_{Re} > 10.000, maka

$P = \frac{K_T N^3 d^5 \rho}{g_c}$ (Mc Cabe, Pers 9.24)

In baffled tanks at Reynolds numbers larger than about 10,000, the power number is independent of the Reynolds number, and viscosity is not a factor. In this range the flow is fully turbulent and Eq. (9.16) becomes

$$N_P = K_T \qquad (9.23)$$

from which

$$P = \frac{K_T n^3 D_a^5 \rho}{g_c} \qquad (9.24)$$

Magnitudes of the constants K_T and K_L for various types of impellers and tanks are shown in Table 9.3.

K_T = 0,87 (Mc Cabe, Tabel 9.3)

TABLE 9.3
Values of constants K_L and K_T in Eqs. (9.21) and (9.23) for baffled tanks having four baffles at tank wall, with width equal to 10 percent of the tank diameter

Type of impeller	K_L	K_T
Propeller, three blades		
Pitch 1.0[40]	41	0.32
Pitch 1.5[35]	55	0.87
Turbine		
Six-blade disk[35] (S_3 = 0.25, S_4 = 0.2)	65	5.75
Six curved blades[40] (S_4 = 0.2)	70	4.80
Six pitched blades[39] (45°, S_4 = 0.2)	—	1.63
Four pitched blades[35] (45°, S_4 = 0.2)	44.5	1.27
Flat paddle, two blades[40] (S_4 = 0.2)	36.5	1.70
Anchor[35]	300	0.35

$$P = \frac{K_T N^3 d^5 \rho}{g_c}$$

$$= \frac{0,87 \times (0,53)^3 (2,40)^5 \times 385,26}{32,2}$$

= 121,01 lb.ft/s

= 0,22Hp $\approx 0,5\ Hp$

Desain Jaket Pemanas

- Jumlah *steam* yang dibutuhkan : 97,54 kg/jam
- Beban panas yang disuplai dari *steam* : 268.015,84 kkal =1.063.486,84 Btu
- Temperatur awal, T_o : 75°C = 167 °F
- Temperatur *steam*, T_s : 152°C = 305,6 °F
- Densitas *steam*, ρ : 2,669 kg/m^3
- Koefisien perpindahan panas, U_D : 88,05 Btu/hr.ft^2. °F (engineeringpage.com)

ΔT = $T_s - T_o$

= (305,6 – 167) °F

= 138,6 ^{0}F

- **Luas permukaan perpindahan panas, A**

$$A = \frac{Q}{U_D \times \Delta T}$$

$$= \frac{258.015,84\ Btu}{88,05 \frac{Btu}{hr.ft^2.°F} \times 138,6°F} = 87,14\ ft^2$$

- **Volume *steam*, V_s**

$$V_s = \frac{m\ steam}{\rho\ steam}$$

$$= \frac{97,54\ kg}{2,669 \, kg/m^3}$$

= 36,55 m^3

= 1.290,59 ft^3

$Diameter\ Reaktor\ (D1) = D_t + 2\ t_d$

$= 1{,}66\ m + (2\ x\ 0{,}0016\ m)$

$= 2{,}2\ m$

$Asumsi\ jarak\ jaket = 5\ in = 0.127\ m$

- **Tinggi Jaket, Tj**

  $Tinggi\ jaket = H_c + 2\ t_d + jarak\ jaket$

  $= 86{,}43\ m + (2\ x0{,}0016) + 5in$

  $= 91{,}44\ in$

  = 2,32 m

- **Diameter jaket, Dj**

  Diameter $luar\ jaket\ (D2) = D1 + (2xjarak\ jaket)$

  $= 2{,}2\ m + (2\ x\ 5\ in)$

  $= 96{,}44\ in$

  $= 2{,}45\ m$

- **Luas Daerah laluan Steam**

  $Luas\ Laluan\ Steam\ (A)$

  $$A = \frac{\pi}{4}\ x\ (D_2^2 - D_1^2)$$

  $$A = \frac{\pi}{4}\ x\ (\ 2{,}45\ ^2 - 2{,}2\ ^2)$$

  $= 0{,}93\ m^2$

- **Tekanan Hidrostatik pada jaket :**

  $P_H = \rho_a\ g\ h$

  $= 2{,}6690\ x\ 9{,}8100x\ 2{,}2$

  $= 0.0006\ atm$

- **Tekanan Disain, P_j**

  $P_j = P_{operasi}\ x\ P_c$

  $= 1\ atm + 0.0006\ atm$

  $= 1{,}0006tm$

  $= 14{,}7\ psi$

- **Tebal dinding jaket, t_j**

$$t_d = \frac{PR}{SE - 0.6P} + C \qquad (Walas, Tabel\ 18.3)$$

- Tekanan desain, P : 1,0006 atm = 14,7 psi
- Jari-jari tangki, R : 1,1 m = 43,22 in
- *Allowable stress*, S : 13.700 psi (Walas, Tabel 18.4)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)
- Faktor korosi yang diizinkan : 0,002 in/thn (Perry's Tabel 23-2)
- Tahun digunakan : 10 tahun

Maka,

$$t_j = \frac{14{,}7\ psi\ x\ 43{,}22\ in}{(13700\ psi\ x\ 0.85) - (0.6\ x\ 14{,}7\ psi)} + 0.002\ in/thn\ x\ 10\ thn$$

$$= 0.07\ in$$

$$= 1{,}9\ mm$$

***11. Evaporator* (EV-1131)**

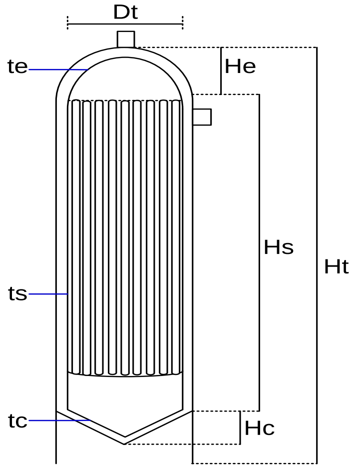
Fungsi : mengurangi kandungan air di dalam larutan nano kitosan

Tipe : *Long tube vertical* (Silinder vertikal dengan tutup *ellipsoidal* dan alas *conical*)

Bahan : *Stainless Steel* (SA-240 Grade 304)

Jumlah : 1 unit

Gambar :



Data :

- Temperatur : 110°C

- Tekanan : 1 atm
- Laju alir umpan : 38.519,02 kg/jam
- Densitas campuran : 5.767 kg/m^3 = 360,0252 lb/ft^3

Kapasitas *evaporator*, V_t

$$V_c = \frac{m}{\rho}$$

$$= \frac{(38.519,02)\frac{kg}{jam}}{5.767\ {kg}/{m^3}} = 6,6792\ m^3$$

Faktor keamanan 10%

Maka,

$$V_c = 0,9\ V_e$$

$$V_e = \frac{V_c}{0,9}$$

$$= \frac{6,6792 m^3}{0,9} = 7,4213\ m^3$$

Dimensi *evaporator*

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4} \times D_e^2 \times H_s \qquad H_s = D_e$$

Maka,

$$V_s = \frac{\pi}{4} \times D_e^3$$

- **Volume *ellipsoidal*, V_e**

$$V_e = \frac{\pi}{6} \times D_e^2 \times H_e \qquad H_e = ¼\ D_e$$

Maka,

$$V_e = \frac{\pi}{24} \times D_e^3$$

- **Volume *conical*, V_c**

$$V_c = \frac{\pi}{6} \times D_e^2 \times H_c \qquad H_c = ½\ D_e \tan 30°$$

Maka,

$$V_c = \frac{\pi}{12} \times D_e^3 \tan 30^o$$

- **Diameter *evaporator*, D_e**

$$V_t = V_s + V_e + V_c$$

$= \left(\frac{\pi}{4} \times D_e^3\right) + \left(\frac{\pi}{24} \times D_e^3\right) + \frac{\pi}{12} \times D_e^3 \tan 30^o$

$= 1.0668\ D_e^3$

D_e^3 $= Vt/1.0668$

$= \frac{7,4213}{1.0668}\ m^3$

D_e $= \sqrt[3]{\frac{7,4213}{1,0668}}$

= 1,9089 m = 75,1561 in = 6,2614 ft

- **Tinggi *evaporator*, H_e**

  Tinggi silinder, $H_s = D_e$ = 1,909 m = 6,2633 ft

  Tinggi *ellipsoidal*, H_e = ¼ D_e = 0,4772 m = 1,5658 ft

  Tinggi *conical*, H_c = ½ D_e tan 30° = 0,5507 m = 1,8070 ft

  Tangki direncanakan diletakkan di atas kaki penyangga yang terbuat dari besi dengan tinggi 2 m.

  Tinggi total, Ht = tinggi silinder + tinggi *ellipsoidal* + tinggi *conical* + (tinggi kaki – tinggi *conical*)

  = 1,909 m + 0,4772 m + 0,5507 m + (2 – 0,5507) m

  = 4,3862 m

- **Tinggi cairan dalam *evaporator*, H_c**

  H_c $= \frac{volume\ cairan}{volume\ evaporator} \times (H_s + H_e + H_c)$

  $= \frac{6,6792\ m^3}{7,4213\ m^3} \times 2,9369\ m$

  = 2,6433 m

- **Tekanan cairan dalam *evaporator*, P_c**

  P_c $= \rho \times g \times H_c$

  = 5.767 kg/m^3 x 9,81 m/dt^2 x 2,6433 m

  = 149.540,2018 kg/m.dt^2

  = 1,4505 atm

- **Tekanan desain, P**

  Pd = Pop + Pc

  = (1 + 1,4505) atm

= 2,4505atm = 36,0129 psi

- **Tebal dinding *evaporator*, t_{ev}**

$$t_{ev} = \frac{PR}{SE-0,6P} + C$$ (Walas, Tabel 18.3)

- Tekanan desain, P	: 36,0129 psi	
- Diameter, De	: 1,7410 m = 68,5430 in	
- Jari-jari tangki, R	: 0,8705 m = 34,2715 in	
- *Allowable stress*, S	: 16.568 psi	(Walas, Tabel 18.4)
- Efisiensi pengelasan, E	: 0,85	(Peter, Tabel 4 Hal 538)
- Faktor korosi yang diizinkan	: 0,002 in/thn	(Perry's Tabel 23-2)

Maka,

$$t_{ev} = \frac{36,0129\ psi \times 34,2715\ in}{(16,568 psi \times 0,85)-(0,6\times 36,0129\ psi)} + 0,002\frac{in}{tahun} \times 10 tahun$$

= 0,1078 in

= 0,0027 m

- **Tebal tutup *ellipsoidal*, t_e**

$$t_e = \frac{PD_e}{2SE-0,2P} + C$$ (Walas, Tabel 18.3)

$$= \frac{36,0129\ \text{psi}\times 68,5430\ in}{(2\times 16.568\times 0,85)-(0,2\times 36,0129\ psi)} + 0,002\frac{in}{tahun} \times 10 tahun$$

= 0,1077 in

= 2,7346 mm

=0,0027 m

- **Tebal dinding alas *conical*, t_c**

$$t_c = \frac{PD_e}{2(SE-0,6P)\cos 30^o} + C$$ (Walas, Tabel 18.3)

$$= \frac{36,0129\ psi \times 34,2715\ in}{2(16.568\ psi \times 0,85-0,6\times 36,0129\ psi)\cos 30^o} + 0,002\frac{in}{tahun} \times 10 tahun$$

= 0,1721 in

= 4,3719 mm

= 0,0044 m

Spesifikasi *tube* pemanas

- Panas yang disuplai oleh steam, Q = 464,7337 kkal/jam

= 1.842,979 Btu/jam

- Temperatur umpan masuk : 30 °C = 86 °F
- Temperatur umpan keluar : 110 °C = 212°F
- Temperatur steam : 152 °C = 305,6 °F
- U_c : 500 Btu/hr.ft^2.°F (Mc Cabe, Tabel 16.1)
- R_d (organik) : 0,001 (Dq. Kern, Hal. 852)

$$U_D = \frac{U_c \times {}^1/_{R_d}}{U_c + {}^1/_{R_d}}$$

$$= \frac{500 \times \frac{1}{0,001}}{500 + \frac{1}{0,001}} = 333 \text{ Btu/hr.ft}^2.°F$$

Bahan *tube* yang digunakan adalah *steel* yang tersedia dengan panjang 12ft

Diameter tube = 0,0035 Dt

= 0,0067 m

= 0,2630 in

Maka,

Dari table 10, Dq. Keren, hal. 850 didapatkan nilai

BWG : 16

OD : 1/2 in

Luas permukaan per ft, a” : 0,1076 ft^2/ft

Luas perpindahan panas yang dibutuhkan, A

$$A = \frac{Q}{U_D \times \Delta T}$$

$$= \frac{1.842,9805 \ Btu/jam}{333 \ \frac{Btu}{hr.ft^2.°F} \times (305,6 - 212)°F} = 0,0394 \text{ ft}^2$$

Luas area *tube* = L x a”

= 12 ft x 0,1076 ft^2/ft

= 1,2912 ft^2

Jumlah *tube* yang dibutuhkan $= \frac{Luas\ perpindahan\ panas}{Luas\ area\ tube}$

$$= \frac{0,0394\ ft^2}{1,2912\ ft^2}$$

= 0,0305 buah

≈ 11 buah

12. Pneumatic Conveyor (PC-171)

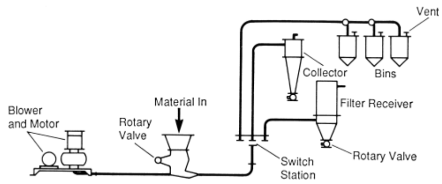
Fungsi : Transportasi nano kitosan ke silo

Jumlah : 1 buah

Bahan : stainless steel

Tipe : Pneumatic Conveyor

Gambar :



Laju alir : 4.194,2859 kg /jam = 4,1942859 ton /jam

Faktor keamanan : 10%

Dari wallas, table 5.1 flow rate and power requirements of vacuum and low preassure pneumatic conveying systems

TABLE 5.1. Flow Rates and Power Requirements of Vacuum and Low Pressure Pneumatic Conveying Systems[a]

		Vacuum System (8–9 psia)									Low Pressure System (6–12 psig)							
		Conveying Distance										Conveying Distance						
		100 ft		150 ft		250 ft		400 ft				100 ft		250 ft		400 ft		
Material	Wt per cu ft	Sat.	hp/T	Sat.	hp/T	Sat.	hp/T	Sat.	hp/T	Velocity ft/sec	Pressure Factor	Sat.	hp/T	Sat.	hp/T	Sat.	hp/T	Velocity (ft/sec)
Alum	50	3.6	4.5	3.9	5.0	4.3	5.7	4.7	6.3	110	4.0	1.6	2.7	2.0	3.4	2.2	3.8	65
Alumina	60	2.4	4.0	2.8	4.7	3.4	5.7	4.0	6.4	105	5.0	1.1	2.4	1.6	3.4	1.9	3.9	60
Carbonate, calcium	25–30	3.1	4.2	3.0	5.0	3.9	5.5	4.2	6.0	110	3.5	1.4	2.5	1.8	3.3	2.0	3.6	65
Cellulose acetate	22	3.2	4.7	3.5	5.1	3.8	5.7	4.1	6.0	100	3.0	1.4	2.8	1.7	3.4	1.9	3.6	55
Clay, air floated	30	3.3	4.5	3.5	5.0	3.9	5.5	4.2	6.0	105	4.0	1.5	2.7	1.8	3.3	1.9	3.6	50
Clay, water washed	40–50	3.5	5.0	3.8	5.6	4.2	6.5	4.5	7.2	115	4.5	1.6	3.0	1.9	3.9	2.1	4.4	60
Clay, spray dried	60	3.4	4.7	3.6	5.2	4.0	6.2	4.4	7.1	110	4.3	1.5	2.8	1.8	3.7	2.0	4.3	55
Coffee beans	42	1.2	2.0	1.6	3.0	2.1	3.5	2.4	4.2	75	5.0	0.6	1.2	0.9	2.1	1.1	2.5	45
Corn, shelled	45	1.9	2.5	2.1	2.9	2.4	3.6	2.8	4.3	105	5.0	0.9	1.5	1.1	2.2	1.3	2.6	55
Flour, wheat	40	1.5	3.0	1.7	3.3	2.0	3.7	2.5	4.4	90	2.5	0.7	1.8	0.9	2.2	1.1	2.7	35
Grits, corn	33	1.7	2.5	2.2	3.0	2.9	4.0	3.5	4.8	100	3.5	0.8	1.5	1.3	2.4	1.6	2.9	70
Lime, pebble	56	2.8	3.8	3.0	4.0	3.4	4.7	3.9	5.4	105	5.0	1.3	2.3	1.6	2.8	1.8	3.3	70
Lime, hydrated	30	2.1	3.3	2.4	3.9	2.8	4.7	3.4	6.0	90	4.0	0.6	1.8	0.8	2.2	0.9	2.6	40
Malt	28	1.8	2.5	2.0	2.8	2.3	3.4	2.8	4.2	100	5.0	0.8	1.5	1.1	2.0	1.3	2.5	55
Oats	25	2.3	3.0	2.6	3.5	3.0	4.4	3.4	5.2	100	5.0	1.0	1.8	1.4	2.6	1.6	3.1	55
Phosphate, trisodium	65	3.1	4.2	3.6	5.0	3.9	5.5	4.2	6.0	110	4.5	1.4	2.5	1.8	3.3	1.9	3.6	75
Polyethylene pellets	30	1.2	2.0	1.6	3.0	2.1	3.5	2.4	4.2	80	5.0	0.55	1.2	0.9	2.1	1.1	2.5	70
Rubber pellets	40	2.9	4.2	3.5	5.0	4.0	6.0	4.5	7.2	110								
Salt cake	90	4.0	6.5	4.2	6.8	4.6	7.5	5.0	8.5	120	5.0	2.9	3.9	3.5	4.5	4.0	5.1	83
Soda ash, light	35	3.1	4.2	3.6	5.0	3.9	5.5	4.2	6.0	110	5.0	1.4	2.5	1.8	3.3	1.9	3.6	65
Soft feeds	20–40	3.0	4.2	3.4	4.5	3.7	5.0	4.2	5.5	110	3.8	1.3	2.5	1.7	3.1	1.9	3.7	70
Starch, pulverized	40	1.7	3.0	2.0	3.4	2.6	4.0	3.4	5.0	90	3.0	0.8	1.7	1.1	2.4	1.5	3.0	55
Sugar, granulated	50	3.0	3.7	3.2	4.0	3.4	5.2	3.9	6.0	110	5.0	1.4	2.2	1.6	3.1	1.7	3.6	60
Wheat	48	1.9	2.5	2.1	2.9	2.4	3.6	2.8	4.3	105	5.0	0.9	1.5	1.1	2.1	1.3	2.6	55
Wood flour	12–20	2.5	3.5	2.8	4.0	3.4	4.9	4.4	6.5	100								

[a] HP/ton = (pressure factor)(hp/T)(sat.). The units of sat. = $\left(\frac{\text{cu ft air}}{\text{min.}}\right) / \left(\frac{\text{lb solid transferred}}{\text{min.}}\right) = \frac{\text{cu ft air}}{\text{lb. solid transferred}}$ and those of hp/T are horsepower/(tons/hr of solid transferred). (Stoess, 1983).

Material : Flour, Wheat

Preassure : 7 psig

Preassure Factor :2,5

Daya :0,7 Hp/ ton $\approx 1\ HP$

Kecepatan : 35 ft/sec

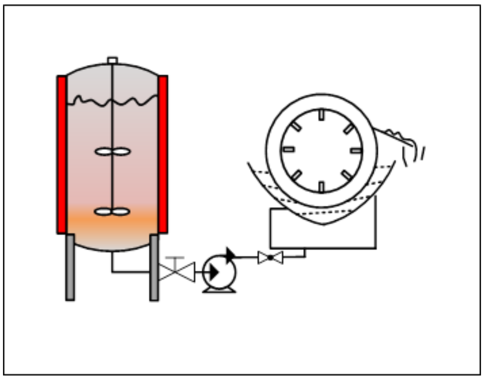
13. Pompa

Fungsi : Mengalirkan filtrat ke rotary vaccum drum filter dari rekator demineralisasi

Tipe : Centrifugal Pump

Bahan : Wrought iron steel

Gambar :



Gambar 10.1 Pompa

Data :

Laju alir massa, m : 166.714,7984 kg/jam = 102,1128 lb/s

Densitas , ρ : 1.031,8426 kg/m3 = 64,4062 lb/ft3

Viskositas , μ : 2,27 lb/ft.hr

Tinggi pompa terhadap cairan masuk, Za : 1 m = 3,28 ft

Tinggi pompa terhadap cairan keluar, Zb : 1,5 m = 4,92 ft

Panjang pipa hisap, Ls : 1 m = 3,28 ft

Panjang pipa buang, Ld : 2 m = 6,56 ft

Faktor keamanan 10%

TABLE 6
Factors in equipment scale-up and design

Type of equipment	Is pilot plant usually neces-sary?	Major variables for operational design (other than flow rate)	Major variables characterizing size or capacity	Maximum scale-up ratio based on indi-cated char-acterizing variable	Approxi-mate recom-mended safety or over-design factor, %
Agitated batch crystallizers	Yes	Solubility-temperature relationship	Flow rate Heat transfer area	>100:1	20
Batch reactors	Yes	Reaction rate Equilibrium state	Volume Residence time	>100:1	20
Centrifugal pumps	No	Discharge head	Flow rate Power input Impeller diameter	>100:1 >100:1 10:1	10

Laju alir volumetrik, Q_v

$$Q_p = \frac{m}{0.9}$$

$$= \frac{166.714,7984\ kg/jam}{0.9} = 185.238,6649\ \text{kg/jam}$$

$$Q_v = \frac{Q_p}{\rho}$$

$$= \frac{185.238,6649\ kg/jam}{1.031,8426\ kg/m^3}$$

$$= 179,5222\ m^3/jam$$

$$= 1,7608\ ft^3/s$$

$$= 790,3588\ gal/min$$

Diameter optimum, D_{opt}

Asumsi aliran turbulen

$$D_{opt} = 3,9*Q_v^{0,45}*\rho^{0,13}$$ (Peter, Pers 14.15 Hal 496)

The derivation of equations for determining optimum economic pipe diameters is presented in Chap. 11 (Optimum Design and Design Strategy). The following simplified equations [Eqs. (45) and (47) from Chap. 11] can be used for making design estimates:

For turbulent flow ($N_{Re} > 2100$) in steel pipes

$$D_{i,opt} = 3.9 q_f^{0.45} \rho^{0.13} \qquad (15)$$

For viscous flow ($N_{Re} < 2100$) in steel pipes

$$D_{i,opt} = 3.0 q_f^{0.36} \mu_c^{0.18} \qquad (16)$$

MATERIALS TRANSFER, HANDLING, AND TREATMENT EQUIPMENT 497

where $D_{i\ opt}$ = optimum inside pipe diameter, in.
q_f = fluid flow rate, ft^3/s
ρ = fluid density, lb/ft^3
μ_c = fluid viscosity, centipoises

D_{opt} $= 3,9 * Q_v^{0,45} * \rho^{0,13}$

$= 3,9 * (1,74)^{0,45} * (64,41)^{0,13}$

$= 8,6456$ in

Berdasarkan Tabel 11 Kern, diperoleh pipa baja dengan ukuran sebagai berikut :

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	sectional area of metal, in.^{2}	Inside sectional area, ft^2	or surface, ft^2/ft of length: Outside	Inside	velocity: U.S. gal/min	Water, lb/h	Pipe weight lb/ft
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.541	10.45	5,225	3.65
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600	5.02
2½	2.875	40	0.203	2,469	1.704	0.03322	0.753	0.647	14.92	7,460	5.79
		80	0.276	2.323	2.254	0.02942	0.753	0.608	13.20	6,600	7.66
3	3.500	40	0.216	3.068	2.228	0.05130	0.916	0.803	23.00	11,500	7.58
		80	0.300	2.900	3.016	0.04587	0.916	0.759	20.55	10,275	10.25
3½	4.000	40	0.226	3.548	2.680	0.06870	1.047	0.929	30.80	15,400	9.11
		80	0.318	3.364	3.678	0.06170	1.047	0.881	27.70	13,850	12.51
4	4.500	40	0.237	4.026	3.17	0.08840	1.178	1.054	39.6	19,800	10.79
		80	0.337	3.826	4.41	0.07986	1.178	1.002	35.8	17,900	14.98
5	5.563	40	0.258	5.047	4.30	0.1390	1.456	1.321	62.3	31,150	14.62
		80	0.375	4.813	6.11	0.1263	1.456	1.260	57.7	28,850	20.78
6	6.625	40	0.280	6.065	5.58	0.2006	1.734	1.588	90.0	45,000	18.97
		80	0.432	5.761	8.40	0.1810	1.734	1.508	81.1	40,550	28.57
8	8.625	40	0.322	7.981	8.396	0.3474	2.258	2.089	155.7	77,850	28.55
		80	0.500	7.625	12.76	0.3171	2.258	1.996	142.3	71,150	43.39
10	10.75	40	0.365	10.020	11.91	0.5475	2.814	2.620	246.0	123,000	40.48
		80	0.594	9.562	18.95	0.4987	2.814	2.503	223.4	111,700	64.40

	Suction (a)	Discharge (b)
IPS	8 in Sch 80	
ID	10,02 in = 0,8350 ft	10,02 in = 0,8350 ft
OD	10,75 in = 0,8958 ft	10,75 in = 0,8958 ft
a”	0,4987 ft^2	

Kecepatan aliran, V

Va = Vb, karena ukuran pipa hisap dan pipa buang sama

$V \quad = \frac{Q_v}{a"}$

$= \frac{1{,}7608\ ft^3/s}{0{,}4987 ft^2}$ = 3,5308 ft/s

$\frac{V^2}{2g_c} \quad = \frac{(3{,}5308)^2}{2 \times 32{,}17}$ = 0,1938 ft-lb$_f$/lb

Bilangan Reynolds, N$_{Re}$

$N_{Re} = \frac{\rho \times V \times D}{\mu}$ (Mc Cabe, pers 9.17)

SIGNIFICANCE OF DIMENSIONLESS GROUPS.[23] The three dimensionless groups in Eq. (9.14) may be given simple interpretations. Consider the group $nD_a^2\rho/\mu$. Since the impeller tip speed u_2 equals $\pi D_a n$,

$$N_{Re} = \frac{nD_a^2\rho}{\mu} = \frac{(nD_a)D_a\rho}{\mu} \propto \frac{u_2 D_a \rho}{\mu} \qquad (9.17)$$

$$N_{Re} = \frac{\rho \times V \times D}{\mu}$$

$$= \frac{64{,}4062\frac{lb}{ft^3} \times 3{,}5308\frac{ft}{dt} \times 0{,}8350 ft}{2{,}2686\frac{lb}{ft.hr}} = 83{,}7012$$

Rugi Gesek

- **Pipa hisap (*suction*)**

Pada pipa hisap, rugi gesek timbul akibat gesekan dengan kulit pipa

$h_{fsa} \quad = f \frac{\Delta L}{r_H} \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.56)

The hydraulic radius is a useful parameter for generalizing fluid-flow phenomena in turbulent flow. Equation (5.7) can be so generalized by substituting $4r_H$ for D or $2r_H$ for r_w:

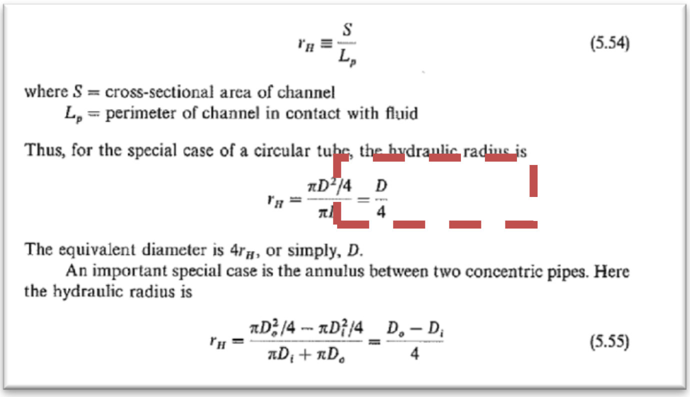
$$h_{fs} = \frac{\tau_w}{\rho r_H} \Delta L = \frac{\Delta p_s}{\rho} = f \frac{\Delta L}{r_H} \frac{\bar{V}^2}{2g_c} \qquad (5.56)$$

$$N_{Re} = \frac{4 r_H \bar{V} \rho}{\mu} \qquad (5.57)$$

The simple hydraulic-radius rule does not apply to laminar flow through noncircular sections. For laminar flow through an annulus, for example, f and N_{Re} are related by the equation[3]

$$f = \frac{16}{N_{Re}} \phi_a \qquad (5.58)$$

$r_H \quad = \frac{ID}{4}$ (Mc Cabe, Hal 103)



$$r_H \equiv \frac{S}{L_p} \qquad (5.54)$$

where S = cross-sectional area of channel
L_p = perimeter of channel in contact with fluid

Thus, for the special case of a circular tube, the hydraulic radius is

$$r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$

The equivalent diameter is $4r_H$, or simply, D.

An important special case is the annulus between two concentric pipes. Here the hydraulic radius is

$$r_H = \frac{\pi D_o^2/4 - \pi D_i^2/4}{\pi D_i + \pi D_o} = \frac{D_o - D_i}{4} \qquad (5.55)$$

$r_H \quad = \frac{ID}{4}$

$\quad = \frac{0.8350\ ft}{4} = 0,2088$ ft

$N_{Re} \quad = 83,7012$

Material yang digunakan untuk konstruksi pipa adalah *commercial steel pipe*, dimana

$k \quad = 0,00015$ ft (Mc Cabe, Fig. 5.9)

$\frac{k}{ID} \quad = \frac{0,00015 ft}{0,8350 ft} = 0,00023$

$f \quad = 0,15$ (Mc Cabe, Fig. 5.9)

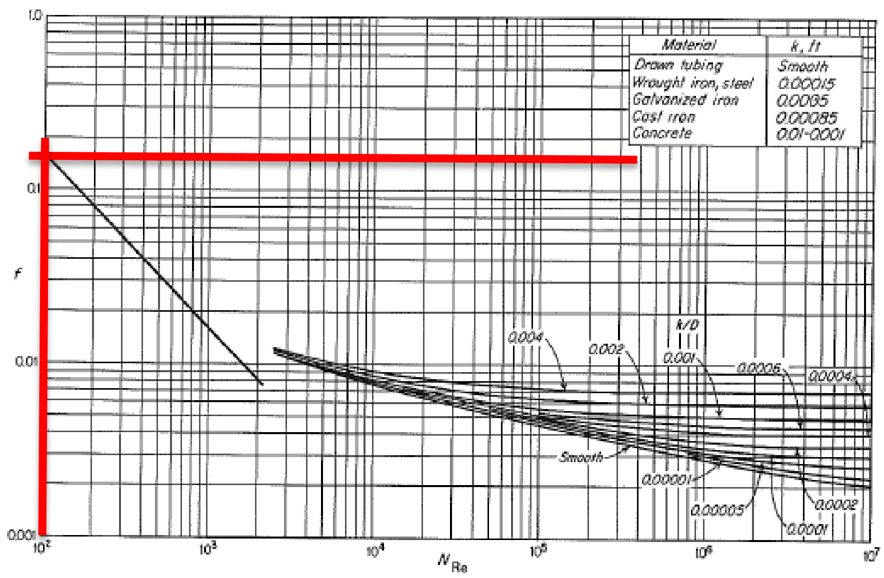


FIGURE 5.9
Friction-factor chart.

Maka,

h_{fsa} $= 0{,}15 \times \frac{3{,}2808 ft}{0{,}2088 ft} \times 0{,}1938\ ft.lb_f/lb$

$= 0{,}4568$ ft-lb$_f$/lb

- Rugi gesek akibat *fitting*

h_{ffa} $= K_f \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.67)

EFFECT OF FITTINGS AND VALVES. Fittings and valves disturb the normal flow lines and cause friction. In short lines with many fittings, the friction loss from the fittings may be greater than that from the straight pipe. The friction loss h_{ff} from fittings is found from an equation similar to Eqs. (5.59) and (5.65):

$$h_{ff} = K_f \frac{\bar{V}_a^2}{2g_c} \quad (5.67)$$

where K_f = loss factor for fitting
$\bar{V}_a$ = average velocity in pipe leading to fitting

Factor K_f is found by experiment and differs for each type of connection. A short list of factors is given in Table 5.1.

K_f (*elbow* 90°) = 0,9 (Mc Cabe, Tabel 5.1)

TABLE 5.1
Loss coefficients for standard threaded pipe fittings†

Fitting	K_f
Globe valve, wide open	10.0
Angle valve, wide open	5.0
Gate valve	
Wide open	0.2
Half open	5.6
Return bend	2.2
Tee	1.8
Elbow	
90°	0.9
45°	0.4

† From J. K. Vennard, in V. L. Streeter (ed.), *Handbook of Fluid Dynamics*, McGraw-Hill Book Company, New York, 1961, p. 3-23.

Total K_f = 1x0,9 = 0,9

Maka,

h_{ffa} $= 0{,}9 \times 0{,}1938\ ft.lb_f/lb = 0{,}1744$ ft-lb$_f$/lb

- **Pipa buang (*discharge*)**

Pada pipa buang, rugi gesek timbul akibat gesekan dengan kulit pipa, pengaruh *fitting* dan *valve*.

- Rugi gesek akibat kulit

$h_{fsb} \quad = f \frac{\Delta L}{r_H} \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.56)

The hydraulic radius is a useful parameter for generalizing fluid-flow phenomena in turbulent flow. Equation (5.7) can be so generalized by substituting $4r_H$ for D or $2r_H$ for r_w:

$$h_{fs} = \frac{\tau_w}{\rho r_H} \Delta L = \frac{\Delta p_s}{\rho} = f \frac{\Delta L}{r_H} \frac{\bar{V}^2}{2g_c} \qquad (5.56)$$

$$N_{Re} = \frac{4 r_H \bar{V} \rho}{\mu} \qquad (5.57)$$

The simple hydraulic-radius rule does not apply to laminar flow through noncircular sections. For laminar flow through an annulus, for example, f and N_{Re} are related by the equation[3]

$$f = \frac{16}{N_{Re}} \phi_a \qquad (5.58)$$

$r_H \quad = \frac{ID}{4}$ (Mc Cabe, Hal 103)

$$r_H \equiv \frac{S}{L_p} \qquad (5.54)$$

where S = cross-sectional area of channel
L_p = perimeter of channel in contact with fluid

Thus, for the special case of a circular tube, the hydraulic radius is

$$r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$

The equivalent diameter is $4r_H$, or simply, D.

An important special case is the annulus between two concentric pipes. Here the hydraulic radius is

$$r_H = \frac{\pi D_o^2/4 - \pi D_i^2/4}{\pi D_i + \pi D_o} = \frac{D_o - D_i}{4} \qquad (5.55)$$

$= \frac{0{,}8350\ ft}{4} = 0{,}2088$ ft

$N_{Re} \quad = 83{,}7012$

Material yang digunakan untuk konstruksi pipa adalah *commercial steel pipe*, dimana

$k \quad = 0{,}00015$ ft (Mc Cabe, Fig. 5.9)

$\frac{k}{ID} \quad = \frac{0{,}00015 ft}{0{,}67 ft} = 0{,}00023$

$f \quad = 0{,}15$ (Mc Cabe, Fig. 5.9)

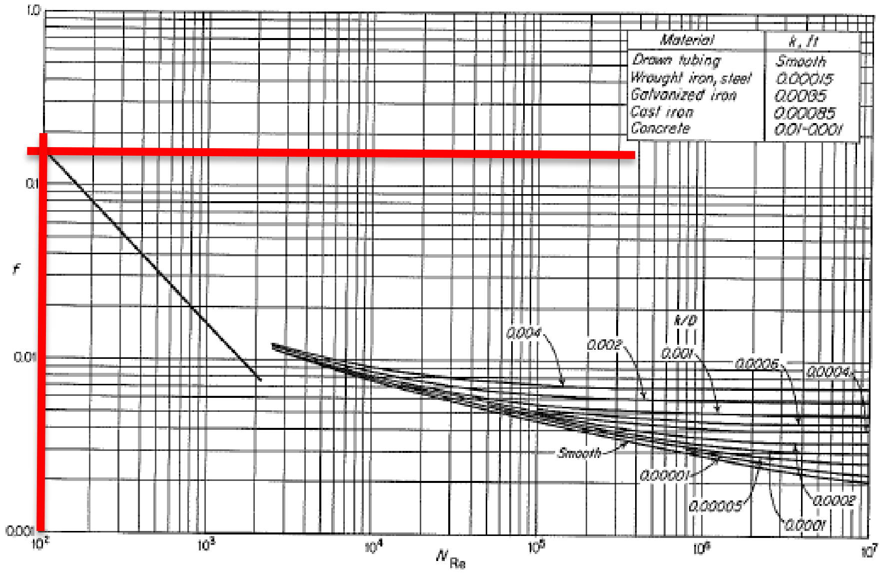


FIGURE 5.9
Friction-factor chart.

Maka,

$$h_{fsb} = 0{,}15 \times \frac{6{,}5617 ft}{0{,}2088 ft} \times 0{,}1938 ft.lb_f/lb$$

$= 0{,}9136$ ft-lb_f/lb

- Rugi gesek akibat *fitting* dan *valve*

$$h_{ffb} = K_f \frac{V^2}{2g_c}$$ (Mc Cabe, Pers 5.67)

EFFECT OF FITTINGS AND VALVES. Fittings and valves disturb the normal flow lines and cause friction. In short lines with many fittings, the friction loss from the fittings may be greater than that from the straight pipe. The friction loss h_{ff} from fittings is found from an equation similar to Eqs. (5.59) and (5.65):

$$h_{ff} = K_f \frac{\bar{V}_a^2}{2g_c} \qquad (5.67)$$

where K_f = loss factor for fitting
$\bar{V}_a$ = average velocity in pipe leading to fitting

Factor K_f is found by experiment and differs for each type of connection. A short list of factors is given in Table 5.1.

K_f (*elbow* 90°) = 0,9 (Mc Cabe, Tabel 5.1)

K_f (*globe valve*) = 10 (Mc Cabe, Tabel 5.1

TABLE 5.1
Loss coefficients for standard threaded pipe fittings†

Fitting	K_f
Globe valve, wide open	10.0
Angle valve, wide open	5.0
Gate valve	
Wide open	0.2
Half open	5.6
Return bend	2.2
Tee	1.8
Elbow	
90°	0.9
45°	0.4

† From J. K. Vennard, in V. L. Streeter (ed.), *Handbook of Fluid Dynamics*, McGraw-Hill Book Company, New York, 1961, p. 3-23.

Total K_f = 3x0,9 + 1x10 = 12,7

Maka,

h_{ffb} = 12,7 × 0,1938 $ft.lb_f/lb$ = 2,4608 ft-lb_f/lb

Sehingga, total rugi gesek adalah

= $h_{fsa} + h_{fsb} + h_{ffa} + h_{ffb}$

= (0,4568 + 0,1744 + 0,9136 + 2,4608) ft-lb_f/lb

= 4,0055 ft-lb_f/lb

Daya pompa (BHP)

Daya pompa dihitung menggunakan Persamaan Bernoulli :

(Mc.Cabe, pers 4.32)

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

fluid is $W_p - h_{fp}$. In practice, in place of h_{fp} a pump efficiency denoted by η is used, defined by the equation

$$W_p - h_{fp} \equiv \eta W_p$$

or

$$\eta = \frac{W_p - h_{fp}}{W_p} \qquad (4.31)$$

The mechanical energy delivered to the fluid is, then, ηW_p, where $\eta < 1$. Equation (4.29) corrected for pump work is

$$\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a \bar{V}_a^2}{2g_c} + \eta W_p = \frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b \bar{V}_b^2}{2g_c} + h_f \qquad (4.32)$$

Equation (4.32) is a final working equation for problems on the flow of incompressible fluids.

Atau

$$\eta W_p = \left(\frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c}\right) - \left(\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c}\right) + h_f$$

Dimana

$P_a = P_b$

$V_a = Vb$

$\rho_a = \rho_b$

$g/g_c = 1$

$\alpha_a = \alpha_b$

$\eta = 76$ % (Peters, Fig. 14.37)

FIGURE 1436
Characteristic curves for a typical centrifugal pump showing effect of viscosity.

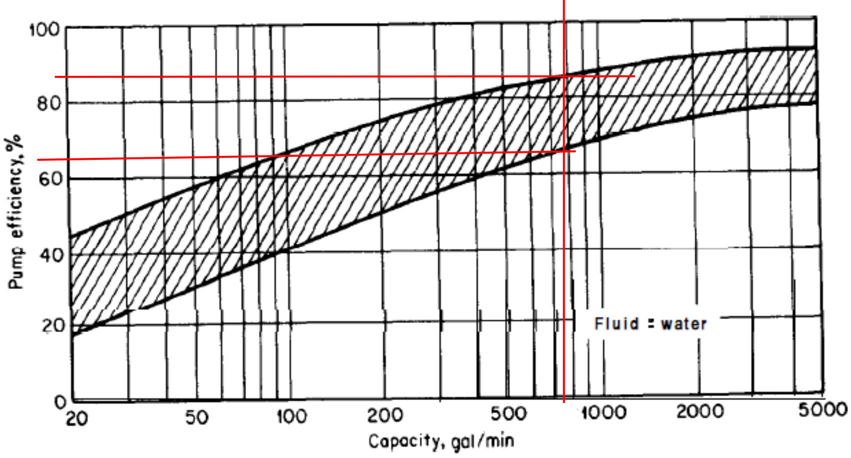


FIGURE 1437
Efficiencies of centrifugal pumps.

Sehingga persamaan di atas dapat disederhanakan menjadi :

$\eta W_p = (Z_b - Z_a) + h_f$

0,76 W_p= (1,5 – 1)ft + 4,0055 ft-lb$_f$/lb

W_p = ft-lb$_f$/lb

BHP $= \frac{W_p \times m}{550}$

$= \frac{12{,}28^{ft.lb_f}/_{lb} \times 102{,}1128^{lb}/_{dt}}{550}$

= 1,1079 Hp

Daya motor (MHP)

MPH $= \frac{BHP}{\eta}$

η = 80 % (Peters, Fig 14.38)

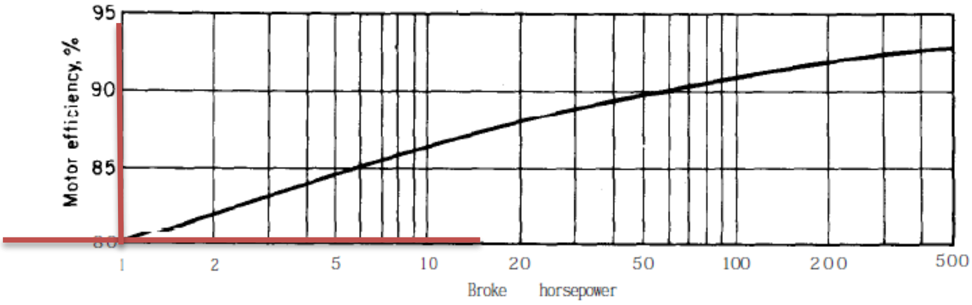


FIGURE 1438
Efficiencies of three-phase motors.

MPH $= \frac{1{,}1079\ HP}{0{,}8}$

= 1,3849 HP

≈ 0,5 Hp

Dengan cara yang sama, maka diperoleh daya pada masing-masing pompa untuk peralatan proses seperti pada Tabel C.3 berikut ini.

Tabel C.3 Daya Pompa pada Peralatan Proses

Kode Alat	Keterangan	Daya (HP)
P-1171	Pompa ke *RVDF*	0,5
P-1172	Pompa *Evaporator*	0,5
P-2173	Pompa larutan NaTPP 1%	0,5
P-2174	Pompa larutan NaOH 3,5 %	0,5
P-2175	Pompa larutan NaOH 40 %	0,5
P-2176	Pompa larutan HCl 3,65 %	0,5
P-2177	Pompa larutan CH3COOH 0,2 %	0,5

B. Spesifikasi Peralatan Utilitas

Dalam suatu pabrik, unit utilitas merupakan bagian yang penting agar proses utama dapat berlangsung sesuai dengan fungsinya. Unit utilitas disediakan berdasarkan kebutuhan operasional pabrik, yaitu :

a. Kebutuhan tenaga listrik
b. Kebutuhan air

c. Kebutuhan steam

B.1 KEBUTUHAN LISTRIK

1. Kebutuhan Listrik Pada Peralatan Proses

Tabel C.4 Kebutuhan Listrik pada Peralatan Proses

No	Nama Alat	Kode Alat	Daya (HP)
1	Reaktor *Demineralisasi*	R-1101	1,67
2	Tangki *Deproteinasi*	R-2102	0,50
3	Tangki *Deasetilasi*	R-3102	1
4	*Rotary vacum filter 1*	RVDF-1111	0,5
5	*Rotary vacum filter 2*	RVDF-2112	0,5
6	*Rotary vacum filter 3*	RVDF-3113	0,5
7	Tangki pelarutan kitosan	MT-3121	0,5
8	Tangki nano kitosan	MT-3122	0,5
9	*Evaporator*	EV-3131	0,50
10	*Spray Dryer*	SD-3141	1
11	Tangki pelarutan NaOH 3,5 %	TP-1165	0,5
12	Tangki pelarutan NaOH 40 %	TP-1164	6
13	Tangki pelarutan HCl 3,65 %	TP-1163	5
14	Tangki pelarutan CH3COOH 0,2%	TP-1162	2,5
15	Tangki pelarutan NaTPP 1%	TP-1161	2
16	Grinding Hammer mill	GHM-151	5,00
17	Tumbling mill	TM-161	5,00
18	belt conveyor	BC-121	3,11
19	scrapper conveyer	SC-191	0,15
20	bucket conveyor	BE-141	0,50
21	peumatic conveyor	PC-171	1,50
22	Pompa Sentrifugal	P-2131	0,48
23	Pompa Sentrifugal	P-3151	0,40
24	Pompa Sentrifugal	P-4207	0,01
25	Pompa Sentrifugal	P-4218	0,44
26	Pompa Sentrifugal	P-4222	0,24
27	Pompa Sentrifugal	P-4233	1,25
28	Pompa Sentrifugal	P-4234	0,06
29	Pompa Sentrifugal	P-4235	0,26
30	Pompa Sentrifugal	P-4236	1,22
Total			43

Kebutuhan listrik pada peralatan proses

= (43 Hp × 0,7457 Kwh/Hp) = 31,9213 Kwh

2. Kebutuhan Listrik Untuk Peralatan Utilitas

Tabel C.5 Kebutuhan Listrik pada Peralatan Utilitas

No	Nama Alat	Kode Alat	Daya (Hp)
1	*Mixing PAC*	ST-2032	2
2	*Mixing Kaporit*	ST-2043	0,5
3	*Mixing Kapur Tohor*	ST-2054	0,5
4	*Coagulantion Tank*	CT-2061	0,5
5	*Floculation Tank*	FLT-2071	0,5
6	*Cooling Tower*	CT-3161	0,5
7	Pompa Sentrifugal	P-1011	22,5
8	Pompa Sentrifugal	P-1021	22,5
9	Pompa Sentrifugal	P-2034	0,5
10	Pompa Sentrifugal	P-2061	0,5
11	Pompa Sentrifugal	P-2071	0,5
12	Pompa Sentrifugal	P-2081	14
13	Pompa Sentrifugal	P-3091	17
14	Pompa Sentrifugal	P-3101	4,5
15	Pompa Sentrifugal	P-3115	4,5
16	Pompa Sentrifugal	P-3121	18
17	Pompa Sentrifugal	P-3136	4,5
18	Pompa Sentrifugal	P-3141	8,5
19	Pompa Sentrifugal	p-3142	7
Total			**129**

Kebutuhan listrik pada peralatan utilitas

= (129 Hp × 0,7457 Kwh/Hp) = 96,234 Kwh

3. Kebutuhan energi listrik untuk peralatan instrumentasi diperkirakan 50 kwh.

Seperti : Alat – alat pengendali

4. Kebutuhan energi listrik untuk bengkel diperkirakan 100 kwh.

Seperti : Alat pemotong, mesin las, dll

5. Kebutuhan energi listrik untuk penerangan

a. Luas area pabrik = 10.000 m^2

- In Door

  Penerangan rata-rata = 10 watt/m^2

  Total penerangan untuk pabrik = 7.500 m^2 × 10 watt/m^2

  = 75.000 watt

  = 75 kwh

- Out Door

  Penerangan rata-rata = 15 watt/m^2

  Total penerangan untuk pabrik = 2.500 m^2 × 15 watt/m^2

  = 37.500 watt

  = 37,5 kwh

b. Luas area perumahan dan fasilitas lain = 20.000 m^2

- In Door

  Asumsi : 1 rumah karyawan memiliki daya listrik 900 watt

  = 900 watt × 25 unit rumah

  = 22.500 watt

  = 22,5 Kwh

- Out Door

  Penerangan rata-rata = 10 watt/m^2

  Total penerangan untuk luar = 3.000 m^2 × 10 watt/m^2

  = 30.000 watt

  = 30 Kwh

6. Kebutuhan listrik untuk peralatan kantor dan komunikasi

Seperti :

- 25 unit komputer (@ 300 watt) = 7.500 watt
- 25 unit AC (@ 300 watt) = 7.500 watt
- 15 unit dispenser (@ 300 watt) = 4.500 watt

- 4 unit kulkas (@ 110 watt) = 440 watt
- 3 unit mesin photo kopi (@ 800 watt) = 2.400 watt
- Dan lain-lain = 800 watt

Jumlah =23.140 watt = 23,14 Kwatt

Total kebutuhan listrik :

= (31,9213 + 96,234 + 50 + 100 +75 + 37,5 + 22,5 + 30 + 23,14) Kwh

= 466,29534 Kwh

Faktor keamanan 20%

Kebutuhan listrik sebenarnya = 1,2 x 466,29534 Kwh

= 559,554 Kwh

B.2 KEBUTUHAN STEAM

Tabel C.6 Kebutuhan *Steam* untuk Proses

Kebutuhan steam	**Kg/jam**
R-Demineralisasi	97,5419
R- Deproteinasi	7,7748
R- Deasetilasi	16,9144
Evaporator	464,7337
Belt Conveyor	142,9572
Spray Dryer	322,1561
total	1.052,0780

B.3 KEBUTUHAN AIR

1. Air Proses

Tabel C.7 Kebutuhan Air Proses

Kebutuhan air proses	**Kg/jam**
Bak pencucian	88.145,528
Tangki pelarutan NaOH 40%	32.679,438
Tangki pelarutan NaOH 3,50%	70.812,957
Tangki Pelarutan HCl	148.469,660
Tangki Pelarutan CH3COOH	17.085,295
Tangki Pelarutan NaTPP	16.948,339
RVDF-1	60.920,677

RVDF-2	78.855,873
RVDF-3	28.681,796
Total	**542.599,564**
Effisiensi termal	0,820
Total air untuk produksi steam	**1.283,022**

2. Air Pendingin

Tabel C.8 Kebutuhan Air Pendingin

Nama Alat	Kebutuhan (Kg/jam)
T-mix Kitosan	996,9332
Total	996,9332

3. Air sanitasi

Air sanitasi digunakan untuk :

a. Perumahan

Diperkirakan kebutuhan air perorangan ± 250 L/hari atau setara dengan 66 gallon/hari. Pabrik MSG ini memiliki 25 unit rumah yang disediakan untuk golongan tertentu. Asumsi 1 orang karyawan memiliki 4 orang anggota keluarga, sehingga jumlahnya menjadi 100 orang, maka kebutuhan air setiap jam:

$$= 100 \times \frac{66\ gallon}{hari} \times \frac{m^3}{264{,}17\ gallon} \times \frac{hari}{24\ jam}$$

= 1,25 m^3/jam

= 1.250 kg/jam

b. Perkantoran

Kebutuhan air perorangan ± 100 L/hari atau 27 gallon/hari, dengan jumlah karyawan 120 orang, kebutuhan air setiap jam adalah :

$$= 120 \times \frac{27\ gallon}{hari} \times \frac{m^3}{264{,}17\ gallon} \times \frac{hari}{24\ jam}$$

= 0,50 m^3/jam = 500 kg/jam

c. Laboraturium diperkirakan sebanyak = 15 kg/jam

d. Poliklinik diperkirakan sebanyak = 5 kg/jam

e. Pemadam kebakaran diperkirakan sebanyak = 50 kg/jam

f. Masjid dan kantin diperkirakan sebanyak = 50 kg/jam

Total kebutuhan air untuk sanitasi = 1.870 kg/jam

1. Total Kebutuhan Air

Kebutuhan Air perjam

- Air pendingin = 994,03 kg/jam
- Air proses = 542.599,56 kg/jam
- Produksi steam = 1.411,32 kg/jam
- Air sanitasi = 1.870,00 kg/jam

Total = 546.874,91 kg/jam

Pada saat operasi kontinu sejumlah air akan disirkulasikan dengan asumsi kehilangan air sebesar ± 20%

Air make up untuk *cooling tower* dan boiler = sejumlah air make up

= 20% (umpan boiler+cooler)

= 481,07 kg/jam

Jumlah air yang hilang = air sanitasi + air proses + air make up

= (1.870 + 542.599,56 + 481,07) kg/jam

= 544.950,63 kg/jam

Jumlah air yang dibutuhkan pada saat operasi kontinu adalah

= faktor keamanan × jumlah yang hilang

= 1,2 × 544.950,63 kg/jam

= 653.940,76 kg/jam

B. SPESIFIKASI PERALATAN UTILITAS

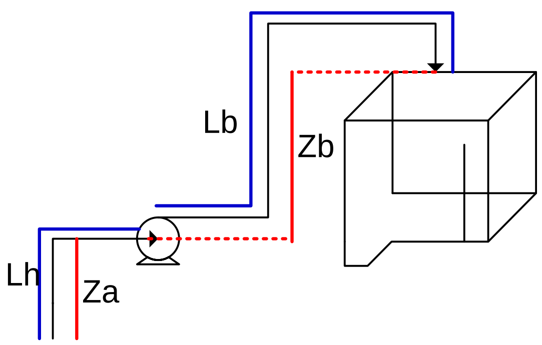
1. Pompa

Fungsi : Mengalirkan air dari sungai ke bak penampungan

Tipe : *Centriugal pump*

Bahan : *Commercial steel pipe*

Gambar :



Daya pompa (BHP)

Daya pompa dapat dihitung dengan menggunakan Persamaan Bernoulli :

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

Atau

$$\eta W_p = \left(\frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c}\right) - \left(\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c}\right) + h_f$$

Dimana

$P_a = P_b$

$V_a = V_b$

$\rho_a = \rho_b$

$g/g_c = 1$

$\alpha_a = \alpha_b$

$\eta = 80\%$ (Peters, Fig. 14.37)

Data :

- Laju alir massa, m : 653.940,76 $\frac{kg}{jam}$ = 400,3571$\frac{lb}{dt}$
- Densitas air, ρ : 1000 kg/m^3 = 62,4280 lb/ft^3
- Viskositas air, μ : 2,4248 lb/ft.hr
- Tinggi pompa terhadap cairan masuk, Za : 2 m = 6,56 ft
- Tinggi pompa terhadap cairan keluar, Zb : 15 m = 49,21 ft
- Panjang pipa hisap, Ls : 8 m = 26,25 ft
- Panjang pipa buang, Ld : 12m = 39,37 ft
- Faktor keamanan 10%

Laju alir volumetrik, Q_v

Q_p = $m - 0,9$

= 653.940,76 kg/jam / 0,9

= 726.600,845 kg/jam

= 444,841lb/s

Q_v = $\frac{Q_p}{\rho}$

$= \frac{444{,}841 \text{lb lb/s}}{62{,}42\ lb/ft^3}$

$= 7{,}1254\ ft^3/s$

Direncanakan akan disediakan dua buah pompa untuk mengalirkan air sungai ke dua bak penampung, sehingga laju alir volumetrik masing-masing pompa adalah 3,86 ft^3/dt

Diameter optimum, D_{opt}

Asumsi aliran turbulen

$D_{opt} = 3{,}9 * Q_v^{0{,}45} * \rho^{0{,}13}$ (Peter, Pers 14.15)

$= 3{,}9 * (3{,}56)^{0{,}45} * (62{,}428)^{0{,}13}$

$= 11{,}8241$ in

Berdasarkan Tabel 11 Kern, diperoleh pipa baja dengan ukuran sebagai berikut :

	Suction (a)	Discharge (b)
IPS	12 in Sch 80	
OD	12,75 in = 1,06 ft	12,75 in = 1,06 ft
ID	11,37 in = 0,95 ft	11,37 in = 0,95 ft
S	0,71 ft^2	

Kecepatan aliran, V

Va = Vb, karena ukuran pipa hisap dan pipa buang sama

$V = \frac{Q_v}{S}$

$= \frac{3{,}56\ ft^3/dt}{0{,}71\ ft^2} = 5{,}47$ ft/dt

$\frac{V^2}{2g_c} = \frac{(5{,}47)^2}{2 \times 32{,}17} = 0{,}47$ ft-lb_f/lb

Bilangan Reynolds, N_{Re}

$$N_{Re} = \frac{\rho \times V \times D}{\mu}$$

$$= \frac{62{,}428\ \frac{lb}{ft^3} \times 5{,}47\ \frac{ft}{dt} \times 0{,}95 ft}{0{,}0007 \frac{lb}{ft.s}} = 480.579{,}44$$

Rugi Gesek

- **Pipa hisap (*suction*)**

  Pada pipa hisap, rugi gesek timbul akibat gesekan dengan kulit pipa, serta pengaruh *fitting* dan *valve*.

  - Rugi gesek akibat kulit

h_{fsa} $= f \frac{\Delta L}{r_H} \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.56)

r_H $= \frac{ID}{4}$

$= \frac{0{,}95 ft}{4} = 0{,}24$ ft

N_{Re} = 256.654,28

Material yang digunakan untuk konstruksi pipa adalah *commercial steel pipe*, dimana

k = 0,00015 ft (Mc Cabe, Fig. 5.9)

$\frac{k}{ID}$ $= \frac{0{,}00015 ft}{0{,}95\ ft} = 0{,}00016$

f = 0,006 (Mc Cabe, Fig. 5.9)

Maka,

h_{fsa} $= 0{,}006 \times \frac{26{,}25 ft}{0{,}24 ft} \times 0{,}47\ ft.lb_f/lb$

$= 0{,}31$ ft-lb_f/lb

- Rugi gesek akibat *fitting*

h_{ffa} $= K_f \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.67)

K_f (*elbow* 90°) = 0,9 (Mc Cabe, Tabel 5.1)

Total K_f = 1x0,9 = 0,9

Maka,

h_{ffa} $= 0{,}1 \times 0{,}47\ ft.lb_f/lb$

$= 0{,}51$ ft-lb_f/lb

- **Pipa buang (*discharge*)**

  Pada pipa buang, rugi gesek timbul akibat gesekan dengan kulit pipa, serta pengaruh *fitting* dan *valve*.

  - Rugi gesek akibat kulit

h_{fsb} $= f \frac{\Delta L}{r_H} \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.56)

r_H $= \frac{ID}{4}$

$= \frac{0.95\ ft}{4}$ = 0,24 ft

N_{Re} = 480.579,44

Material yang digunakan untuk konstruksi pipa adalah *commercial steel pipe*, dimana

k = 0,00015 ft (Mc Cabe, Fig. 5.9)

$\frac{k}{ID}$ $= \frac{0{,}00015 ft}{0{,}6354 ft}$ = 0,0002

f = 0,006 (Mc Cabe, Fig. 5.9)

Maka,

h_{fsb} $= 0{,}006 \times \frac{39{,}37 ft}{0{,}24 ft} \times 0{,}47 ft.lb_f/lb$

= 0,46 ft-lb_f/lb

- Rugi gesek akibat *fitting* dan *valve*

h_{ffb} $= K_f \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.67)

K_f (*elbow* 90°) = 0,9 (Mc Cabe, Tabel 5.1)

K_f (*globe valve*) = 10 (Mc Cabe, Tabel 5.1)

Total K_f = 2x0,9 + 1x10 = 11,8

Maka,

h_{ffb} $= 11{,}8 \times 0{,}47\ ft.lb_f/lb$

= 5,49 ft-lb_f/lb

Sehingga, total rugi gesek adalah

= h_{fsa} + h_{fsb} + h_{ffa} + h_{ffb}

= (0,31 + 0,46 + 0,51 + 5,49) ft-lbf/lb

= 6,78 ft-lb_f/lb

- **Daya Pompa**

ηW_p $= (Z_b - Z_a) + h_f$

0,35 W_p= (49,21 – 6,56)ft + 6,78 ft-lb_f/lb

W_p = 141,22 ft-lb_f/lb

$$BHP = \frac{W_p \times m}{550}$$

$$= \frac{141{,}22\ ^{ft.lb_f}/_{lb} \times 433{,}75\ ^{lb}/_{dt}}{550}$$

$$= 24{,}21\ \text{HP}$$

Daya motor (MHP)

$$MPH = \frac{BHP}{\eta}$$

η = 87% (Peters, Fig 14.38)

$$MPH = \frac{24{,}21\ HP}{0{,}93}$$

$$= 27{,}83\ \text{HP} \approx 28\ \text{HP}$$

Dengan cara yang sama, maka diperoleh daya pada masing-masing pompa untuk peralatan utilitas seperti pada Tabel C.9 berikut ini.

Tabel C.9 Daya Pompa pada Peralatan Proses

Kode Alat	Keterangan	Daya (HP)
P-1002	Pompa ke Bak Penampungan	28
P-1003	Pompa Tangki Pelarutan Kaporit	0,5
P-1004	Pompa Tangki Pelarutan kapur Tohor	0,5
P-1005	Pompa Tangki Pelarutan Alum	1
P-1006	Pompa ke Unit Pengolahan *Raw Water*	2,5
P-1007	Pompa ke *Sand Filter*	2
P-1008	Pompa ke Bak Penampungan Air Bersih	2
P-1009	Pompa ke *Softener Tank*	2
P-1010	Pompa ke Tangki Air Demin	2
P-1011	Pompa dari *Plant* Masuk *Cooling Tower*	2
P-1012	Pompa ke *Cooling Tower*	2
P-1013	Pompa ke *Deaerator*	0,5
P-1014	Pompa kondensat masuk *Deaerator*	0,5
P-1015	Pompa bahan bakar masuk *Boiler*	0,5

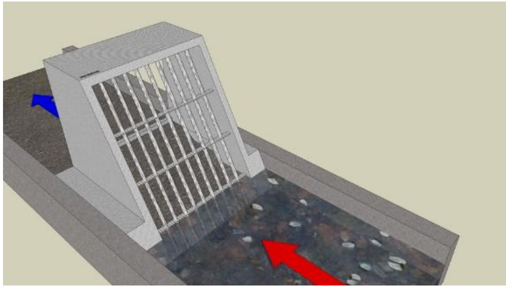
1) *Screening* (BS-1011)

Fungsi : Menyaring partikel-partikel padat yang berukuran besar dari air sungai

Tipe : *Bar screen*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit



Gambar LC-33. *Screening*

Data:

- Laju alir umpan : 653.940,761 kg/jam
- Laju alir volumetrik : 653,940 m^3/jam : 0,1881650211 m^3/s
- Densitas campuran : 1.000 kg/m^3
- Tekanan : 1 atm
- Temperatur : 30 ^oC

Digunakan ukuran *bar* standar dengan dimensi sebagai berikut.

Lebar *bar* = 5 mm

Tebal *bar* = 20 mm

Bar clear spacing = 20 mm

Slope = 28^o

Direncanakan ukuran *screening* dengan dimensi sebagai berikut.

Panjang *screen* = 2 m

Lebar *screen* = 2 m

Misalkan jumlah bar = x , maka

$5x + 2(x + 1) = 2000$

$25x = 19$

80

$x = 79$ buah bar

Luas bukaan

$A = 20x\ (x + 1) \times 2000$

$A = 20 \times 79(79 + 1) \times 2000 = 3.208.000\ mm^2 = 3{,}208\ m^2$

Asumsi C_d=0,6 dan 30% screen tersumbat, maka

$$\text{Head loss } (\Delta H) = \frac{Q^2}{2gC_d{}^2A^2}$$

$$\text{Head loss } (\Delta H) = \frac{(0{,}1881650211\ m^3/s)^2}{2 \times 9{,}81\ \frac{m}{s^2} \times 0{,}6^2 \times (3{,}208\ m^2)^2} = 0{,}005099993$$

2. Bak Penampung Air Sungai

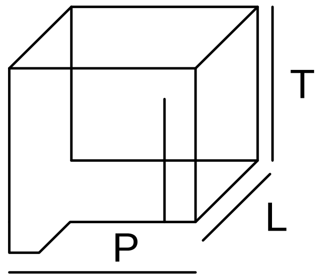
Fungsi : Menampung air sungai sebelum diolah menjadi air bersih

Jenis : Bak berbentuk empat persegi panjang

Jumlah : 2 buah

Konstruksi : Beton bertulang

Gambar :



Data :

- Laju alir massa, m : 653.940,761 kg/jam
- Densitas, ρ : 1000 kg/m^3
- Waktu tinggal : 24 jam

Laju alir volumetrik, Q

$$Q = \frac{m}{\rho}$$

$$= \frac{653.940{,}761\ \frac{kg}{jam}}{1000\ kg/m^3} = 653{,}941\ m^3/jam$$

Dimensi bak

V = 653,941 m^3/jam x 24 jam

= 15.694,578 m^3

Direncanakan akan digunakan 2 unit bak penampungan sehingga kapasitas masing-masing bak adalah 7.847,289 m^3

Faktor keamanan 20%

$$\text{Volume bak} = \frac{7.847{,}289\ m^3}{0{,}8} = 9.809{,}111\ m^3$$

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

9.809,1114 m^3 = 3T x 2T x T

$6T^3$ = 9.809,1114 m^3

T = 11,75 = 38,54 ft

Sehingga diperoleh dimensi bak :

Panjang = 3T = 35,25 m = 115,63 ft

Lebar = 2T = 23,50 m = 77,09 ft

Tinggi = T = 11,75 m = 38,54 ft

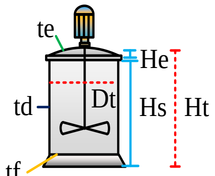
3. Tangki Pelarutan PAC

Fungsi : Tempat melarutkan PAC

Jenis : Silinder vertikal dengan alas datar dan tutup *ellipsiodal*

Konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Gambar :



ST-2032

Data :

- Laju alir = 653.940,761 kg/jam = 653,941 l/jam
- Densitas campuran, ρ = 1172,5 kg/m^3
- Viskositas campuran, μ = 0,0007 lb/ft.dtk
- Faktor keamanan 20%

Kebutuhan PAC

Kekeruhan air sungai Cimanis yaitu sebesar 113,67 NTU (SLHD Cirebon, 2014)

Berdasarkan *jar test* PDAM Padang, untuk kekeruhan 22,5-30 NTU penggunaan PAC yaitu sebesar 20 mg/ltr = $2x10^{-5}$ kg/ltr air

Kebutuhan alum = $2x10^{-5}$ kg/ltr air x 653,941 l/jam

= 98,09 kg/jam

= 2.354,19 kg/hari

PAC yang digunakan berupa larutan alum dengan konsentrasi 25% berat.

Berat larutan PAC $= \frac{2.354{,}19 \text{ kg/hari}}{0{,}25}$ = 588,55 kg/hari

Volume alum 25% $= \frac{2.354{,}19 \text{ kg/hari}}{1172{,}500\ kg/m^3}$ = 2,01 m^3/hari

Kapasitas tangki

Kebutuhan alum direncanakan untuk pemakaian selama 30 hari

Volume tangki = 12,01 m^3/hari x 30 hari

= 60,24 m^3

Faktor keamanan = 20%

Kapasitas tangki (Vt) = 60,24 m^3 / 0,8

= 75,29 m^3

Dimensi tangki,

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s \qquad H_s = 1{,}5\ D_t$$

Maka,

$$V_s = \frac{\pi}{4}\ x\ D_t^3$$

- **Volume *ellipsoidal*, V_e**

$$V_e = 0{,}1308\ D_t^3 \qquad H_e = 1/4\ D_t$$ (Wallas Tabel 18.5, hal650)

- **Diameter Tangki, D_t**

$$V_r = V_s + 2\ V_e$$

$$V_r = \left(\frac{\pi}{4}\ x\ D_t^3\right) + 2(0{,}1308\ D_t^3)$$

$$D_t^3 = \frac{V_t}{1{,}3083}$$

$$= \frac{75{,}29}{1{,}3083}$$

$$D_t = \sqrt[3]{\frac{75{,}29}{1{,}3083}}$$

$= 4{,}15\ m = 13{,}6219\ ft = 163{,}505\ in$

- **Tinggi *tangki*, H_r**

  Tinggi silinder,

  $H_s = 1{,}5\ D_t = 6{,}23\ m$

  Tinggi *Ellipsidal*,

  $H_e = \frac{1}{4} D_t = 1{,}03\ m$

  Tangki direncanakan diletakkan di atas kaki penyangga yang terbuat dari besi dengan tinggi 2 m.

  Tinggi total,

  $H_b = t\ silinder + t\ ellipsoidal$

  $= 6{,}23\ m + 1{,}03$

  $= 7{,}27\ m$

- **Tinggi Cairan, H_c**

  $$\boxed{H_c = \frac{V_c x (H_s + H_e)}{V_t}}$$

  $H_c = 5{,}81\ m$

- **Tekanan Cairan, P_c**

  $P_c = \rho\ .\ g\ .\ h$

  $P_c = 1172{,}5 \frac{kg}{m^3 x} 9.810 \frac{m}{s} x\ 5{,}81\ m$

  $66.876{,}657\ kg/m\ dt^2$

  $= 0{,}6487\ atm$

  = 9,533 psi

- **Tekanan Disain, P_d**

  $P_d = P_{operasi}\ x\ P_c$

  $= 1\ atm + 0{,}6487\ atm$

  $= 1{,}648704\ atm$

  $= 24{,}2359\ psi$

- **Tebal dinding tangki, t_d**

$$t_d = \frac{PR}{SE - 0.6P} + C \qquad (Walas, Tabel\ 18.3)$$

- Tekanan desain, P : 1,648704 atm = 24,2359 psi
- Diametar, D : 4,15 m =163,50 in
- Jari-jari tangki, R : 2,08 m = 81,7523 in
- *Allowable stress*, S : 18700 psi (Peter, Tabel 4 Hal 538)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)
- Faktor korosi yang diizinkan : 0,02 in/thn (Perry's Tabel 23-2)
- Tahun digunakan : 10 tahun

Maka,

$$t_d = \frac{24{,}2359\ \ psi\ x\ 81{,}7523\ in}{(18700\ psi\ x\ 0.85) - (0.6\ x\ 24{,}2359\ \ psi)} + 0.02\ \ in/thn\ x\ 10\ thn$$

$$= 0{,}325\ in$$

$$= 0{,}008\ m$$

- **Tebal dinding alas *ellipsoidal*, t_e**

$$t_e = \frac{PD_t}{2(SE - 0.2P)} + C \qquad (Walas, Tabel\ 18.3)$$

$$= \frac{24{,}2359\ \ psi\ x\ 163{,}50\ in}{2(18700\ \ psi\ x\ 0.85 - 0.2\ x\ 24{,}2359\ \ psi)} + 0.02\frac{in}{thn}x\ 10\ thn$$

$$= 0{,}325\ in$$

$$= 0{,}008\ m$$

Disain pengaduk

Untuk umpan dengan viskositas ≤ 4.000 cP, maka dipilih pengaduk jenis propeller berdaun 3 (Walas, hal 288)

Untuk mencegah *vortex*, maka pada *dissolved* tangki dipasang *buffle*

$$\frac{D_a}{D_t} = \frac{1}{3} \qquad \frac{H}{D_t} = 1 \qquad \frac{J}{D_t} = \frac{1}{12}$$

$$\frac{E}{D_t} = \frac{1}{3} \qquad \frac{W}{D_a} = \frac{1}{5} \qquad \frac{L}{D_a} = \frac{1}{4}$$

(Mc. Cabe, hal 264)

- **Diameter pengaduk, d**

$D_a = {}^{D_t}/_{3}$

$= {}^{4,15\ m}/_{3} = 1,38\ m = 4,54\ ft$

- **Panjang daun pengaduk, L**

$L = {}^{D_a}/_{4}$

$= {}^{1,38\ m}/_{4} = 0,35\ m = 1,14\ ft$

- **Lebar daun pengaduk, W**

$W = {}^{D_a}/_{5}$

$= {}^{1,38\ m}/_{5} = 0,27\ m = 0,908\ ft$

- **Tinggi pengaduk dari dasar tangki, E**

$E = D_{t/3}$

$= 4,15\ m\frac{}{3} = 1,38\ m = 4,54\ ft$

- **Lebar *baffle*, J**

$J = {}^{D_t}/_{12}$

$= {}^{4,15\ \ m}/_{12} = 0,346\ m = 1,135\ ft$

- **Kecepatan putar pengaduk, N**

$\frac{N \times d}{\left(\frac{\sigma\, g_c}{\rho}\right)^{0.25}} = 1,22 + 1,25\left(\frac{T}{di}\right)$ (Robert E-Trybal, pers 6.18, hal 171)

$\sigma = 72,75\ dyn/cm$

= 72,75 g/s^2

= 0.05 lbf/ft

$g_c = 32.17\ ft/dt^2$

Maka,

$$N = \frac{\left(1,22 + 1,25\left(\frac{D_t}{d}\right) x \left(\frac{\sigma g_c}{\rho}\right)^{0,25}\right)}{d}$$

$= 0.58\ rps$

- **Daya pengadukan, P**

$$N_{Re} = \frac{\rho \times N \times d^2}{\mu}$$

$$= \frac{73{,}24\ \frac{lb}{ft^3} x\ 0.58\ rps\ x\ (6{,}81)^2}{0.0074 \frac{lb}{ft\ dt}}$$ (MC. Cabe Per 19.17, hal 270)

$$= 1.317.686{,}91$$

Karena N_{Re} > 10000, maka

$$P = \frac{K_T N^3 d^5 \rho}{g_c}$$ (Mc Cabe, Pers 9.24, hal 274)

$K_T = 0.87$ (Mc Cabe, Tabel 9.23, hal 275)

$$P = \frac{0.87\ x\ (0.58\ rps)^3\ x\ (6{,}81)^5\ x\ 73{,}2355}{32.17} x \frac{1\ hp}{550\ ft\ lbf/s}$$

$$= 771{,}0424\ lb/ft\ dt$$

$$= 1{,}40\ HP$$

$Efisiensi\ motor = 80\ \%$

$$Daya\ Motor = \frac{1{,}40\ HP}{0.8} = 1{,}75\ HP\ \approx 2\ HP$$

4. Tangki Pelarutan Kapur Tohor

Fungsi : Tempat melarutkan kapur tohor ($Ca(OH)_2$)

Jenis : Silinder vertikal dengan alas datar dan tutup *ellipsoidal*

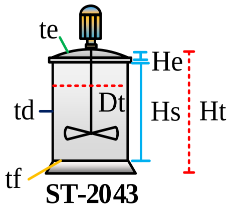
Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil, tidak korosif dan tidak higroskopis

Fasa : Cair

Gambar :



Data :

- Laju alir = 653.940,761 kg/jam = 653,941 l/jam
  Densitas campuran, ρ = 92,7171 lb/ft^3
- Viskositas campuran, μ = 0,000311 lb/ft.dtk
- Faktor keamanan 10%
- Lama penyimpanan = 30 hari = 180 jam

1. Kebutuhan kapur tohor

Kekeruhan air sungai Cimanis yaitu sebesar 113,67 NTU (SLHD Cirebon, 2014)

Berdasarkan *jar test* PDAM Padang, untuk kekeruhan 22,5-30 NTU penggunaan kapur tohor yaitu sebesar 15 mg/ltr = 1,5x10^{-5} kg/ltr air

Kebutuhan kapur tohor = 1,5x10^{-5} kg/ltr air x 653.940,761 kg/jam

= 9,81 kg/jam

= 235,42 kg/hari

Kapur tohor yang digunakan berupa larutan kapur tohor dengan konsentrasi 40% berat.

Berat larutan kapur tohor = $\frac{=235{,}42\ \text{kg/hari}}{0{,}40}$ = 94,17 kg/hari

Volume kapur tohor 40% = $\frac{= 94{,}17\ \text{kg/h}}{1.484{,}4\ kg/m^3}$ = 0,0634 m^3/hari

2. Kapasitas tangki

Kebutuhan kapur tohor direncanakan untuk pemakaian selama 30 hari

$$V_p = V \times t$$

Volume tangki (Vp) = 0,0634 m^3/hari x 30 hari

= 3,19 m^3

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}8\ V_t$

$V_t = \dfrac{V_p}{0{,}8}$

Kapasitas tangki, Vt = 3,19 m^3 / 0,8 = 3,99 m^3

3. Dimensi tangki

a. Volume silinder

$V_s = \dfrac{\pi}{4} \times D_t^2 \times H_s$ Dengan $H_s = 1{,}5\ D_t$

$V_s = \dfrac{\pi}{4} \times 1{,}5\ D_t^3$

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1{,}1775\ D_t^3 + \left(0{,}1308\ D_t^3\right)$

$V_t = 1{,}3083\ D_t^3$

$D_t^3 = \dfrac{V_t}{1{,}3083}$

$D_t^3 = \dfrac{3{,}99\ m^3}{1{,}3083}$

$D_t = \sqrt[3]{\dfrac{3{,}99\ \ m^3}{1{,}3083}}$

$D_t = 1{,}31$ m

= 4,31 ft

= 51,74 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 1{,}31$ m

$H_s = 1{,}97$ m

= 6,47 ft

= 77,61 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 1,31\ \text{m}$

$H_e = 0,33\ \text{m}$

= 1,07 ft

= 12,94 in

f. Tinggi Tangki

$H_t = H_s + H_e$

$H_t = 1,971\ \text{m} + 0,328\ \text{m}$

$H_t = 2,299\ \text{m}$

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{3,19\ \text{m}^3 \times (1,971\ \text{m} + (0,33\ \text{m}))}{3,99\ \text{m}^3}$$

$H_c = 1,839\ \text{m}$

= 6,034 ft

= 72,436 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.485,1370\ \text{kg/m}^3 \times 9,81\ \text{m/s}^2 \times 1,839\ \text{m}$

$P_c = 26.805,90774\ \text{kg.m/s}^2$

= 0,26 atm

= 3,821 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

$P_d = 1\ \text{atm} + 0,26\ \text{atm}$

$P_d = 1,26\ \text{atm}$

= 18,52 psi

P_d = 15,7713 psi

R = 7,25 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0{,}6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{18{,}522 \text{ psi} \times 25{,}87 \text{ in}}{17500 \text{ psi} \times 0{,}85 - 0{,}6 \times 18{,}522 \text{ psi}} + 0{,}002 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,052 in

= 0,00132684 m

= 0,0043 ft

= 1,3268 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0{,}2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{18{,}522 \text{ psi} \times 51{,}74 \text{ in}}{2 \times 17500 \text{ psi} \times 0{,}85 - 0{,}2 \times 18{,}522 \text{ psi}} + 0{,}002 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,0522 in

= 0,00132 m

= 0,00435 ft

$= 1{,}3263$ mm

l. Tebal Alas Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 14{,}5\ \text{in}\sqrt{\frac{0{,}3 \times 18{,}522\ \text{psi}}{17500\ \text{psi}}} + 0{,}02\ \text{in/tahun} \times 10\ \text{tahun} = 0{,}0102\ \text{in}$$

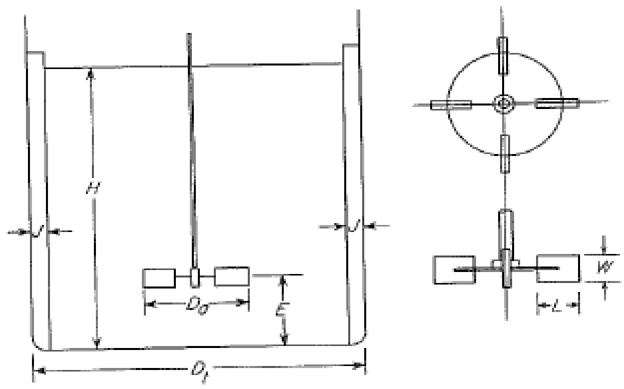
$= 0{,}4021$ m

$= 1{,}3190$ ft

$= 10{,}2144$ mm

4. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-38. Desain Pengaduk Tangki Pelarutan Kapur Tohor

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{1{,}31\ \text{m}}{3}$$

$d = 0{,}438$ m

$= 1{,}436$ ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0{,}438 \text{ m}}{4}$$

L = 0,1095 m

= 0,359 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0{,}438 \text{ m}}{5}$$

W = 0,0876 m

= 0,2873 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{1{,}31 \text{ m}}{3}$$

E = 0,438 m

= 1,436 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{1{,}31 \text{ m}}{12}$$

J = 0,1095 m

= 0,3592 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32{,}2 \text{ ft/s}^2$

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering* 5^{th} *Page 274*).

= 0,0537 lb/ft

$$\frac{N_d}{\left(\frac{\sigma\ g_c}{\rho}\right)^{0,25}} = 1,22 + 1,25\ \left(\frac{D_t}{d}\right)$$

$$\frac{N_d}{\left(\frac{0,0537\ lb/ft \times 32,2\ ft/s^2}{92,7171\ lb/ft^3}\right)^{0,25}} = 1,22 + 1,25\ \left(\frac{1,208ft}{0,402\ ft}\right)$$

$$N_d = 1,796\ rps$$

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering* 5^t, bilangan *reynold* dapat dihitung dengan persamaan berikut.

$$N_{Re} = \frac{\rho N d^2}{\mu}$$

$$N_{Re} = \frac{92,7171\ lb/ft^3 \times 1,796\ \ rps \times (0402\ ft)^2}{0,0003\ lb/ft.s}$$

N_{Re} = 1.105.743,237

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering* 5^t, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 {D_a}^5 \rho}{g_c}$$

$$P = \frac{0,87 \times (1,796\ rps)^3 \times (0,122\ ft)^5 \times 92,7171\ lb/ft^3}{32,2\ ft/s^2}$$

P = 88,9545 ft.lbf/s

P = 0,1617 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{0{,}1617 \text{ HP}}{80\%}$$

Daya Motor = 0,2021 HP

$\approx$ 0,5 HP

5. Tangki Pelarutan Kaporit

Fungsi : Tempat melarutkan kaporit ($Ca(OCl)_2$)

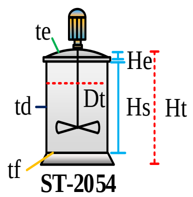
Jenis : Silinder vertikal dengan alas datar dan tutup *ellipsiodal*

Konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit

Fasa : Cair

Gambar :



Data :

- Laju alir = 653.940,761 kg/jam
- Densitas campuran, ρ = 1.180 kg/m^3 : 73,6674 lb/ft^3
- Viskositas campuran, μ = 0,0005162 lb/ft.dtk
- Lama penyimpanan = 30 hari = 180 jam
- Faktor keamanan 20%

1. Kebutuhan kaporit

Kekeruhan air sungai Cimanis yaitu sebesar 113,67 NTU (SLHD Cirebon, 2014)

Kebutuhan kaporit = 2x10^{-5} kg/ltr air x 653.940,761 l/jam

= 13,08 kg/jam

= 313,89 kg/hari

Kaporit yang digunakan berupa larutan kaporit dengan konsentrasi 40% berat.

Berat larutan kaporit $= \frac{313,89 \text{ kg/hari}}{0,4} = 125,56$ kg/hari

Volume kaporit 25% $= \frac{125,56 \text{ kg/hari}}{1180 kg/m^3} = 0,1064 \text{ m}^3\text{/hari}$

2. Kapasitas tangki

Kebutuhan kaporit direncanakan untuk pemakaian selama 30 hari

Volume tangki $= 0,1064 \text{ m}^3\text{/hari} \times 30$ hari

Vp $= 3,19 \text{ m}^3$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0,8 \, V_t$

$V_t = \frac{V_p}{0,8}$

$V_t = \frac{3,19 \text{ m}^3}{0,8}$

$V_t = 3,99 \text{ m}^3$

3. Dimensi Tangki

a. Volume Silinder

$V_s = \frac{\pi}{4} \times D_t^2 \times H_s$ Dengan $H_s = 1,5 \, D_t$

$V_s = \frac{\pi}{4} \times 1,5 \, D_t^3$

$V_s = 0,13083 \, D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4 \, D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,785 \, D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 0,13083 \, D_t^3 + (0,785 \, D_t^3)$

$V_t = 0,92583 \, D_t^3$

$$D_t^3 = \frac{V_t}{0,92583}$$

$$D_t^3 = \frac{3,99\ m^3}{0,92583}$$

$$D_t = \sqrt[3]{\frac{3,99\ m^3}{0,92583}}$$

$D_t = 3,81$ m

= 1,56 ft

= 61,4749 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 3,81$ m

$H_s = 2,34$ m

= 7,6824 ft

= 92,2124 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 3,81$ m

$H_e = 0,390367$ m

= 1,280403 ft

= 15,3687 in

f. Tinggi Tangki

$H_t = H_s + H_e$

$H_t = 2,34$ m + 0,39 m

$H_t = 2,73$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times \left(H_s + (H_e)\right)}{V_t}$$

$$H_c = \frac{3,19\ m^3 \times \left(2,34\ m + (0,390367\ m)\right)}{3,99\ m^3}$$

H_c = 2,19 m

= 7,17026 ft

= 86,064997 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.180kg/m^3× 9,81 m/s^2 × 2,19 m

P_c = 25.305,33891 kg.m/s^2

= 0,24546 atm

= 3,60728 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,24546 atm

P_d = 1,24546 atm

= 18,30828 psi

P_d = 18,308 psi

R = 30,7375 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering,Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{18,308 \text{ psi} \times 30,7375 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 18,308 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2354 in

= 0,0059 m

= 0,0196 ft

= 5,979 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{18,308 \text{ psi} \times 61,4750 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 18,308 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2354 in

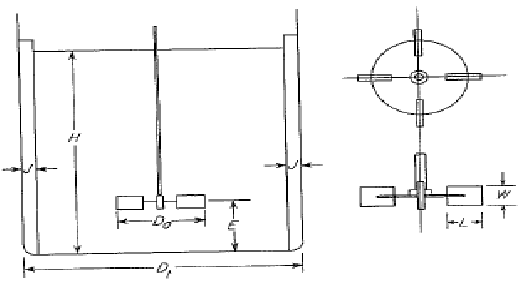
= 0,0059 m

= 0,0196 ft

= 5,979 mm

2. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-40. Desain Pengaduk Tangki Pelarutan Kaporit

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{1{,}56\ m}{3}$$

d = 0,52 m

= 1,7072 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0{,}52\ \ m}{4}$$

L = 0,1301 m

= 0,4268 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0{,}52\ m}{5}$$

W = 0,104 m

= 0,3414 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{1{,}56\ m}{3}$$

E = 0,52 m

= 1,7072 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{1{,}56\ m}{12}$$

J = 0,130122 m

= 0,4268 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan g_c = 32,2 ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

$$\frac{N_d}{\left(\frac{\sigma\, g_c}{\rho}\right)^{0,25}} = 1,22 + 1,25\left(\frac{D_t}{d}\right)$$

$$\frac{N_d}{\left(\frac{0,0537\ \text{lb/ft} \times 32,2\ \text{ft/s}^2}{73,6674\ \text{lb/ft}^3}\right)^{0,25}} = 1,22 + 1,25\left(\frac{1,56\ \text{ft}}{1,7072\ \text{ft}}\right)$$

N_d = 1,559 rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t}*, bilangan *reynold* dapat dihitung dengan persamaan berikut.

$$N_{Re} = \frac{\rho N d^2}{\mu}$$

$$N_{Re} = \frac{73,6674\ \text{lb/ft}^3 \times 1,559\ \text{rps} \times (0,5003\ \text{ft})^2}{0,0005\ \text{lb/ft.s}}$$

N_{Re} =655.482,517

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t}*, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^{\ 5} \rho}{g_c}$$

$$P = \frac{0{,}87 \times (5{,}3209\ rps)^3 \times (0{,}5003\ ft)^5 \times 73{,}6674\ lb/ft^3}{32{,}2\ ft/s^2}$$

P = 109,41048 ft.lbf/s

P = 0,1989 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{0{,}1989\ \text{HP}}{80\%}$$

Daya Motor = 0,24866 HP

≈ 0,5 HP

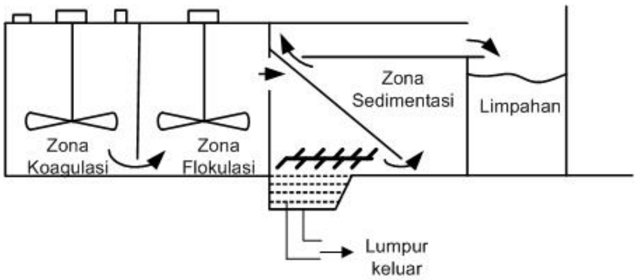
6. Unit Pengolahan *Raw Water*

Fungsi : Tempat pencampuran, pembentukan dan pengendapan flok-flok yang terkandung dalam air

Bentuk : Persegi panjang

Konstruksi : beton bertulang dengan ketebalan 15 cm

Gambar :



Data :

- Laju alir massa, m = 653.940,761 kg/jam
- Densitas, ρ = 1000 kg/m^3 = 62,4280 lb/ft^3
- Viskositas, μ = 1 cP = 0,00067 lb/ft.dtk
- Waktu tinggal = 2 jam
- Faktor keamanan 20%

Kapasitas bak

$$Q = \frac{m}{\rho}$$

$$= \frac{653.940{,}761\ \text{kg/jam}}{1000\ kg/m^3} = 653{,}940\ m^3/\text{jam}$$

Faktor keamanan 10%

Kapasitas bak $= \frac{653{,}940\ \frac{m^3}{jam} \times 2\ jam}{0{,}9}$ = 1.453,201 m^3

Dimensi bak

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

1.453,201 m^3 = 3T x 2T x T

$6T^3$ = 1.453,201 m^3

T = 6,22 m = 20,408 ft

Sehingga diperoleh dimensi bak :

Panjang = 3T = 18,67 m = 61,22 ft

Lebar = 2T= 12,44 m = 40,82 ft

Tinggi = T = 6,22 m = 20,96 ft

a. Bak Pencampur

Volume bak pencampur

Direncanakan panjang bak pencampur adalah 20% dari panjang bak unit pengolahan *raw water*.

Panjang bak pencampur = 20% x 18,67 m = 3,73 m

Sehingga ukuran bak pencampur adalah

Panjang = 3,73 m = 12,25 ft

Lebar = 12,44 m = 40,82 ft

Tinggi = 6,222 m = 20,408 ft

Volume bak pencampur = P x L x T

= 289,049 m^3

= 10.207,48213 ft^3

Perencanaan sistem pengaduk

Dimensi Pengaduk

- Diameter impeller = 0,33 m
- Panjang daun pengaduk = 0,33 m
- Lebar daun pengaduk = 0,85 m
- Tinggi impeler dari dasar tangki = 4,26 m
- Lebar *baffle* = 1,07 m

- Kecapatan pengadukan = 0,2 rps
- Daya motor = 11 hp

b. Bak Pembentukan Flok

Volume bak pembentukan flok

Direncanakan panjang bak pembentukan flok adalah 20% dari panjang bak unit pengolahan *raw water*.

Panjang bak flokulasi = 20% x 18,67 m = 3,73 m = 12,24 ft

Sehingga ukuran bak flokulasi adalah

Panjang = 3,73 m = 12,24 ft

Lebar = 12,44 m = 40,82 ft

Tinggi = 6,22 m = 20,41 ft

Volume bak flokulasi = P x L x T

= 289,049 m^3

= 10.207,48213 ft^3

Perencanaan pengaduk

Perencanaan sistem pengaduk

Dimensi Pengaduk

- Diameter impeller = 4,26 m
- Panjang daun pengaduk = 1,07 m
- Lebar daun pengaduk = 0,85 m
- Tinggi impeler dari dasar tangki = 4,26 m
- Lebar *baffle* = 1,07 m
- Kecapatan pengadukan = 0,200 rps
- Daya motor = 11 HP

c. Bak Sedimentasi

Volume bak sedimentasi

Direncanakan panjang bak sedimentasi adalah 30% dari panjang bak unit pengolahan *raw water*.

Panjang bak sedimentasi = 30% x 18,67 m = 5,60 m

Sehingga ukuran bak sedimentasi adalah

Panjang = 5,60 m = 18,36 ft

Lebar = 12,44 m = 40,82 ft

Tinggi = 6,22 m = 20,41 ft

Volume bak sedimentasi = P x L x T

= 433,57 m^3

= 15.311,223 ft^3

d. Bak Penampung Berpelampung (*Float Chamber*)

Direncanakan panjang bak penampung adalah 30% dari panjang bak unit pengolahan *raw water*.

Panjang bak penampung = 30% x 19,17 m = 5,75m

Sehingga ukuran bak penampung adalah

Panjang = 5,75 m = 18,87 ft

Lebar = 12,44 m = 40,82 ft

Tinggi = 6,22 m = 20,41 ft

Volume bak sedimentasi = P x L x T

= 433,574 m^3 = = 15.311,22319 ft^3

7. *Sand Filter*

Fungsi : Menyaring sisa-sisa flok yang berasal dari bak penampung berpelampung (*float chamber*)

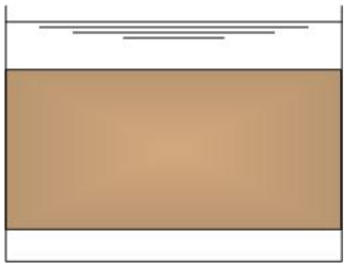
Bentuk : Persegi panjang

Konstruksi : beton bertulang

Isi : pasir silica, karbon dan batu-batu kecil

Jumlah : 2 unit

Gambar :



Data :

- Laju alir massa, m = 326.970,38 kg/jam
- Densitas, ρ = 1000 kg/m^3 = 62,4280 lb/ft^3
- Waktu tinggal = 20 menit = 0,333 jam
- Viskositas = 1 cP = 0,000672 lb/ft.s

- Faktor keamanan 10%

Kapasitas bak

$$Q = \frac{m}{\rho}$$

$$= \frac{326.970,38\ \frac{kg}{jam}}{1000\ kg/m^3} = 326,97038\ m^3/jam$$

Direncanakan jumlah bak *sand filter* sebanyak 2 unit dan waktu tinggal 20 menit = 0,333 jam.

Maka, kapasitas per unit adalah

$$V = \frac{326,97038\ \frac{m^3}{jam} x\ 0,333\ jam}{2} = 108,99\ m^3$$

Faktor keamanan 10%

Kapasitas bak $= \frac{108,99\ m3}{0,9} = 98,0911\ m^3$

Kondisi *filter*

Porositas unggun, ε = 0,4

Air yang terisi dalam unggun 60% dari air masuk.

Volume ruang kosong = Volume yang terisi air

Volume unggun = V air yang mengisi unggun + V partikel

Air yang mengisi unggun = 60% x 108,99 m^3

= 65,39 m^3

Volume partikel $= \frac{108,99\ m^3}{0,4} = 43,5961\ m^3$

Maka, volume unggun = (108,99 + 43,5961) m^3 = 217,9803 m^3

Volume air yang tidak mengisi unggun= 10% x volume unggun

= 242,20028 m^3

Dimensi bak *sand filter*

Perbandingan dimensi bak *sand filter* yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

242,20028 m^3 = 3T x 2T x T

$6T^3$ = 242,20028 m^3

T = 4,18 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 12,55 m

Lebar = 2T = 8,36 m

Tinggi = T = 4,18 m

8. Bak Penampung Air Bersih

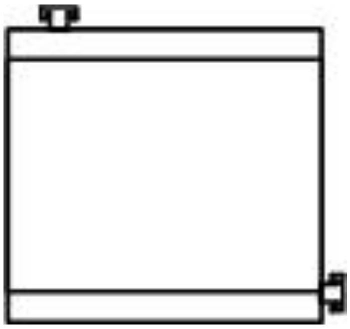
Fungsi : Menampung air bersih hasil penyaringan di *sand filter*

Jenis : Bak berbentuk empat persegi panjang

Jumlah : 2 unit

Konstruksi : Beton bertulang dengan ketebalan 15 cm

Gambar :



Data :

- Laju alir massa, m : 653.940,761 kg/jam
- Densitas, ρ : 1000 kg/m^3
- Waktu tinggal : 24 jam
- Viskositas, μ : 1 cP = 0,00067 lb/ft.dt

Laju alir volumetrik, Q

$$Q = \frac{m}{\rho}$$

$$= \frac{653.940,761 \frac{kg}{jam}}{1000\ kg/m^3} = 653,940\ m^3/jam$$

Dimensi bak

V = 653,940 m^3/jam x 24 jam

= 7.847,289 m^3

Direncanakan akan digunakan 2 unit bak penampungan sehingga kapasitas masing-masing bak adalah 8.501,78 m^3

Faktor keamanan 10%

Volume bak $= \frac{7.847,289\ m^3}{0,9} = 8.719,210144\ m^3$

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

$8.719,210\ m^3 = 3T \times 2T \times T$

$6T^3 = 8.719,210\ m^3$

$T = 11,29$ m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 33,89 m

Lebar = 2T = 22,59 m

Tinggi = T = 11,29 m

9. *Softener Tank (Kation + Anion Exchanger)*

Fungsi : Tempat pertukaran kation dan anion dalam air dengan H^+ dan OH^- dari resin

Jenis : Silinder vertikal dengan tutup dan alas *dished*

Jumlah : 1 unit

Konstruksi : *Carbon steel*

Gambar :

Data :

- Laju alir massa, m : 272.502,457 kg/jam
- Densitas, ρ : 1000 kg/m^3 = 62,428 lb/ft^3

Laju alir volumetrik, Q

$$Q = \frac{m}{\rho}$$

$$= \frac{272.502,457\ \frac{kg}{jam}}{1000\ kg/m^3} = 272,502\ m^3/jam$$

Faktor keamanan 10%

Maka,

$$Q = \frac{272,502\ \ m^3/jam}{0,9}$$

$= 302,781\ m^3/jam$

$= 10.692,39\ ft^3/jam$

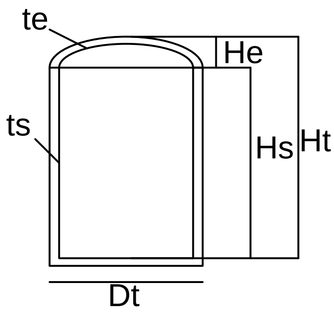
= 1.333,102 galon/menit (GPM)

Berdasarkan data kapasitas yang diperoleh, maka dipilih alat *softener tank* tipe MHC-5400-6 dengan spesifikasi sebagai berikut (Marlo, 2012)

Laju alir maksimum	: 215 GPM
Ukuran pipa aliran air antar tangki	: 3 in
Ukuran pipa aliran air keluar tangki	: 2 in
Volume resin	: 40 ft^3
Diameter	: 48 in
Tinggi	: 60 in

10. Tangki Air Demin

Fungsi	: Tempat penyimpanan air bersih bebas mineral
Jenis	: Silinder vertikal dengan alas datar dan tutup *ellipsiodal*
Jumlah	: 1 unit
Konstruksi	: *Stainless steel*
Gambar	:



Data :

- Laju alir massa, m : 272.502,457 kg/jam
- Densitas, ρ : 1000 kg/m^3 = 62,428 lb/ft^3
- Viskositas : 1 cP = 0,000672 lb/ft.s
- Waktu tinggal : 15 menit = 0,25 jam

Kapasitas tangki

$$V = \frac{m \times t}{\rho}$$

$$= \frac{272.502,457 \ \frac{kg}{jam} \times 0,25 \ jam}{1000 kg/m^3} = 68,126 \text{ m}^3$$

Faktor keamanan 10%

Maka,

$$V = \frac{68,126 \text{ m3}}{0,9} = 75,695 \text{ m}^3$$

Dimensi tangki

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4} \times D_e^2 \times H_s \qquad H_s = D_e$$

Maka,

$$V_s = \frac{\pi}{4} \times D_e^3$$

- **Volume *ellipsoidal*, V_e**

$$V_e = \frac{\pi}{6} \times D_e^2 \times H_e \qquad H_e = ¼ \ D_e$$

Maka,

$$V_e = \frac{\pi}{24} \times D_e^3$$

- **Diameter Tangki, D_t**

V_t $= V_s + V_e$

$$= \left(\frac{\pi}{4} \times D_e^3\right) + \left(\frac{\pi}{24} \times D_e^3\right)$$

$$= 0{,}9158\ D_e^3$$

D_e^3 $= 0.9158\ V_t$

$$= \frac{75{,}695}{0.9158}\ m^3$$

$$D_e = \sqrt[3]{\frac{75{,}695}{0.9158}}$$

= 4,35 m = 14,27 ft

- **Tinggi tangki, H_t**

  Tinggi silinder, Hs = 1,5 Dt = 6,52 m

- **Tinggi tutup, He**

  He = 0,25 Dt

  = 1,33 m

- **Tinggi Cairan**

$$H_c = \frac{Volume\ cairan}{volume\ tangki} x\ Ht$$

$$H_c = \frac{118{,}44}{131{,}6} x\ 6{,}67$$

$$= 6\ m$$

- **Tekanan Cairan, P_c**

$$P_c = \rho\ .\ g\ .\ h$$

$$P_c = 1000\ kg/m^3 x\ 9.810\ m/s\ x\ 5{,}99\ m$$

$$= 59.946{,}9\ kg/m\ dt^2$$

$$= 0.59\ atm$$

- **Tekanan Design, Pd**

  $P_d = P_{operasi} + P_c$

  = 1 atm + 0,59 atm

  = 1,59atm

  = 23,39 psi

- **Tebal dinding tangki, t_d**

$t_d \quad = \frac{PR}{SE-0,6P} + C$ (Peter, Tabel 18.3)

- Tekanan desain, P : 1,59 atm = 23,39 psi
- Diameter, D : 5,33 m = 0,44 in
- Jari-jari tangki, R : 2,66 m = 0,22 in
- *Allowable stress*, S : 13700 psi (Peter, Tabel 4 Hal 538)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)
- Faktor korosi yang diizinkan : 0,002 in/thn (Perry's Tabel 23-2)
- Waktu operasi pabrik : 10 tahun

Maka,

$T_s \quad = \frac{23,39\ psi \times 0,22\ in}{(13700\ psi \times 0,85) - (0,6 \times 23,39\ psi)} + (0,002 \frac{in}{tahun} \times 10\ tahun)$

= 0,02 in

= 0,0005 m

- **Tebal tutup *ellipsoidal*, t_e** (Peter, Tabel 18.3)

$t_e \quad = \frac{PD_t}{2SE-0,2P} + C$

$= \frac{23,39\ psi \times 0,22\ in}{(13700\ psi \times 0,85) - (0,6 \times 23,39 psi)} + (0,002 \frac{in}{tahun} \times 10\ tahun)$

= 0,02 in

= 0,0005 m

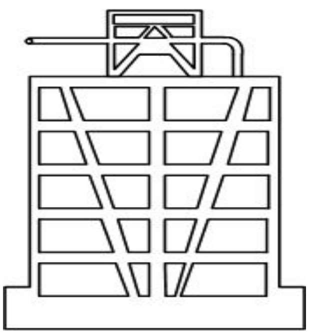
11. *Cooling Tower*

Fungsi : Mendinginkan air sirkulasi yang telah dipakai untuk pendinginan

Jenis : *Induced draft cooling tower*

Jumlah : 1 unit

Gambar :



Data :

- Laju alir massa, m : 11.417,95 kg/jam
- Densitas, ρ : 1000 kg/m^3 = 62,428 lb/ft^3
- Temperatur masuk : 40°C = 104°F
- Temperatur keluar : 30°C = 86°F
- h_{udara} = h_u : 22 Btu/lb udara kering
- h_{air} = h_a : 105 Btu/lb udara kering

Berdasarkan Fig. 12.2 dan Fig. 12.3 Perry's, diperoleh data sebagai berikut :

- Temperatur bola basah : 65°F
- Temperatur bola kering : 72°F
- T_{av} = 95°F

Laju alir volumetrik, Wc

$$Wc = \frac{m}{\rho}$$

$$= \frac{11.417,95\ \frac{kg}{jam}}{1000 kg/m^3} = 11,42\ m^3/jam$$

$$= 50,27\ \text{galon/menit}$$

Cooling tower yang digunakan adalah tipe *induced draft cooling tower* dengan aliran *counter current*.

Cooling range = 104°F - 86°F = 18°F

Luas *tower*, A

Kandungan air, Ca = 1,25 gall/menit.ft^2 (Perry's, Fig 12-14)

$$\text{Luas menara} = \frac{Wc}{Ca}$$

$$= \frac{50,27\ gall/menit}{1,25 \frac{gall}{menit.ft^2}} = 40,22\ ft^2$$

Factor keamanan 10%

Maka, $A = \frac{40,22\ \text{ft2}}{0,9} = 44,69\ ft^2 = 13,62\ m^2$

Daya yang dibutuhkan *fan*

Performa standar menara 97%

Maka, daya yang didapatkan = 0,04 HP/ft^2 (Perry's, Fig 12-15)

Sehingga,

P_{act} = 0,04 HP/ft^2 x 44,69 ft^2

= 1,88 HP ≈ 17 HP

Dimensi *tower*

$$Dt = \frac{A \times \sqrt{Z_t}}{C_t \times \sqrt{C_t}}$$ (Perry's, Pers 12-15)

Dengan, Dt = koefisien bahan menara

A = luas menara

Zt = tinggi menara

Ct = koefisien performa menara = 5 (Perry's, Hal 12-21)

Untuk menghitung Dt digunakan persamaan :

$$\frac{W_L}{Dt} = 90{,}85\left(\frac{\Delta h}{\Delta T}\right)\sqrt{\Delta t + (0{,}3124\Delta h)}$$ (Perry's, Pers 12-16)

Dengan Δh = perubahan panas = $h_a - h_u$ = 83 Btu/lb

ΔT = perubahan temperatur melalui menara

= 104°F - 86°F = 18°F

W_L = beban air pada menara

= 11.417,95 kg/jam = 25.172,01 lb/jam

Δt = T keluar – T bola kering

= 86°F – 73,4°F = 12,6°F

Maka,

$$\frac{25.172{,}01}{Dt} = 90{,}85\left(\frac{83}{18}\right)\sqrt{12{,}6 + (0{,}3124 \times 83)}$$

Dt = 9,68 ft

Direncanakan Zt = 1,5 D

$$Zt^{0,5} = \frac{Dt\left(Ct\sqrt{Ct}\right)}{A}$$

$$(1{,}5\ D)^{0,5} = \frac{Dt\left(Ct\sqrt{Ct}\right)}{A}$$

$(1,5\ D)^{0,5}$ = $\left(\frac{9,68\ (5\sqrt{5})}{44,69}\right)$ = 2,42

D = 5,87 ft ≈ 62ft = 1,19 m

Sehingga, tinggi menara = 1,5 x 5,87 ft = 3,91 ft = 1,79 m

12. Unit Pengolahan Air Umpan *Boiler*

Air umpan *boiler* merupakan air yang digunakan untuk menghasilkan *steam*. Kebutuhan air umpan *boiler* = 617,94 kg/jam. Jika kondensat yang dapat diregenerasi 617,94 kg/jam dan asumsi 90 % yang dapat disirkulasikan kembali, maka kondensat yang disirkulasikan adalah = 617,94 kg/jam x 90% = 556,15 kg/jam. Maka air *make-up* yang dibutuhkan oleh *boiler* adalah

= (617,94 kg/jam – 556,15 kg/jam)

= 61,79 kg/jam

13. Deaerator

Fungsi : Menghilangkan gas terlarut dalam air umpan *boiler*

Bentuk : Silinder horizontal dengan tutup dan alas *ellipsoidal*

Konstruksi : *Carbon steel*

Jumlah : 1 unit

Gambar :

Data :

- Air umpan boiler : 61,79 kg/jam = 0,04 lb/jam

Direncanakan akan didesain *duo-tank deaerator* yang mampu mengolah 61,79 lb/jam air umpan boiler.

Berdasarkan kapasitas tersebut, diperoleh data sebagai berikut.

- Tipe : SM7 D
- Diameter : 36 in = 0,9144 m
- Panjang tangki : 9 ft = 2,7432 m

Table 1-7. General Information, Duo-Tank Deaerator (Spraymaster Only)

Model No.	Rating lb/hr	Gallons to Overflow 10 Minute Storage	Tank Size
SM7 D	7,000	230/160	36" x 9'0"
SM15 D	15,000	300	48" x 11'6"
SM30 D	30,000	600	54" x 15'0"
SM45 D	45,000	900	60" x 17'3"
SM70 D	70,000	1,400	66" x 22'8"
SM100 D	100,000	2,000	72" x 26'0"
SM140 D	140,000	2,800	84' x 25'0"
SM200 D	200,000	4,000	96' x 26'3"
SM280 D	280,000	5,600	108' x 28'4"

NOTES:
Duo-Tank Deaerators have a 10 minute storage capacity in each section.
200 and 280 Models use two internal sprays.

(CleaverBrooks "Operation, maintenance, And Parts Manual Deaerator and Surge Controls)

14. *Boiler*

Fungsi : Menghasilkan *steam*

Tipe : *Fire-tube boiler*

Konstruksi : *Carbon steel*

Jumlah : 1 unit

Gambar :

Data-data :

- Jumlah *steam* dibutuhkan = 617,94 kg/jam = 1.361,94 lb/jam
- Kondensat yang diregenerasi = 556,15 kg/jam = 1.225,75 lb/jam
- Air *make-up* = 61,79 kg/jam = 136,19 lb/jam
- *Steam* yang akan dihasilkan diproduksi 30 % berlebih

Jumlah *steam* yang dihasilkan = 1,3 x 617,94 kg/jam

= 803,32 kg/jam = 1.770,52 lb/jam

Berdasarkan data jumlah *steam* yang dihasilkan, maka dipilih *boiler* tipe TW-I 35 –NTE 25 dengan spesifikasi sebagai berikut.

- Daya operasi : 52 kW = 69,73 HP ≈ 70 HP
- Efisiensi 92 %
- Temperatur *flue gas* : 175°C
- Tekanan operasi : 10 bar
- Panjang : 3,98 m
- Lebar : 1,85m
- Tinggi : 2,53 m
- Ketebalan insulasi : 0,1 m

Technical data THW-I ... NTE Type	Boiler output kW*	Water content litres	Transport weight bar/kg	Net efficiency %**	L x W x H mm
(23/15)	1500 - 2300	2800	10 / 4500	91.3 - 93.3	3480 x 1750 x 2430
(28/20)	2000 - 2800	3500	10 / 6000	91.4 - 92.9	3980 x 1850 x 2530
(35/25)	2500 - 3300	4500	10 / 6900	91.7 - 93.1	4330 x 1950 x 2630
(40/30)	3000 - 4000	5000	10 / 7600	91.9 - 93.2	4630 x 2000 x 2835
(45/35)	3500 - 4500	5500	10 / 8200	92.1 - 93.2	4780 x 2050 x 2885
(50/40)	4000 - 5000	6500	10 / 10000	92.4 - 93.3	5180 x 2150 x 3065
(55/45)	4500 - 5500	7000	10 / 10800	92.3 - 93.2	5430 x 2200 x 3165
(60/50)	5000 - 6000	8000	10 / 12200	92.4 - 93.2	5480 x 2250 x 3215
(70/60)	6000 - 7000	9000	10 / 13500	92.6 - 93.2	5970 x 2450 x 3505
(80/70)	7000 - 8000	10000	10 / 15000	92.4 - 93.0	6270 x 2550 x 3605
(90/80)	8000 - 9000	11500	10 / 17000	92.6 - 92.9	6570 x 2650 x 3705
(100/90)	9000 - 10000	13000	10 / 18500	92.3 - 92.8	6720 x 2750 x 3910
(120/100)	10000 - 12000	14000	10 / 21000	92.4 - 93.2	7020 x 2850 x 4060
(140/120)	12000 - 14000	15000	10 / 23000	92.2 - 92.9	7220 x 3050 x 4260
(160/140)	14000 - 16000	16500	10 / 26500	92.2 - 92.9	7420 x 3250 x 4460
(180/160)	16000 - 18000	20000	10 / 30500	92.6 - 93.1	7620 x 3350 x 4745
(200/180)	18000 - 20000	25000	10 / 35500	92.8 - 93.2	7920 x 3650 x 5245

Boiler pressure: standard 6 and 10 bar

Subject to modifications

* kW Burner setting full load, air coefficient λ = 1.1 (CO_2, heating oil EL = 13.9%, natural gas = 10.8%),

** % With a clean boiler, boiler water (average temperature) = 70 °C

Flue gas temperature at nominal output approx. 175° C
Dimensions and weight: incl. insulation, without burner and other fitted parts

(Hoval Industrial Boilers, Advantages at a glance)

LAMPIRAN D

PERHITUNGAN ANALISA EKONOMI

Analisa ekonomi dihitung untuk menentukan jumlah modal yang dibutuhkan untuk mendirikan dan mengoperasikan pabrik serta tinjauan kelayakan suatu pabrik.

1. Perhitungan Jumlah Modal

Pra rancangan pabrik nano kitosan dari cangkang kerang hijau dengan kapasitas produksi 32.000 ton/tahun. Dalam hal ini, untuk menentukan jumlah modal yang dibutuhkan untuk mendirikan dan mengoperasikan pabrik diperoleh dari hasil perkiraan dengan metoda *percentage delivered equipment cost* untuk *solid-liquid processing plant* (Peters, 1991).

1.1 Perhitungan Harga Alat

Untuk menghitung harga peralatan pada tahun 2026 ditentukan dengan persamaan :

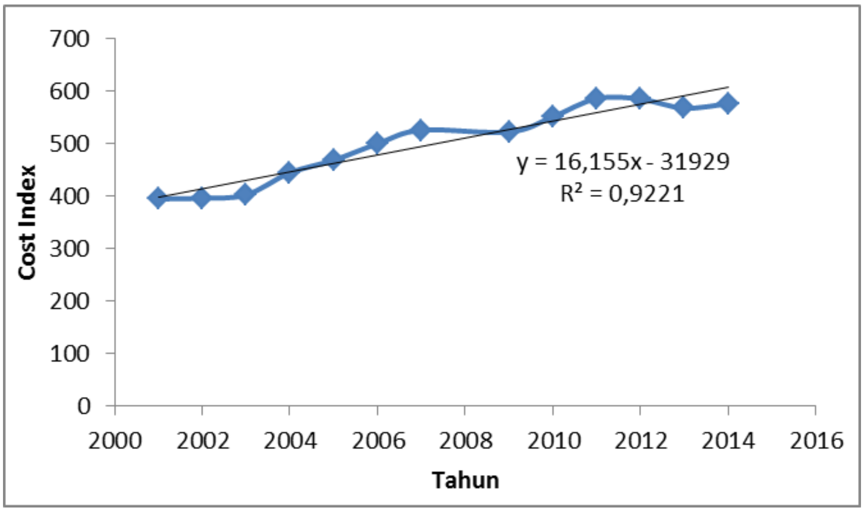
$$\text{Harga sekarang} = \text{Harga awal x} \left(\frac{\text{Indeks harga sekarang}}{\text{indeks harga awal}}\right) \qquad \text{(Peter's, 1991)}$$

Daftar indeks harga rata-rata tahunan menurut *Engineering Plant Cost* dapat dilihat pada Tabel D.1 dan Gambar D.1 di bawah ini.

Tabel D.1 Daftar Indeks Harga Rata-Rata Tahunan

Tahun	**Indeks Harga (*Cost Index*)**
2001	394,3
2002	395,6
2003	402
2004	444,2
2005	468,2
2006	499,6
2007	525,4
2009	521,9
2010	550,8
2011	585,7
2012	584,6
2013	567,3
2014	576,1

2015	623,325
2016	639,48
2017	655,635
2018	671,79
2026	801,03



Gambar D.1 Grafik Hubungan Harga Indeks Terhadap Tahun

Persamaan yang diperoleh sesuai Gambar D.1 adalah :

y = 16,155x – 31929

Dengan menggunakan persamaan di atas dapat dicari harga indeks pada tahun 2015, 2016, 2017, 2018 dan 2025:

- *Cost index* tahun 2015

  y = 16, 155 (2015) – 31929

  y = 623,325

- *Cost index* tahun 2016

  y = 16, 155 (2016) – 31929

  y = 639,48

- *Cost index* tahun 2017

  y = 16, 155 (2017) – 31929

  y = 655,635

- *Cost index* tahun 2018

  y = 16, 155 (2018) – 31929

  y = 671,79

- *Cost index* tahun 2026

y = 16, 155 (2026) – 31929

y = 801,03

Contoh perhitungan harga peralatan :

Harga reaktor 4.629 galon pada tahun 2018 adalah US$ 861.300

Nilai indeks harga tahun 2018 : 671,79

Nilai indeks harga tahun 2026 : 801,03

Harga satu buah tangki tahun 2026 adalah :

$= 861.300 \times \left(\frac{671,79}{801,03}\right)$

= US$ 546.997,39= Rp 7.738.563.663,45

Dengan cara yang sama, diperoleh perkiraan harga peralatan utama ,utilitas, dan peralatan kantor seperti yang terlihat pada Tabel D.2, dan Tabel D.3

Tabel D.2 Daftar Perkiraan Harga Peralatan Proses

No	Nama Alat	Jumlah	Harga ($)	2014		2026	
				US$	Rp	US$	Rp
1	Water Spray	4	95,42	381,70	5.399.998,22	530,72	7.508.350,25
2	metalic belt chain Conveyor	1	110,00	110,00	1.556.208,50	152,95	2.163.807,84
3	Bucket Elevator	1	15.500,00	15.500,00	219.283.925,00	21.551,75	304.900.195,18
4	Hammer Mill	1	646.100,00	646.100,00	9.140.602.835,00	898.360,50	12.709.420.393,89
5	Tumbling Mill	1	729.200,00	729.200,00	10.316.247.620,00	1.013.905,70	14.344.078.859,66
6	Bin NaTPP	1	13.400,00	13.400,00	189.574.490,00	18.631,84	263.591.136,48
7	Tumbling Mill	1	9.599,00	9.599,00	135.800.412,65	13.346,79	188.821.740,23
8	Bin NaOH	3	403.600,00	1.210.800,00	17.129.611.380,00	1.683.539,53	23.817.622.988,58
9	Bin Tepung Cangkang Kerang	1	132.100,00	132.100,00	1.868.864.935,00	183.676,55	2.598.536.502,14
10	Storage Produk	1	160.000,00	160.000,00	2.263.576.000,00	222.469,71	3.147.356.853,46
11	Storage HCl	1	401.200,00	401.200,00	5.675.916.820,00	557.842,80	7.891.997.310,06
12	Storage Liquid CH3COOH	1	6.500,00	6.500,00	91.957.775,00	9.037,83	127.861.372,17
13	Whare House	1	118.700,00	118.700,00	1.679.290.445,00	165.044,72	2.334.945.365,66
14	Reaktor Demineralisasi	3	393.400,00	1.180.200,00	16.696.702.470,00	1.640.992,20	23.215.690.990,36
15	Reaktor Deproteinasi	1	861.300,00	861.300,00	12.185.112.555,00	1.197.582,26	16.942.615.361,80
16	Reaktor Deasetilasi	1	107.600,00	107.600,00	1.522.254.860,00	149.610,88	2.116.597.483,95
17	T-Mixing HCl	1	37.000,00	37.000,00	523.451.950,00	51.446,12	727.826.272,36
18	T-Mixing NaOH 3,50%	1	11.500,00	11.500,00	162.694.525,00	15.990,01	226.216.273,84
19	T-Mixing NaOH 40%	1	9.500,00	9.500,00	134.399.825,00	13.209,14	186.874.313,17
20	T-Mixing CH3COOH	1	5.900,00	5.900,00	83.469.365,00	8.203,57	116.058.783,97
21	T-Mixing NaTPP	1	181.700,00	181.700,00	2.570.573.495,00	252.642,16	3.574.217.126,71

22	T-Pelarutan Kitosan	1	34.000,00	34.000,00	481.009.900,00	47.274,81	668.813.331,36
23	T-Kitosan Mikro ke Nano	1	3.867.200,00	3.867.200,00	54.710.631.920,00	5.377.092,89	76.071.615.148,20
24	Scrapper Conveyor	4	410.400,00	1.641.600,00	23.224.289.760,00	2.282.539,23	32.291.881.316,53
25	RVDF	3	370.400,00	1.111.200,00	15.720.535.320,00	1.545.052,14	21.858.393.347,30
26	Pompa Demineralisasi dari Reaktor ke RVDF 1	1	18.300,00	18.300,00	258.896.505,00	25.444,97	359.978.940,11
27	Pompa Deproteinasi dari Reaktor ke RVDF 2	1	11.500,00	11.500,00	162.694.525,00	15.990,01	226.216.273,84
28	Pompa Deasetilasi dari Reaktor ke RVDF 3	1	11.500,00	11.500,00	162.694.525,00	15.990,01	226.216.273,84
29	Pompa Tangki CH3COOH menuju tangki pencampuran	1	11.500,00	11.500,00	162.694.525,00	15.990,01	226.216.273,84
30	Pompa Tangki NaTPP menuju tangki pencampuran	1	18.300,00	18.300,00	258.896.505,00	25.444,97	359.978.940,11
31	Pompa Tangki Pelarutan menuju Tangki Nano Kitosan	1	18.800,00	18.800,00	265.970.180,00	26.140,19	369.814.430,28
32	Pompa Tangki Nano Kitosan ke Evaporator	1	11.500,00	11.500,00	162.694.525,00	15.990,01	226.216.273,84
33	Pompa Tangki HCl menuju reaktor demineralisasi	1	22.300,00	22.300,00	315.485.905,00	31.006,72	438.662.861,45
34	Pompa Tangki NaOH 3,50% ke reaktor deproteinasi	1	26.000,00	26.000,00	367.831.100,00	36.151,33	511.445.488,69
35	Pompa Tangki NaOH 40% ke reaktor deasetilasi	1	13.900,00	13.900,00	196.648.165,00	19.327,06	273.426.626,64
36	Pompa Evaporator ke Spray Dryer	1	5.600,00	5.600,00	79.225.160,00	7.786,44	110.157.489,87
37	Pneumatic Conveyor	2	5.000,00	10.000,00	141.473.500,00	13.904,36	196.709.803,34
38	cyclon	1	8.900,00	8.900,00	125.911.415,00	12.374,88	175.071.724,97

39	Spray Drayer	1	3.500,00	3.500,00	49.515.725,00	4.866,52	68.848.431,17
40	Evaporator	1	60.000,00	60.000,00	848.841.000,00	83.426,14	1.180.258.820,05
TOTAL				**12.743.890,70**	**180.292.282.049,37**	**17.719.560,43**	**250.684.823.277,23**

(Sumber harga : *report supepro*)

Total Harga Peralatan Proses

- Harga peralatan proses (A) =US$17.719.560,4 =Rp.250.684.823.277,23
- Biaya Transportasi dan Asuransi (12,5%A)= US $ 2.214.945,05 = Rp. 31.335.602.909,65
- Pajak bea cukai (10% A) = US $ 1.771.956,04 = Rp. 25.068.482.327,72 +

Total = US $ 21.706.461,53 =Rp. 307.088.908.514,60

Tabel D.3 Daftar Perkiraan Harga Peralatan Utilitas

No	Alat	Jumlah	Harga ($)	2014			2026	
				US$	**$**	**Rp**	**$**	**Rp**
1	Bar Screen	1	35.000,00	48.665,25	48.665,25	688.484.311,70	67.665,90	957.293.157,78
2	Bak penampungan Air Sungai	2	122.100,00	169.772,20	339.544,40	4.803.653.397,60	472.114,64	6.679.171.118,00
3	Tangki Pelarutan Alum	1	1.600,00	2.224,70	2.224,70	31.473.568,53	3.093,30	43.761.972,93
4	Tangki Pelarutan Kapur Tohor	1	1.600,00	2.224,70	2.224,70	31.473.568,53	3.093,30	43.761.972,93
5	Tangki Pelarutan Kaporit	1	1.600,00	2.224,70	2.224,70	31.473.568,53	3.093,30	43.761.972,93
6	Coagulation Tank	1	93.100,00	129.449,56	129.449,56	1.831.368.269,11	179.991,29	2.546.399.799,69
7	Floculation Tank	1	93.100,00	129.449,56	129.449,56	1.831.368.269,11	179.991,29	2.546.399.799,69
8	Sedimentation Tank	1	6.100,00	8.481,66	8.481,66	119.992.980,04	11.793,20	166.842.521,78

9	Sand filter	2	14.500,00	20.161,32	40.322,63	570.458.429,69	56.066,03	793.185.759,30
10	Carbon Filter	2	14.500,00	20.161,32	40.322,63	570.458.429,69	56.066,03	793.185.759,30
11	Bak Air Bersih	2	122.100,00	169.772,20	339.544,40	4.803.653.397,60	472.114,64	6.679.171.118,00
12	Mix-Bed Ion Exchange	2	14.500,00	20.161,32	40.322,63	570.458.429,69	56.066,03	793.185.759,30
13	Demind Water Tank	1	6.400,00	8.898,79	8.898,79	125.894.274,14	12.373,19	175.047.891,71
14	Cooling Tower	1	97.600,00	135.706,52	135.706,52	1.919.887.680,61	188.691,19	2.669.480.348,55
15	Deaerator	1	47.100,00	65.489,52	65.489,52	926.503.173,74	91.058,97	1.288.243.078,04
16	Boiler	1	1.942.600,00	2.701.060,37	2.701.060,37	38.212.846.397,11	3.755.650,73	53.132.505.380,10
17	Pompa Air Sungai Ke Bak Penampungan Air	2	39.100,00	54.366,04	108.732,07	1.538.270.662,13	151.184,95	2.138.866.426,81
18	Tangki air demin	1	117.500,00	163.376,19	163.376,19	2.311.340.189,26	227.164,09	3.213.769.886,83
19	Pompa air demin masuk Deaerator	1	9.900,00	13.765,31	13.765,31	194.742.705,31	19.139,78	270.777.207,49
20	Pompa air Demin menuju Plant	1	1.600,00	2.224,70	2.224,70	31.473.568,53	3.093,30	43.761.972,93
21	Pompa Plant menuju Cooling Tower	1	1.600,00	2.224,70	2.224,70	31.473.568,53	3.093,30	43.761.972,93
22	Cooling tower	1	405.800,00	564.238,80	564.238,80	7.982.483.819,60	784.537,77	11.099.130.383,63
23	Pompa Cooling tower menuju reaktor	1	1.600,00	2.224,70	2.224,70	31.473.568,53	3.093,30	43.761.972,93
24	Air Handling Unit	1	250.000,00	347.608,92	347.608,92	4.917.745.083,54	483.327,85	6.837.808.269,86
25	Pompa Plant menuju Deaerator	1	9.900,00	13.765,31	13.765,31	194.742.705,31	19.139,78	270.777.207,49
26	Dearator	1	5.800,00	8.064,53	8.064,53	114.091.685,94	11.213,21	158.637.151,86
27	Pompa Dearator menuju Boiler	1	9.900,00	13.765,31	13.765,31	194.742.705,31	19.139,78	270.777.207,49
28	Boiler	1	212.400,00	295.328,54	295.328,54	4.178.116.222,97	410.635,34	5.809.401.906,07
Total					**5.569.251,11**	78.790.144.630,38	7.743.685,49	109.552.628.976,34

Total Harga Peralatan Utilitas

- Harga peralatan Utilitas (B) = US $ 7.743.685,49 = Rp. 109.552.628.976,34
- Biaya Transportasi dan Asuransi (12,5%B) = US $ 967.960,69 = Rp. 13.694.078.622,04
- Pajak bea cukai (10% B) = US $ 774.368,55 = Rp. 10.955.262.897,63 +

Total = US $ 9.486.014,73 = Rp. 134.201.970.496,02

Tabel D.4 Harga Peralatan Kantor

Nama Alat	Unit	Harga Per Unit (US$)	2014		2026	
			US $	RP	$	RP
Komputer	25	700,00	17.500,00	247.578.625,00	24.332,62	344.242.155,85
Meja	35	100,00	3.500,00	49.515.725,00	4.866,52	68.848.431,17
AC	25	700,00	17.500,00	247.578.625,00	24.332,62	344.242.155,85
Dispenser	15	50,00	750,00	10.610.512,50	1.042,83	14.753.235,25
Kulkas	4	300,00	1.200,00	16.976.820,00	1.668,52	23.605.176,40
Fotocopy	3	1.600,00	4.800,00	67.907.280,00	6.674,09	94.420.705,60
Total			**45.250,00**	**640.167.587,50**	**62.917,21**	**890.111.860,12**

Total harga peralatan = harga peralatan proses + harga peralatan utilitas + harga peralatan kantor

= US$ 21.706.461,53 + US$ 9.486.014,73 + US$ 62.917,21

= US$ 31.255.393,47 = Rp. 442.180.990.870,74

1.2 Perhitungan Komponen-Komponen Investasi

Perkiraan investasi dihitung dengan menggunakan faktor rasio berdasarkan metode *delivered equipment cost* untuk *solid-fluid processing plant* seperti yang dapat dilihat pada Tabel D.5 di bawah ini.

Tabel D.5 Perhitungan *Capital Investment* Pabrik Nano Kitosan

Komponen	**%**	**Biaya (US$)**	**Biaya (Rp)**
Direct Cost			
Biaya peralatan	**100%**	31.255.393	442.180.990.871
pemasangan alat	**39%**	12.189.603	172.450.586.440
instrumentasi dan alat kontrol	**13%**	4.063.201	57.483.528.813
pemasangan pipa	**31%**	9.689.172	137.076.107.170
Pemasangan instalasi listrik	**10%**	3.125.539	44.218.099.087
Bangunan	**29%**	9.064.064	128.232.487.353
Pengembangan area	**10%**	3.125.539	44.218.099.087
Fasilitas pelayanan	**55%**	17.190.466	243.199.544.979
Lahan	**6%**	1.875.324	26.530.859.452
Total Direct Cost		**91.578.303**	**1.295.590.303.251**
Indirect Cost			
Engineering and supervision	**32%**	10.001.726	141.497.917.079
Biaya konstruksi	**34%**	10.626.834	150.341.536.896
Total Indirect Cost		**20.628.560**	**291.839.453.975**
Total DC dan IC		**112.206.863**	**1.587.429.757.226**
Biaya kontraktor	**18%**	5.625.971	79.592.578.357
Biaya tidak terduga	**36%**	11.251.942	159.185.156.713

Fixed Capital Investment		**129.084.775**	**1.826.207.492.296**
Work Capital Investment	**15%TCI**	**22.779.666**	**322.271.910.405**
Total Capital Iinvestment		**151.864.441**	**2.148.479.402.701**

2. Sumber Investasi

Sumber investasi atau permodalan berasal dari modal sendiri dan modal pinjaman bank dengan persentase 50% - 50%.

Modal sendiri = 50% x US$ 151.864.441

= US$ 75.932.221 = Rp. 1.074.239.701.351

Pinjaman bank = 50% x US$ 151.864.441

= US$ 75.932.221 = Rp. 1.074.239.701.351

3. Biaya Produksi Total (*Total Production Cost*)

3.1 Biaya Bahan Baku

Daftar biaya bahan baku prarancangan pabrik nano kitosan dari cangkang kerang hijau dapat dilihat pada Tabel D.6.

Tabel D.6 Biaya Bahan Baku

Bahan Baku	Jumlah			Harga	Total harga	
	Kg/jam	Kg/hari	Kg/tahun	Rp	Rp	USD
Cangkang Kerang Hijau	14.690,92	352.582,11	105.774.633,92	4.000,00	423.098.535.682,41	29.906.557,46
HCl	5.624,43	134.986,43	40.495.927,89	45.000,00	1.822.316.754.947,41	128.809.759,77
NaOH	24.354,64	584.511,31	175.353.392,94	25.000,00	4.383.834.823.604,77	309.869.680,44

CH_3COOH	34,24	821,74	246.521,29	160.000,00	39.443.406.955,83	2.788.042,07
NaP_3O_4	171,20	4.108,69	1.232.606,47	36.000,00	44.373.832.825,31	3.136.547,33
$Al2(SO4)_3.18\ H_2O$	0,03	0,65	195,00	20.600,00	4.017.000,00	283,94
$Ca(OH)_2$	0,01	0,14	42,00	10.000,00	420.000,00	29,69
$Ca(ClO)_2$	0,09	2,06	618,00	34.000,00	21.012.000,00	1.485,23
Total					6.713.092.803.015,73	474.512.385,92

3.2 Gaji Karyawan

Sistem gaji karyawan di pabrik nano kitosan berdasarkan gaji upah minimum relatif (UMR) wilayah Cirebon, tahun 2026 dengan nilai UMR sebesar Rp. 3.102.379 Daftar gaji karyawan pra rancangan pabrik nano kitosan dapat dilihat pada Tabel D.7.

Tabel D.7 Daftar Gaji karyawan

Jabatan	Jumlah	Sistem Gaji	Total/Bulan (US$)	Total/tahun (US$)	Total/tahun (Rp)
Dewan Komisaris	1	5 x UMR	1.096	13.157	186.142.751
Direktur	1	3.5 x UMR	768	9.210	130.299.926
Kepala bagian					
-S2 Teknik Kimia	1	2,5 x UMR	548	6.579	93.071.376
-S2 Teknik Industri	1	2,5 x UMR	548	6.579	93.071.376
-S2 Teknik Manajemen	3	2,5 x UMR	1.645	19.736	279.214.127
-S2 Teknik Mesin	1	2,5 x UMR	548	6.579	

					93.071.376
-S2 Teknik Akuntansi	1	2,5 x UMR	548	6.579	93.071.376
Karyawan Akuntasi dan Anggaran					
- S1 Akutansi	1	1,5 x UMR	329	3.947	55.842.825
Karyawan Pemasaran					
- S1 Manajemen	1	1,5 x UMR	329	3.947	55.842.825
Karyawan Administrasi dan SDM					
- S1 Akutansi	1	1,5 x UMR	329	3.947	55.842.825
- S1 Manajemen	1	1,5 x UMR			
Karyawan Logistik					
- S1 Manajemen	1	1,5 x UMR	329	3.947	55.842.825
Karyawan Litbang					
- S1 Manajemen	1	1,5 x UMR	329	3.947	55.842.825
- S1 Teknik Kimia	1	1,5 x UMR	329	3.947	55.842.825
- S1 Kimia/MIPA	1	1,5 x UMR	329	3.947	55.842.825
Sekretaris					
- S1 Manajemen	1	1,5 x UMR	329	3.947	55.842.825

Kepala satpam					
- SMA Sederajat	3	1,1 x UMR	724	8.684	122.854.216
Sopir					
- SMA Sederajat	2	1 x UMR	439	5.263	74.457.101
Dokter					
- S1 Kedokteran	2	2 x UMR	877	10.526	148.914.201
Perawat					
- D3 Keperawatan	2	1 x UMR	439	5.263	74.457.101
Karyawan Produksi					
- D3 Teknik Kimia/Sederajat	3	1,5 x UMR	987	11.842	167.528.476
- D3 Teknik Elektro/Sederajat	8	1,5 x UMR	2.631	31.578	446.742.603
Karyawan Utilitas					
- D3 Teknik kimia	16	1,5 x UMR	5.263	63.156	893.485.207
- D3 Teknik Lingkungan	3	1,5 x UMR	987	11.842	167.528.476
Karyawan Mesin					
- D3 Teknik mesin	12	1,5 x UMR	3.947	47.367	670.113.905
Karyawan Laboratorium					

a. Laboratorium produksi					
- D3 Kimia Analis	4	1,5 x UMR	1.316	15.789	223.371.302
- SMK Analis	4	1,5 x UMR	1.316	15.789	223.371.302
b. Laboratorium Pengendalian Mutu					
- D3 Kimia Analis	4	1,5 x UMR	1.316	15.789	223.371.302
- SMK Analis	4	1,5 x UMR	1.316	15.789	223.371.302
Karyawan Instrumentasi dan Elektrikal					
- D3 Teknik Elektro	8	1,5 x UMR	2.631	31.578	446.742.603
Satpam					
- SMA Sederajat	12	1 x UMR	2.631,49	31.577,83	446.742.603,36
Supervisor					
- S1 teknik kimia	4	1,5 x UMR	1.754,32	21.051,89	297.828.402,24
Office boy					
- SMA	9	1 x UMR	1.973,61	23.683,37	335.056.952,52
Total	120		39.538	474.457	6.712.307.615

3.3 Perhitungan Komponen Biaya Produksi Total

Perhitungan komponen biaya produksi total dapat dilihat pada Tabel D.8.

Tabel D.8 Perhitungan Komponen Biaya Produksi Total

Parameter	**Fixed Cost (US$)**	**Variable Cost (US$)**
Direct Production Cost (DPC)		
Raw Materials (10-50% TPC)		474.512.386
Operating Labor (10-20% TPC)	474.457	
Direct Supervisory (10-20% OL)		47.446
Utilities (10-20% TPC)		0,10 TPC
Maintenance and Repairs (2-10% FCI)	2.581.696	
Operating Supplies (0,5-1% FCI)	645.424	
Laboratory Charges (10-20% OL)		47.446
Patents and Royalties (0-6% TPC)	0,01 TPC	
Total DPC	**3.701.576**	**474.607.277**
Fixed Charge		
Depreciation(10% FCI)	12.908.478	
Local Taxes (1-4% FCI)	1.290.848	

Insurance (0,4-1% FCI)	516.339	
Total FC	**14.715.664**	
Plant Overhead Cost		**0,1 TPC**
General Expenses		
Administrative cost (2-6% TPC)	0,02 TPC	
Distribution Cost (2-20% TPC)	0,02 TPC	
Research and Development (5% TPC)	0,05 TPC	
Financing (0-10% TCI)	1.518.644	
Total General Expenses	**1.518.644**	
Total Production Cost	**19.935.885**	**474.607.277**

Total Production Cost = *Manufacturing Cost* + *General Expenses*

= (*Fixed Cost* + *Variable Cost*)

TPC = (19.935.885 + 0,1 TPC) + (474.607.277 + 0,2 TPC)

TPC = 494.543.162 + 0,3 TPC

TPC = US$ 1.648.477.208 = Rp. 23.321.584.025.368

	US$	Rp
Direct Production Cost (DPC)	659.641.346	9.332.177.002.252
Fixed Charge	14.715.664	208.187.654.122
Plant Overhead Cost	164.847.721	2.332.158.402.537
General Expenses	149.881.593	2.120.427.356.310
Fixed Cost	184.783.606	2.614.198.345.609
Variable Cost	804.302.719	11.378.752.069.613

4. Harga Penjualan Produk (*Total Sales*)

Produksi nano kitosan = 4444kg/jam = 32.000 ton/tahun

Harga jual pasaran = US$ 57 /kg

Harga jual pabrik = US$ 57 – 20% = US$ 56,30 /kg

Maka, total penjualan = US$ 1.801.600.000

= Rp. 25.487.865.760.000

Sumber (alibaba.com)

5. Analisa Kelayakan Investasi

5.1 Laba

Total Capital Investment (TCI)	= US$ 151.864.441
Depresiasi (10% FCI)	= US$ 12.908.478
Total Penjualan (TS)	= US$ 1.801.600.000
Total Production Cost (TPC)	= US$ 1.648.477.208

Laba sebelum pajak (Laba Kotor)

= TS -TPC

= 1.801.600.000 - 1.648.477.208

= US$ 153.122.792

= Rp. 2.166.281.734.632

Pajak 12,5%

Laba Bersih = Laba Kotor - Pajak

= 153.122.792 - (153.122.792 x 12,5%)

= US$ 133.982.443

= Rp. 1.895.496.517.803

5.2 Laju Pengembalian Pinjaman, (*Rate Of Return*)

ROR $= \dfrac{\text{Laba Bersih}}{\text{TCI}} \text{ x } 100\%$

$= \dfrac{\$ \ 133.982.443}{\$151.864.441} x 100\%$

= 88%

5.3 Waktu Pengembalian Modal (*Pay Of Time*)

Massa start up 2 tahun

Umur pabrik 10 tahun

Kapasitas Produksi pabrik selama produksi :

Tahun I = 70% x 1.801.600.000 = $ 1.261.120.000

Tahun II = 90% x 1.801.600.000 = $ 1.621.440.000

Tahun III, dst = 100% x 1.801.600.000 = $ 1.801.600.000

Keuntungan pada masing-masing kapasitas setelah ditambah depresiasi :

1. Kapasitas 70%

   = Total penjualan 70% - {Fixed cost + (Variable cost x 70%)+ Depresiasi}

   = 1.261.120.000– { 184.783.606 + (804.302.719 x 70%)+ 12.908.478 }

   = US$ 500.416.013

2. Kapasitas 90%

   = Total penjualan 90% - {Fixed cost + (Variable cost x 90%)+ Depresiasi}

= 1.621.440.000– { 184.783.606 + (804.302.719 x 90%)+ 12.908.478 }

= US$ 699.875.470

Keuntungan massa *start up* = keuntungan tahun I + keuntungan tahun II

= 500.416.013+ 699.875.470

=US$ 1.200.291.483

3. Kapasitas 100%

= Total penjualan 100% - {Fixed cost + (Variable cost x 100%)+ Depresiasi}

= 1.801.600.000– { 184.783.606 + (804.302.719 x 100%)+ 12.908.478 }

= US$ 799.605.198

$$POT = 2 + \frac{\text{TCI - Jumlah keuntungan selama start up}}{\text{keuntungan kapasitas 100\%}}$$

$$= 2 + \frac{151.864.441 - 1.200.291.483}{799.605.198}$$

= 0,69 (POT < 5 tahun , maka pabrik masih layak)

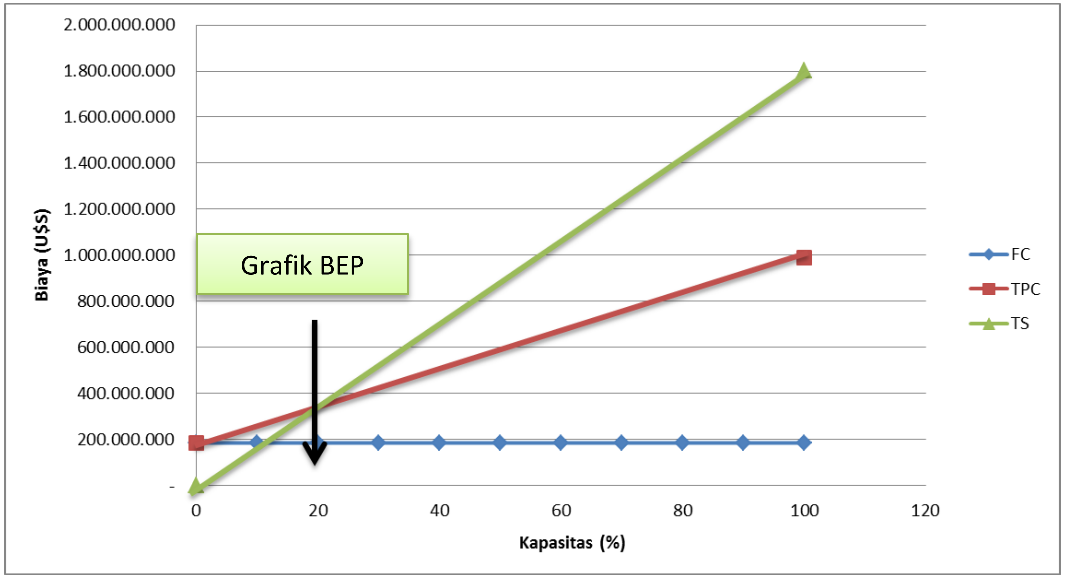
= 6 bulan 22 hari

5.4 Titik impas (*Break event Point*)

$$BEP = \frac{\textit{Fixed Cost}}{\textit{Total sale - Variabel Cost}} \times 100\%$$

$$BEP = \frac{184.783.013}{1.801.600.000 - 804.302.719} x100\%$$

BEP = 18,5 %



Gambar D.2 Kurva *Break Event Point* (BEP)