APPENDIX A

PERHITUNGAN NERACA MASSA

Kapasitas produksi = 547406,3 ton / tahun

= 69116,9564 kg / jam

(asumsi 1 tahun = 330 hari dan 1 hari = 24 jam)

Basis operasi = 1 jam

Berat molekul :

H_2O	= 18
$Ca(OH)_2$	= 74
$CaCl_2$	= 111
$CaCl_2.2H_2O$	= 147
HCl	= 36,5

Perhitungan :

- Produk akhir berupa serbuk $CaCl_2 . 2H_2O$.
- Feed berupa limbah $Ca(OH)_2$ yang mempunyai komposisi sebagai berikut (Departemen Perindustrian, 1983) :

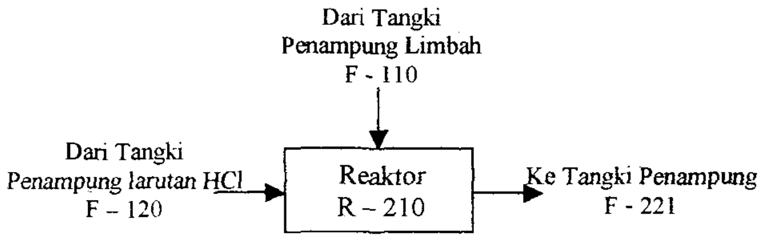
-	H_2O	83,62%
-	$Ca(OH)_2$	15,12%
-	SiO_2	0,92%
-	Fe_2O_3	0,32%
-	MgO	0,02%

- **Total kebutuhan limbah masuk adalah 239,3939 kg untuk setiap kebutuhan** 69116,9564 kg produk serbuk $CaCl_2 . 2H_2O$ per jam.

1. NERACA MASSA PADA REAKTOR R – 210

Larutan asam klorida yang masuk berlebih 20% dan mempunyai kadar 32% berat.

Asumsi konversi reaksi 95%.



- **Masuk**

  - Dari Tangki Penampung Limbah F – 110

    H_2O = 83,62% . 239,3939 kg = 200,1812 kg

    $Ca(OH)_2$ = 15,12% . 239,3939 kg = 36,1964 kg

    SiO_2 = 0,92% . 239,3939 kg = 2,2024 kg

    Fe_2O_3 = 0,32% . 239,3939 kg = 0,7661 kg

    MgO = 0,02% . 239,3939 kg = 0,0479 kg
    \+
    Total limbah masuk reaktor = 239,3939 kg

  - Dari Tangki Penampung Larutan HCl 32% F – 120

    Reaksi yang terjadi pada reaktor R – 210 adalah :

    $$Ca(OH)_2 + 2\ HCl \rightarrow CaCl_2 + 2\ H_2O$$

    0,4891 ~ 0,9294

    HCl yang dibutuhkan = 0,9294 kmol = 33,9219 kg

HCl masuk diasumsi berlebih 20%, sehingga :

HCl $= \frac{120\%}{100\%}.0{,}9294$ kmol = 1,1152 kmol = 40,7062 kg

H_2O $= \frac{68\%}{32\%}$. 40,7062 kg = 86,5007 kg

\+

Larutan HCl = 127,2070 kg

Total massa masuk reaktor = 366,6009 kg

- **Keluar**

- Ke Tangki Penampung F – 211

Reaksi :

$Ca(OH)_2 + 2\ HCl \rightarrow CaCl_2 + 2\ H_2O$

	$Ca(OH)_2$	HCl	$CaCl_2$	H_2O
Mula^2 :	0,4891	1,1152	-	-
Reaksi :	0,4647 ~	0,9294 ~	0,4647 ~	0,9294
Akhir :	0,0245	0,1859	0,4647	0,9294

H_2O = H_2O masuk dari (F – 110 + F – 120 + hasil reaksi)

= 200,1812 kg + 86,5007 kg + 0,9294 kmol . 18 kg/kmol

= 303,4106 kg

$CaCl_2$ = $CaCl_2$ terbentuk dari reaksi = 0,4647 kmol = 51,5798 kg

$Ca(OH)_2$ = $Ca(OH)_2$ masuk – $Ca(OH)_2$ bereaksi

= 36,1964 kg – 0,4647 kmol . 74 kg/kmol

= 1,8098 kg

SiO_2 = SiO_2 masuk reaktor = 2,2024 kg

Fe_2O_3 = Fe_2O_3 masuk reaktor = 0,7661 kg

MgO = MgO masuk reaktor = 0,0479 kg

HCl = HCl masuk – HCl bereaksi

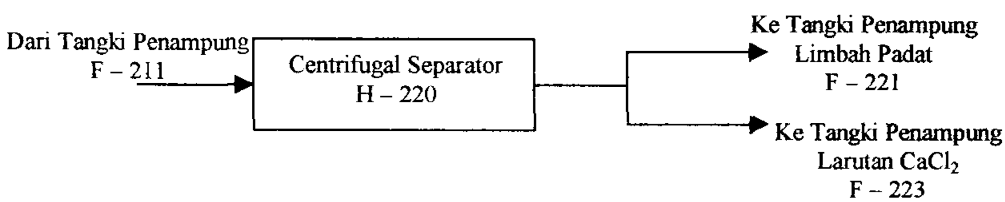
= 40,7062 kg – 0,9294 kmol .36,5 kg/kmol

= 6,7844 kg

———————————————————— +

Total massa keluar reaktor = 366,6009 kg

2. NERACA MASSA PADA CENTRIFUGAL SEPARATOR H – 220



- **Masuk**

  - Dari Tangki Penampung F – 211

H_2O = H_2O keluar dari R – 210 = 303,4106 kg

$CaCl_2$ = $CaCl_2$ keluar dari R – 210 = 51,5798 kg

$Ca(OH)_2$ = $Ca(OH)_2$ keluar dari R – 210 = 1,8098 kg

SiO_2 = SiO_2 keluar dari R – 210 = 2,2024 kg

Fe_2O_3 = Fe_2O_3 keluar dari R – 210 = 0,7661 kg

MgO = MgO keluar dari R – 210 = 0,0479 kg

HCl = HCl keluar dari R – 210 = 6,7844 kg

———————————————————— +

Total massa masuk = 366,6009 kg

- **Keluar**

  - Ke Tangki Penampung Larutan $CaCl_2$ F – 223

Asumsi : larutan $CaCl_2$ yang terpisah berkadar 15% (Feith, 1957)

$CaCl_2$ = $CaCl_2$ masuk dari Tangki Penampung F – 211 = 51,5798 kg

4. Lokasi pabrik

Pabrik ini didirikan di PIER - Pasuruan, Jawa Timur, dengan pertimbangan :

a. Sumber bahan baku limbah $Ca(OH)_2$ di sekitar Surabaya melimpah sehingga kebutuhan bahan baku limbah $Ca(OH)_2$ dapat terpenuhi.
b. Sarana transportasi yang memadai sehingga mempermudah dalam pemasaran produk maupun pengangkutan bahan baku.
c. Tenaga kerja mudah didapat.

B. Analisa Ekonomi

Dari segi ekonomi, pra rencana pabrik ini dipakai metode perhitungan linier dan metode perhitungan discounted cash flow.

Rate pengembalian modal sesudah pajak dengan menggunakan metode perhitungan linier (21,58%) berada di atas bunga bank (20 %) dan menggunakan perhitungan discounted cash flow (15,79%) berada di bawah bunga bank (20 %).

Waktu pengembalian modal sesudah pajak dengan menggunakan metode perhitungan linier (1 tahun 7 bulan) dan dengan menggunakan metode perhitungan discounted cash flow (4 tahun 7 bulan) sudah memenuhi syarat maksimum pada pendirian pabrik kimia, dimana waktu pengembalian maksimum adalah 5 tahun. Break even point masih menguntungkan (35,21%)

IX.2 Kesimpulan

Pra rencana pabrik Calcium Chloride secara teknis maupun ekonomis layak didirikan.

Ringkasan :

Proses	:	Kontinyu
Perencanaan operasi	:	24 jam / hari, 330 hari / tahun
Kapasitas	:	540.000 ton / tahun
Hasil	:	Calcium Chloride
Bahan baku	:	limbah $Ca(OH)_2$ dan HCl
Utilitas	:	- Air = 57,6267 m^3
		- Listrik = 650 kWh
		- Bahan Bakar = 335,53 lt / bulan
Lokasi	:	PIER, Pasuruan, Jawa Timur
Jumlah tenaga kerja	:	60 orang
Analisa ekonomi	:	

1. Metode Linier

Masa konstruksi	: 2 tahun
Investasi total	: Rp 20.496.728.488,-
Laju pengembalian modal sebelum pajak	: 32,89%
Laju pengembalian modal sesudah pajak	: 21,58%
Waktu pengembalian modal sebelum pajak	: 2 tahun 1 bulan

Waktu pengembalian modal sesudah pajak	: 1 tahun 7 bulan
Titik impas (BEP)	: 35,21 %

2. Metode Discounted Cash Flow

Masa konstruksi	: 2 tahun
Investasi total	: Rp 20.496.728.488,-
Laju pengembalian modal sebelum pajak	: 21,12%
Laju pengembalian modal sesudah pajak	: 15,79%
Waktu pengembalian modal sebelum pajak	: 3 tahun 9 bulan
Waktu pengembalian modal sesudah pajak	: 4 tahun 7 bulan
Titik impas (BEP)	: 35,21 %

$H_2O \quad = \dfrac{85\%}{15\%}.51{,}5798 \text{ kg} = 292{,}2856 \text{ kg}$

+

Total massa ke Tangki Penampung Larutan $CaCl_2$ F – 223 = 343,8655 kg

- <u>Ke Tangki Penampung Limbah Padat F – 221</u>

$Ca(OH)_2$ = $Ca(OH)_2$ masuk dr Tangki Penampung F – 211 = 1,8098 kg

SiO_2 = SiO_2 masuk dari Tangki Penampung F – 211 = 2,2024 kg

Fe_2O_3 = Fe_2O_3 masuk dari Tangki Penampung F – 211 = 0,7661 kg

MgO = MgO masuk dari Tangki Penampung F – 211 = 0,0479 kg

HCl = HCl masuk dari Tangki Penampung F – 211 = 6,7844 kg

H_2O = H_2O (dari F – 211 – ke F – 223)

= 303,4106 kg – 292,2856 kg = 11,1249 kg

+

Total massa ke Tangki Penampung Limbah Padat F – 221 = 22,7355 kg

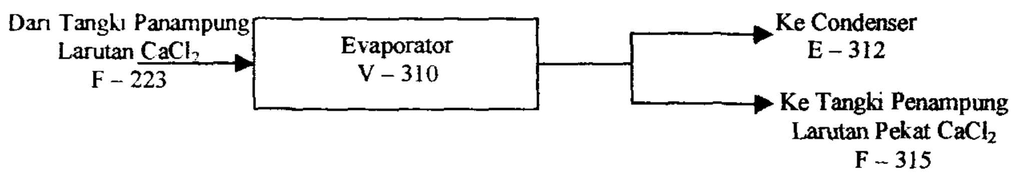
Total massa keluar Centrifugal Separator H – 220

= 343,8655 kg + 22,7355 kg

= 366,6009 kg

3. NERACA MASSA PADA EVAPORATOR V - 310

H_2O yang teruapkan sebanyak 94% dari yang masuk.



- **Masuk**

  - Dari Tangki Penampung Larutan $CaCl_2$ F – 223

    $CaCl_2$ = 51,5798 kg

    H_2O = 292,2856 kg +

    Total massa masuk = 343,8655 kg

- **Keluar**

  - Ke Condenser E – 312

    $H_2O_{(g)}$ = 94% . 292,2856 kg = 274,7485 kg

  - Ke Tangki Penampung Larutan $CaCl_2$ pekat F – 315

    $CaCl_2$ = $CaCl_2$ dari F – 223 = 51,5798 kg

    H_2O = H_2O dari F – 223 – H_2O menguap

    = 292,2856 kg – 274,7485 kg = 17,5371 kg +

    Total massa ke F – 315 = 69,1170 kg

  Total massa keluar dari Evaporator V – 310 = 343,8655 kg

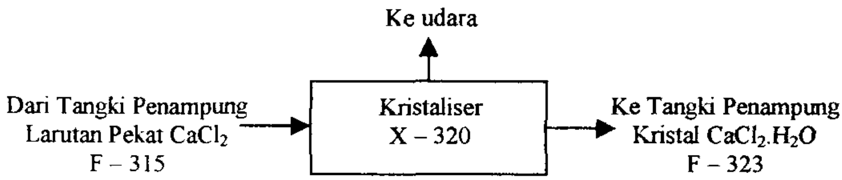
4. NERACA MASSA PADA KRISTALISER X – 320

Asumsi : Suhu operasi kristaliser = 20°C

Tidak ada $CaCl_2$ yang terikut ke udara

Tidak ada H_2O yang teruapkan

Kelarutan $CaCl_2$ = 1,3957 kg $CaCl_2$ / 100 kg H_2O (Perry, 1999)



- **Masuk**

  - <u>Dari Tangki Penampung Larutan Pekat $CaCl_2$ F – 315</u>

    $CaCl_2$ = 51,5798 kg

    H_2O = 17,5371 kg +

    Total massa masuk = 69,1170 kg

- **Keluar**

<u>Neraca massa total</u> :

F – 315 = udara + F – 323

69,1170 kg = 0 + S + C

69,1170 kg = S + C ....(1)

<u>Neraca massa komponen $CaCl_2$</u> :

F – 315 = udara + F – 323

$$51{,}5798 \text{ kg} = 0 + \frac{1{,}3957.S}{1{,}3957 + 100} + \frac{\text{BM CaCl}_2}{\text{BM CaCl}_2.2\text{H}_2\text{O}}.\ C$$

$$51{,}5798 \text{ kg} = \frac{1{,}3957.S}{1{,}3957 + 100} + \frac{111}{147}.C$$

51,5798 kg = 0,0138 S + 0,7551 C ....(2)

<u>Neraca massa komponen H_2O</u> :

F – 315 = udara + F – 323

$$17{,}5371 \text{ kg} = 0 + \frac{100.S}{1{,}3957 + 100} + \frac{2 \text{ BM H}_2\text{O}}{\text{BM CaCl}_2.2\text{H}_2\text{O}}.\ C$$

$$17{,}5371 \text{ kg} = \frac{100.S}{1{,}3957+100} + \frac{2.18}{147}.C$$

$$17{,}5371 \text{ kg} = 0{,}98624 \text{ S} + 0{,}2449 \text{ C} \qquad \text{.........................(3)}$$

Persamaan (2) dan (3) dapat diperoleh :

S = 0,8236 kg

C = 62,2934 kg

- Ke Tangki Penampung Kristal $CaCl_2.2H_2O$ F – 323 :

  $CaCl_2 . 2 H_2O$ = 62,2934 kg

  $$CaCl_2 = \frac{1{,}3957.S}{1{,}3957+100} = 0{,}0113 \text{ kg}$$

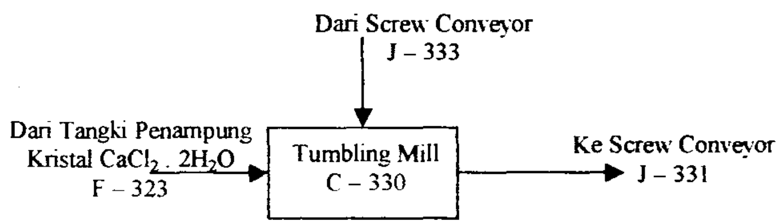
  $$H_2O = \frac{100.S}{1{,}3957+100} = 0{,}8122 \text{ kg}$$

  ——————————————————— +

  Total massa keluar = 69,1170 kg

5. NERACA MASSA PADA TUMBLING MILL C – 330

Recycle yang masuk dari Screw Conveyor J – 333 sebesar 20% dari massa total yang keluar dari Tumbling Mill C – 130.



- **Masuk**

  - Dari Tangki Penampung Kristal $CaCl_2 . 2H_2O$ F – 323 :

    $CaCl_2 . 2 H_2O$ = 68,2934 kg

    $CaCl_2$ = 0,0113 kg

H_2O = 0,8122 kg +

Total massa keluar F – 323 = 69,1170 kg

- Dari Screw Conveyor J – 333 (recycle = R)

Massa masuk dari F – 323 + R = massa keluar dari C – 330

$$\left.\begin{array}{l}69{,}1170\,\text{kg} + R = \text{massa keluar dari C} - 330\\ R = 20\%\,\text{massa keluar dari C} - 330\end{array}\right\} R = \frac{1}{4}.69{,}1170\,\text{kg}$$

$R = 17{,}2792$ kg

Yang terdiri dari :

$CaCl_2 \,.\, 2\,H_2O$ = 17,0733 kg

$$CaCl_2 = \frac{1{,}3957.S}{1{,}3957+100} = 0{,}002834 \text{ kg}$$

$$H_2O = \frac{100.S}{1{,}3957+100} = 0{,}2031 \text{ kg}$$ +

Total massa keluar J – 333 = 17,2792 kg

Total massa masuk = 69,1170 kg + 17,2792 kg = 86,3962 kg

- **Keluar**

  - Ke Screen H – 332

$CaCl_2 \,.\, 2\,H_2O$ = $CaCl_2 \,.\, 2\,H_2O$ dari (F – 323 + J – 333)

= 68.2934 kg + 17.0733 kg = 85,3667 kg

$CaCl_2$ = $CaCl_2$ dari (F – 323 + J – 333)

= 0,0113 kg + 0,002834 kg = 0,0142 kg

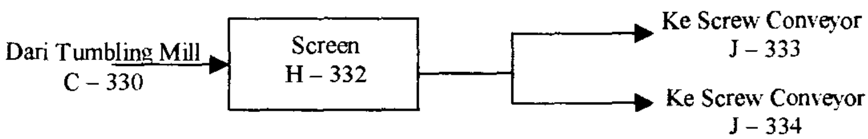
H_2O = H_2O dari (F – 323 + J – 333)

= 0,8122 kg + 0,2031 kg = 1,0153 kg +

Total massa keluar = 86,3962 kg

6. NERACA MASSA PADA SCREEN H – 332

Kristal $CaCl_2 . 2H_2O$ yang masuk ke Screw Conveyor J – 333 merupakan oversize sedangkan yang masuk ke Screw Conveyor J – 334 merupakan undersize.



- **Masuk**

  - Dari Tumbling Mill C – 330

$CaCl_2 . 2 H_2O$	= 85,3667 kg
$CaCl_2$	= 0,0142 kg
H_2O	= 1,0153 kg
	+
Total massa masuk	= 86,3962 kg

- **Keluar**

  - Ke Screw Conveyor J – 333

$CaCl_2 . 2 H_2O$ = 20% $CaCl_2 . 2 H_2O$ dari Tumbling Mill C – 330

= 20% . 85,3667 kg = 17,0733 kg

$CaCl_2$ = 20% $CaCl_2$ dari Tumbling Mill C – 330

= 20% . 0,0142 kg = 0,002834 kg

H_2O = 20% H_2O dari Tumbling Mill C – 330

= 20% . 1,0153 kg = 0,2031 kg +

Total massa keluar ke J – 333 = 17,2792 kg

- <u>Ke Screw Conveyor J – 334</u>

  $CaCl_2 . 2 H_2O$ = 80% $CaCl_2 . 2 H_2O$ dari Tumbling Mill C – 330

  = 80% . 85,3667 kg = 68,2934 kg

  $CaCl_2$ = 80% $CaCl_2$ dari Tumbling Mill C – 330

  = 80% . 0,0142 kg = 0,0113 kg

  H_2O = 80% H_2O dari Tumbling Mill C – 330

  = 80% . 1,0153 kg = 0,8122 kg +

  Total massa keluar ke J – 334 = 69,1170 kg

Total massa keluar dari Screen H – 322 = 17,2792 kg + 69,1170 kg

= 86,3962 kg

JADI DARI 239,3939 KG LIMBAH MASUK PER JAM DAPAT DIHASILKAN 68,2934 KG SERBUK $CaCl_2 . 2H_2O$ DENGAN IMPURITIES SEBANYAK 0,8236 KG YANG TERDIRI DARI :

$CaCl_2$ = 0,0113 KG

H_2O = 0,8122 KG

APPENDIX B

PERHITUNGAN NERACA PANAS

APPENDIX B

PERHITUNGAN NERACA PANAS

Basis : 1 jam

Suhu refrensi = 25°C = 298 K

Berat molekul :

H_2O	= 18	SiO_2	= 60
$Ca(OH)_2$	= 74	Fe_2O_3	= 160
$CaCl_2$	= 111	MgO	= 40
$CaCl_2.2H_2O$	= 147	Udara	= 28,97
HCl	= 36,5		

Cp untuk zat-zat yang digunakan :

- Rumus :

1. Cp (cal / mol . K) = A + B . T + C / T^2
2. Cp (J / kmol . K) = A + B . T + C . T^2 + D . T^3 + E . T^4

(Perry, 1999)

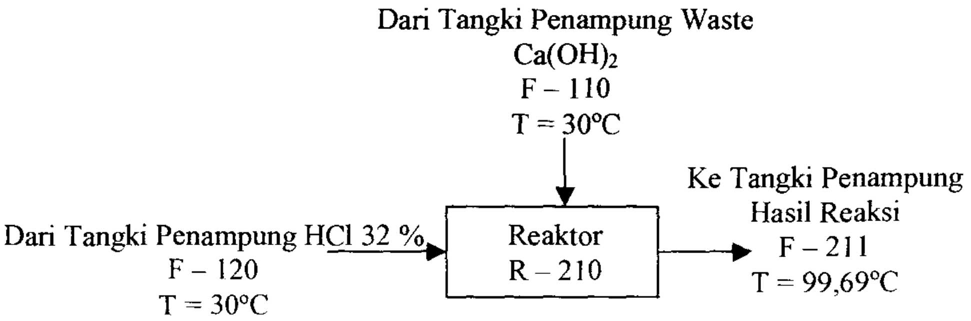
3. Cp (kJ / kgmol) = A + B . T + C . T^2 + D . T^3

(Himmelblau, 1989)

- Data-data :

Zat	Rumus	A	B	C	D
$CaCl_2$	1 (K)	16,9	0,00386	-	-
$Ca(OH)_2$	1 (K)	21,4	-	-	-
$HCl_{(l)}$	2 (K)	$4,73.10^4$	90	-	-
$H_2O_{(l)}$	3 (K)	18,2964	$47,212.10^{-2}$	$-133,88.10^{-5}$	$1314,2.10^{-9}$
$H_2O_{(g)}$	3 (°C)	33,46	$0,688.10^{-2}$	$0,7604.10^{-5}$	$-3,593.10^{-9}$
SiO_2	1 (K)	10,87	$8,712.10^{-3}$	241200	-
Fe_2O_3	1 (K)	24,72	$1,604.10^{-2}$	-423400	-
MgO	1 (K)	10,86	$1,197.10^{-3}$	208700	-

1. REAKTOR R – 210



ΔH masuk = ΔH keluar + ΔH reaksi + Q_{loss}

Entalpi masuk :

Suhu masuk = 30°C = 303 K

- **Dari Tangki Penampung HCl 32% F – 120**

  - HCl

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3 + E.T^4\right)dT$$

$$\Delta H = \frac{40,7062}{36,5}\text{kmol}.\left[4,73.10^4.(303-298)+45.\left(303^2-298^2\right)\right]\text{J/kmol}$$

$$\Delta H = \frac{40,7062}{36,5}\text{kmol}.371725\ \text{J/kmol}$$

$$\Delta H = 414562,3\ \text{J} = 414,5623\ \text{kJ}$$

  - H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{303}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{86{,}5007}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(303+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(303^2+303.298+298^2) + \frac{1314{,}2.10^{-9}}{4}(303^2+298^2)(303+298)\right]$$

$$(303-298)\ \text{kJ / kmol}$$

$$\Delta H = \frac{86{,}5007}{18}\text{kmol}.74{,}9353\ (303-298)\ \text{kJ / kmol}$$

$$\Delta H = 1800{,}5438\ \text{kJ}$$

Entalpi masuk total dari Tangki Penampung HCl 32% F – 120

= (414,5623 + 1800,5438) kJ

= 2215,1061 kJ

- **Dari Tangki Penampung Waste $Ca(OH)_2$ F – 110**

  - H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{303}(A + B.T + C.T^2 + D.T^3)\,dT$$

$$\Delta H = \frac{200{,}1812}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(303+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(303^2+303.298+298^2) + \frac{1314{,}2.10^{-9}}{4}(303^2+298^2)(303+298)\right]$$

$$(303-298)\ \text{kJ / kmol}$$

$$\Delta H = \frac{200{,}1812}{18}\text{kmol}.74{,}9353\ (303-298)\text{kJ / kmol}$$

$$\Delta H = 4166{,}8430\ \text{kJ}$$

  - $Ca(OH)_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{303}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{36{,}1964.10^3}{74} \text{mol}\ [21{,}4\ (303-298)]\ \text{cal/mol}$$

$$= 218{,}0749\ \text{kJ}$$

- <u>SiO_2</u>

$$\Delta H = \frac{m}{BM} . \int_{298}^{303} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{2{,}2024.10^3}{60} \text{mol} \left[10{,}87(303-298) + \frac{0{,}00871}{2}(303^2 - 298^2) + \left(\frac{241200}{303} - \frac{241200}{298} \right) \right] \text{cal/mol}$$

$$= 14{,}8289\ \text{kJ}$$

- <u>Fe_2O_3</u>

$$\Delta H = \frac{m}{BM} . \int_{298}^{303} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}7661.10^3}{140} \text{mol} \left[24{,}72(303-298) + \frac{0{,}01604}{2}(303^2 - 298^2) + \left(\frac{-423400}{303} - \frac{-423400}{298} \right) \right] \text{cal/mol}$$

$$= 2{,}9746\ \text{kJ}$$

- <u>MgO</u>

$$\Delta H = \frac{m}{BM} . \int_{298}^{303} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0479.10^3}{40} \text{mol} \left[10{,}86(303-298) + \frac{0{,}0012}{2}\left(303^2 - 298^2\right) + \left(\frac{208700}{303} - \frac{208700}{298} \right) \right] \text{cal/mol}$$

$$= 0{,}4049 \text{ kJ}$$

Entalpi masuk total dari Tangki Penampung Waste $Ca(OH)_2$ F – 110

= (4166,8630 + 218,0749 + 14,8289 + 2,9746 + 0,4049) kJ

= 4403,1263 kJ

Total entalpi masuk = entalpi masuk dari (F – 120 + F – 110)

= (2215,1061 + 4403,1263) kJ

= 6618,2324 kJ

<u>**Entalpi keluar :**</u>

- **Ke Tangki Penampung Hasil Reaksi F – 211**

Data-data ΔH^o_{298} :

$\Delta H^o_{298\ CaCl_2} = -794{,}9 \text{ kJ/mol}$

$\Delta H^o_{298\ H_2O} = -285{,}84 \text{ kJ/mol}$

$\Delta H^o_{298\ HCl} = -92{,}311 \text{ kJ/mol}$

(Geankoplis, 1993)

$\Delta H^o_{298\ Ca(OH)_2} = -235{,}58 \text{ kcal/mol}$

(Perry, 1999)

Reaksi :

	$Ca(OH)_2$	+ 2 HCl	$\rightarrow CaCl_2$	+ 2 H_2O
Mula ² :	0,4891	1,1152	-	-
Reaksi :	0,4647 ~	0,9294 ~	0,4647 ~	0,9294
Akhir :	0,0245	0,1859	0,4647	0,9294

$$\Delta H_{reaksi} = \Delta H^o_{298} = \sum \Delta H^o_{298} \text{ produk} - \sum \Delta H^o_{298} \text{ reak tan}$$

$$\Delta H^o_{298} = \left[\left(n.\Delta H^o_{298}\right)_{CaCl_2} + \left(n.\Delta H^o_{298}\right)_{H_2O}\right] - \left[\left(n.\Delta H^o_{298}\right)_{HCl} + \left(n.\Delta H^o_{298}\right)_{Ca(OH)_2}\right]$$

$$\Delta H^o_{298} = \left[(0{,}4647\,\text{kmol}.(-794{,}9\text{ kJ/mol})) + (0{,}9294\,\text{kmol}.(-285{,}84\text{ kJ/mol}))\right] - \left[(0{,}9294\,\text{kmol}.(-92{,}311\text{kJ/mol})) + (0{,}4647\,\text{kmol}.(-235{,}58\text{kcal/mol}))\right]$$

$$\Delta H^o_{298} = -93110{,}7106 \text{ kJ}$$

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + ΔH reaksi + Q_{loss}

6618,2324 kJ = ΔH keluar + -93110,7106 kJ + 10% . 6618,2324 kJ

ΔH keluar = 99067,1198 kJ

- $Ca(OH)_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{1{,}8098.10^3}{74}\text{mol}\left[21{,}4\left(T_{out} - 298\right)\right]\text{cal/mol}$$

- $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{51{,}5798.10^3}{111}\text{mol}\left[16{,}9\left(T_{out} - 298\right) + \frac{0{,}000386}{2}\left(T_{out}^2 - 298^2\right)\right]\text{cal/mol}$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{303{,}4106}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out}+298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out}+298\right)\right]$$

$$\left(T_{out} - 298\right)\text{ kJ / kmol}$$

- $\underline{SiO_2}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{2{,}2024}{60}\text{mol}\left[10{,}87(T_{out} - 298) + \frac{0{,}00871}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{241200}{T_{out}}\right.\right.$$

$$\left.\left.-\frac{241200}{298}\right)\right]\text{cal / mol}$$

- $\underline{Fe_2O_3}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0{,}7661}{160}\text{mol}\left[24{,}72(T_{out} - 298) + \frac{0{,}01604}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{-423400}{T_{out}}\right.\right.$$

$$\left.\left.-\frac{-423400}{298}\right)\right]\text{cal / mol}$$

- $\underline{MgO}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0{,}0479}{40}\text{mol}\left[10{,}86(T_{out} - 298) + \frac{0{,}0012}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{208700}{T_{out}}\right.\right.$$

$$\left.\left. - \frac{208700}{298}\right)\right] \text{cal/mol}$$

- HCl

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3 + E.T^4\right)dT$$

$$\Delta H = \frac{6{,}7844}{36{,}5}\text{kmol}.\left[4{,}73.10^4.(T_{out} - 298) + 45.\left(T_{out}^{\ 2} - 298^2\right)\right]\text{J/kmol}$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{CaCl_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO}$$

$$+ \Delta H_{HCl}$$

$$99067{,}1198 \text{ kJ} = \left(\frac{m}{BM}Cp.\Delta T\right)_{Ca(OH)_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}$$

$$+ \left(\frac{m}{BM}Cp.\Delta T\right)_{SiO_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{Fe_2O_3} + \left(\frac{m}{BM}Cp.\Delta T\right)_{MgO}$$

$$+ \left(\frac{m}{BM}Cp.\Delta T\right)_{HCl}$$

Dengan cara trial diperoleh : T_{out} = 372,69 K = 99,69°C, maka :

- $Ca(OH)_2$

$$\Delta H = \frac{1{,}8098.10^3}{74}\text{mol}\left[21{,}4\ (372{,}69 - 298)\right]\text{cal/mol}$$

$$= 162{,}8767 \text{ kJ}$$

- $CaCl_2$

$$\Delta H = \frac{51{,}5798.10^3}{111}\text{ mol}\left[16{,}9\ (372{,}69 - 298) + \frac{0{,}000386}{2}\left(372{,}69^2 -\right.\right.$$

$$\left.\left. - 298^2\right)\right]\text{cal/mol}$$

$$= 2631{,}0990 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{303,4106}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(372,69+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(372,69^2 + 372,69.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(372,69^2 + 298^2\right)$$

$$\left.(372,69+298)\right](372,69-298)\ \text{kJ/kmol}$$

$$= 95197,2822\ \text{kJ}$$

- SiO_2

$$\Delta H = \frac{2,2024}{60}\text{mol}\left[10,87(372,69-298) + \frac{0,00871}{2}\left(372,69^2 - 298^2\right) + \right.$$

$$\left.\left(\frac{241200}{372,69} - \frac{241200}{298}\right)\right]\text{cal/mol}$$

$$= 0,1824\ \text{kJ}$$

- Fe_2O_3

$$\Delta H = \frac{0,7661}{160}\text{mol}\left[24,72(372,69-298) + \frac{0,01604}{2}\left(372,69^2 - 298^2\right) + \right.$$

$$\left.\left(\frac{-423400}{372,69} - \frac{-423400}{298}\right)\right]\text{cal/mol}$$

$$= 0,0392\ \text{kJ}$$

- MgO

$$\Delta H = \frac{0,0479}{40}\text{mol}\left[10,86(372,69-298) + \frac{0,0012}{2}\left(372,69^2 - 298^2\right) + \left(\frac{208700}{372,69}\right.\right.$$

$$\left.\left.- \frac{208700}{298}\right)\right]\text{cal/mol}$$

$$= 0,0049\ \text{kJ}$$

- <u>HCl</u>

$$\Delta H = \frac{6{,}7844}{36{,}5}\,\text{kmol}.\left[4{,}73.10^4.(372{,}69-298)+45.(372{,}69^2-298^2)\right]\text{J/kmol}$$

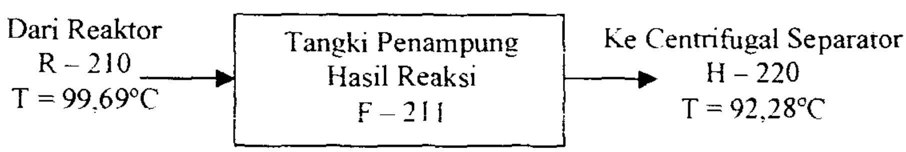
$$= 1075{,}6354 \text{ kJ}$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{CaCl_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$= (162{,}8767 + 2631{,}0990 + 95197{,}2822 + 0{,}1824 + 0{,}0392 + 0{,}0049 + 25{,}8153)\text{ kJ}$$

$$= 99067{,}1198 \text{ kJ}$$

TANGKI PENAMPUNG HASIL REAKSI F – 211



ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

Suhu masuk = 99,69°C = 372,69 K

- **Dari Reaktor R – 220**

$\Delta H_{Ca(OH)_2}$	= 162,8767 kJ
ΔH_{CaCl_2}	= 2631,0990 kJ
ΔH_{H_2O}	= 95197,2822 kJ
ΔH_{SiO_2}	= 0,1824 kJ
$\Delta H_{Fe_2O_3}$	= 0,0392 kJ
ΔH_{MgO}	= 0,0049 kJ
ΔH_{HCl}	= 1075,6354 kJ +
ΔH masuk	= 99067,1198 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

99067,1198 kJ = ΔH keluar + 10% (99067,1198 kJ)

ΔH keluar = 89160,4078 kJ

- **Ke Centrifugal Separator H – 220**

  - $Ca(OH)_2$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{1{,}8098.10^3}{74} \text{mol} \left[21{,}4 \left(T_{out} - 298 \right) \right] \text{cal/mol}$$

  - $CaCl_2$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{51{,}5798.10^3}{111} \text{mol} \left[16{,}9 \left(T_{out} - 298 \right) + \frac{0{,}000386}{2} \left(T_{out}^2 - 298^2 \right) \right] \text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{303{,}4106}{18} \text{kmol} \cdot \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298 \right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^2 + T_{out}.298 + 298^2 \right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^2 + 298^2 \right) \left(T_{out} + 298 \right) \right]$$

$$\left(T_{out} - 298 \right) \text{kJ/kmol}$$

- SiO_2

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{2,2024}{60} mol \left[10,87(T_{out} - 298) + \frac{0,00871}{2}(T_{out}{}^2 - 298^2) + \left(\frac{241200}{T_{out}} - \frac{241200}{298} \right) \right] cal/mol$$

- Fe_2O_3

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0,7661}{160} mol \left[24,72(T_{out} - 298) + \frac{0,01604}{2}(T_{out}{}^2 - 298^2) + \left(\frac{-423400}{T_{out}} - \frac{-423400}{298} \right) \right] cal/mol$$

- MgO

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0,0479}{40} mol \left[10,86(T_{out} - 298) + \frac{0,0012}{2}(T_{out}{}^2 - 298^2) + \left(\frac{208700}{T_{out}} - \frac{208700}{298} \right) \right] cal/mol$$

- HCl

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 + E.T^4 \right) dT$$

$$\Delta H = \frac{6,7844}{36,5} kmol. \left[4,73.10^4.(T_{out} - 298) + 45.(T_{out}{}^2 - 298^2) \right] J/kmol$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{CaCl_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$89160{,}4078 \text{ kJ} = \left(\frac{m}{BM} Cp.\Delta T\right)_{Ca(OH)_2} + \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T\right)_{H_2O} + \left(\frac{m}{BM} Cp.\Delta T\right)_{SiO_2} + \left(\frac{m}{BM} Cp.\Delta T\right)_{Fe_2O_3} + \left(\frac{m}{BM} Cp.\Delta T\right)_{MgO} + \left(\frac{m}{BM} Cp.\Delta T\right)_{HCl}$$

Dengan cara trial diperoleh : T_{out} = 365,28 K = 92,28°C, maka :

- $\underline{Ca(OH)_2}$

$$\Delta H = \frac{1{,}8098.10^3}{74} \text{mol } [21{,}4\ (365{,}28 - 298)] \text{ cal/mol}$$
$$= 146{,}7283 \text{ kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{51{,}5798.10^3}{111} \text{ mol} \left[16{,}9\ (365{,}28 - 298) + \frac{0{,}000386}{2}\left(365{,}28^2 - 298^2\right)\right] \text{cal/mol}$$
$$= 2368{,}3777 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{303{,}4106}{18} \text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(365{,}28 + 298) - \frac{133{,}88.10^{-5}}{3}\left(365{,}28^2 + 365{,}28.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(365{,}28^2 + 298^2\right)(365{,}28 + 298)\right](365{,}28 - 298) \text{ kJ/kmol}$$
$$= 85680{,}2733 \text{ kJ}$$

- $\underline{SiO_2}$

$$\Delta H = \frac{2{,}2024}{60}\text{mol}\left[10{,}87(365{,}28 - 298) + \frac{0{,}00871}{2}(365{,}28^2 - 298^2) + \left(\frac{241200}{365{,}28} - \frac{241200}{298}\right)\right]\text{cal/mol}$$

$$= 0{,}1644 \text{ kJ}$$

- $\underline{Fe_2O_3}$

$$\Delta H = \frac{0{,}7661}{160}\text{mol}\left[24{,}72(365{,}28 - 298) + \frac{0{,}01604}{2}(365{,}28^2 - 298^2) + \left(\frac{-423400}{365{,}28} - \frac{-423400}{298}\right)\right]\text{cal/mol}$$

$$= 0{,}0351 \text{ kJ}$$

- $\underline{MgO}$

$$\Delta H = \frac{0{,}0479}{40}\text{mol}\left[10{,}86(365{,}28 - 298) + \frac{0{,}0012}{2}(365{,}28^2 - 298^2) + \left(\frac{208700}{365{,}28} - \frac{208700}{298}\right)\right]\text{cal/mol}$$

$$= 0{,}0044 \text{ kJ}$$

- $\underline{HCl}$

$$\Delta H = \frac{6{,}7844}{36{,}5}\text{kmol}.\left[4{,}73.10^4.(365{,}28 - 298) + 45.(365{,}28^2 - 298^2)\right]\text{J/kmol}$$

$$= 964{,}8245 \text{ kJ}$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{CaCl_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$= (146{,}7283 + 2368{,}3777 + 85680{,}2733 + 0{,}1644 + 0{,}0351 + 0{,}0044 + 964{,}8245)\ kJ$$

$$= 89160{,}4078\ kJ$$

CENTRIFUGAL SEPARATOR H – 220

Dari Tangki Penampung Hasil Reaksi F – 211 T = 92,28°C → Centrifugal Separator H – 220

→ Ke Tangki Penampung Limbah Padat F – 221 T = 86,26°C

→ Tangki Penampung Larutan $CaCl_2$ F – 223 T = 86,26°C

ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

Suhu masuk = 92,28°C = 365,28 K

- **Dari Tangki Penampung Hasil Reaksi F – 211**

$\Delta H_{Ca(OH)_2}$	= 146,7283 kJ
ΔH_{CaCl_2}	= 2368,3777 kJ
ΔH_{H_2O}	= 85680,2733 kJ
ΔH_{SiO_2}	= 0,1644 kJ
$\Delta H_{Fe_2O_3}$	= 0,0351 kJ
ΔH_{MgO}	= 0,0044 kJ
ΔH_{HCl}	= 964,8245 kJ +
ΔH masuk	= 89160,4078 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

89160,4078 kJ = ΔH keluar + 10% (89160,4078 kJ)

ΔH keluar = 80244,3670 kJ

- **Ke Tangki Penampung Limbah Padat F – 221**

  - $Ca(OH)_2$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{1{,}8098.10^3}{74} \text{mol} \left[21{,}4 \left(T_{out} - 298 \right) \right] \text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{11{,}1249}{18} \text{kmol.} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298 \right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2 \right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^{\ 2} + 298^2 \right) \left(T_{out} + 298 \right) \right]$$

$$\left(T_{out} - 298 \right) \text{kJ/kmol}$$

  - SiO_2

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{2{,}2024}{60} \text{mol} \left[10{,}87 \left(T_{out} - 298 \right) + \frac{0{,}00871}{2} \left(T_{out}^{\ 2} - 298^2 \right) + \left(\frac{241200}{T_{out}} \right. \right.$$

$$\left. \left. - \frac{241200}{298} \right) \right] \text{cal/mol}$$

- $\underline{Fe_2O_3}$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}7661}{160} mol \left[24{,}72(T_{out} - 298) + \frac{0{,}01604}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{-423400}{T_{out}} - \frac{-423400}{298} \right) \right] cal/mol$$

- $\underline{MgO}$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0479}{40} mol \left[10{,}86(T_{out} - 298) + \frac{0{,}0012}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{208700}{T_{out}} - \frac{208700}{298} \right) \right] cal/mol$$

- $\underline{HCl}$

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 + E.T^4 \right) dT$$

$$\Delta H = \frac{6{,}7844}{36{,}5} kmol . \left[4{,}73.10^4 . (T_{out} - 298) + 45 . \left(T_{out}^{\ 2} - 298^2\right) \right] J/kmol$$

$$\Delta H_{F-221} = \Delta H_{Ca(OH)_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$= \left(\frac{m}{BM} Cp.\Delta T \right)_{Ca(OH)_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{SiO_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{Fe_2O_3} + \left(\frac{m}{BM} Cp.\Delta T \right)_{MgO} + \left(\frac{m}{BM} Cp.\Delta T \right)_{HCl}$$

- **Ke Tangki Penampung Larutan $CaCl_2$ F – 223**

  - $\underline{CaCl_2}$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{51{,}5798.10^3}{111} \text{mol} \left[16{,}9 \left(T_{out} - 298\right) + \frac{0{,}000386}{2}\left(T_{out}^{\ 2} - 298^2\right) \right] \text{cal/mol}$$

  - $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3\right) dT$$

$$\Delta H = \frac{292{,}2856}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right) \right]$$

$$\left(T_{out} - 298\right) \text{kJ/kmol}$$

$$\Delta H_{F-223} = \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}$$

$$\Delta H_{keluar} = \Delta H_{F-221} + \Delta H_{F-223}$$

$$80244{,}3670 \text{ kJ} = \left(\Delta H_{Ca(OH)_2} + +\Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}\right)$$

$$+ \left(\Delta H_{CaCl_2} + \Delta H_{H_2O}\right)$$

Dengan cara trial diperoleh : T_{out} = 359,26 K = 86,26°C, maka :

  - $\underline{Ca(OH)_2}$

$$\Delta H = \frac{1{,}8098.10^3}{74}\text{mol} \left[21{,}4 \left(359{,}26 - 298\right)\right] \text{cal/mol}$$

$$= 133{,}5977 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{11,1249}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(359,26+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left(359,26^2 + 359,26.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(359,26^2 + 298^2\right)$$

$$\left.(359,26+298)\right](359,26-298)\ \text{kJ/kmol}$$

$$= 2858,3337\ \text{kJ}$$

- $\underline{SiO_2}$

$$\Delta H = \frac{2,2024}{60}\text{mol}\left[10,87(359,26-298) + \frac{0,00871}{2}\left(359,26^2 - 298^2\right) + \right.$$

$$\left.\left(\frac{241200}{359,26} - \frac{241200}{298}\right)\right]\text{cal/mol}$$

$$= 0,1498\ \text{kJ}$$

- $\underline{Fe_2O_3}$

$$\Delta H = \frac{0,7661}{160}\text{mol}\left[24,72(359,26-298) + \frac{0,01604}{2}\left(359,26^2 - 298^2\right) + \right.$$

$$\left.\left(\frac{-423400}{359,26} - \frac{-423400}{298}\right)\right]\text{cal/mol}$$

$$= 0,0318\ \text{kJ}$$

- $\underline{MgO}$

$$\Delta H = \frac{0,0479}{40}\text{mol}\left[10,86(359,26-298) + \frac{0,0012}{2}\left(359,26^2 - 298^2\right) + \left(\frac{208700}{359,26}\right.\right.$$

$$\left.\left.- \frac{208700}{298}\right)\right]\text{cal/mol}$$

$$= 0,004\ \text{kJ}$$

- HCl

$$\Delta H = \frac{6,7844}{36,5} \text{kmol}.\left[4,73.10^4.(359,26-298)+45.(359,26^2-298^2)\right] \text{J/kmol}$$

$$= 875,3975 \text{ kJ}$$

$$\Delta H_{F-221} = \Delta H_{Ca(OH)_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$= (133,5977 + 2858,3337 + 0,1498 + 0,0318 + 0,004 + 875,3975) \text{ kJ}$$

$$= 2992,1170 \text{ kJ}$$

- $CaCl_2$

$$\Delta H = \frac{51,5798.10^3}{111} \text{ mol}\left[16,9\ (359,26-298) + \frac{0,000386}{2}(359,26^2 - 298^2)\right] \text{cal/mol}$$

$$= 2155,0543 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{292,2856}{18} \text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(359,26+298) - \frac{133,88.10^{-5}}{3}(359,26^2+359,26.298+298^2) + \frac{1314,2.10^{-9}}{4}(359,26^2+298^2)(359,26+298)\right](359,26-298) \text{ kJ/kmol}$$

$$= 75097,1957 \text{ kJ}$$

$$\Delta H_{F-223} = \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (2155,0543 + 75097,1957) \text{ kJ}$$

$$= 77252,25 \text{ kJ}$$

$$\Delta H_{total} = \Delta H_{F-221} + \Delta H_{F-223}$$

$$= (2992,117 + 77252,25) \text{ kJ}$$

$$= 80244,367 \text{ kJ}$$

TANGKI PENAMPUNG LIMBAH PADAT F – 221

Centrifugal Separator H – 220 T = 86,26°C	→	Tangki Penampung Limbah Padat F – 221	→	Ke Screw Conveyor J – 222 T = 80,17°C

ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

Suhu masuk = 86,26°C = 359,26 K

- **Dari Centrifugal Separator H – 220**

  $\Delta H_{Ca(OH)_2}$ = 133,5977 kJ

  ΔH_{H_2O} = 2858,3337 kJ

  ΔH_{SiO_2} = 0,1498 kJ

  $\Delta H_{Fe_2O_3}$ = 0,0318 kJ

  ΔH_{MgO} = 0,004 kJ

  ΔH_{HCl} = 875,3975 kJ +

  ΔH masuk = 2992,1170 kJ

<u>Entalpi keluar :</u>

<u>Asumsi</u> : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

2992,1170 kJ = ΔH keluar + 10% (2992,1170 kJ)

ΔH keluar = 2692,9053 kJ

- **Ke Screw Conveyor J – 222**

  - Ca(OH)₂

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{1{,}8098.10^3}{74} \text{mol} \left[21{,}4 \left(T_{out} - 298 \right) \right] \text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{11{,}1249}{18} \text{kmol.} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298 \right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2 \right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^{\ 2} + 298^2 \right) \left(T_{out} + 298 \right) \right]$$

$$\left(T_{out} - 298 \right) \text{kJ/kmol}$$

  - SiO_2

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{2{,}2024}{60} \text{mol} \left[10{,}87 \left(T_{out} - 298 \right) + \frac{0{,}00871}{2} \left(T_{out}^{\ 2} - 298^2 \right) + \left(\frac{241200}{T_{out}} \right. \right.$$

$$\left. \left. - \frac{241200}{298} \right) \right] \text{cal/mol}$$

  - Fe_2O_3

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}7661}{160} \text{mol} \left[24{,}72(T_{out} - 298) + \frac{0{,}01604}{2}(T_{out}^{2} - 298^{2}) + \left(\frac{-423400}{T_{out}} - \frac{-423400}{298} \right) \right] \text{cal/mol}$$

- <u>MgO</u>

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^{2}} \right) dT$$

$$= \frac{0{,}0479}{40} \text{mol} \left[10{,}86(T_{out} - 298) + \frac{0{,}0012}{2}(T_{out}^{2} - 298^{2}) + \left(\frac{208700}{T_{out}} - \frac{208700}{298} \right) \right] \text{cal/mol}$$

- <u>HCl</u>

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^{2} + D.T^{3} + E.T^{4} \right) dT$$

$$\Delta H = \frac{6{,}7844}{36{,}5} \text{kmol} . \left[4{,}73.10^{4}.(T_{out} - 298) + 45.(T_{out}^{2} - 298^{2}) \right] \text{J/kmol}$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$2692{,}9053 \text{ kJ} = \left(\frac{m}{BM} Cp.\Delta T \right)_{Ca(OH)_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{SiO_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{Fe_2O_3} + \left(\frac{m}{BM} Cp.\Delta T \right)_{MgO} + \left(\frac{m}{BM} Cp.\Delta T \right)_{HCl}$$

Dengan cara trial diperoleh : T_{out} = 353,17 K = 80,17°C, maka :

- <u>$Ca(OH)_2$</u>

$$\Delta H = \frac{1{,}8098.10^{3}}{74} \text{mol } [21{,}4 \ (353{,}17 - 298)] \text{ cal/mol}$$

$$= 120{,}3226 \text{ kJ}$$

- H_2O

$$\Delta H = \frac{11{,}1249}{18}\text{kmol}.\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(353{,}17+298) - \frac{133{,}88.10^{-5}}{3}$$

$$\left(353{,}17^2 + 353{,}17.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(353{,}17^2 + 298^2\right)$$

$$(353{,}17+298)\Big](353{,}17-298)\ \text{kJ/kmol}$$

$$= 2572{,}4155\ \text{kJ}$$

- SiO_2

$$\Delta H = \frac{2{,}2024}{60}\text{mol}\Big[10{,}87(353{,}17-298) + \frac{0{,}00871}{2}\left(353{,}17^2 - 298^2\right) +$$

$$\left(\frac{241200}{353{,}17} - \frac{241200}{298}\right)\Big]\ \text{cal/mol}$$

$$= 0{,}135\ \text{kJ}$$

- Fe_2O_3

$$\Delta H = \frac{0{,}7661}{160}\text{mol}\Big[24{,}72(353{,}17-298) + \frac{0{,}01604}{2}\left(353{,}17^2 - 298^2\right) +$$

$$\left(\frac{-423400}{353{,}17} - \frac{-423400}{298}\right)\Big]\ \text{cal/mol}$$

$$= 0{,}0285\ \text{kJ}$$

- MgO

$$\Delta H = \frac{0{,}0479}{40}\text{mol}\Big[10{,}86(353{,}17-298) - \frac{0{,}0012}{2}\left(353{,}17^2 - 298^2\right) + \Big(\frac{208700}{353{,}17}$$

$$-\frac{208700}{298}\Big)\Big]\ \text{cal/mol}$$

$$= 0{,}0036\ \text{kJ}$$

- <u>HCl</u>

$$\Delta H = \frac{6{,}7844}{36{,}5}\,\text{kmol}\left[4{,}73.10^4(353{,}17-298)+45\left(353{,}17^2-298^2\right)\right]\text{J/kmol}$$

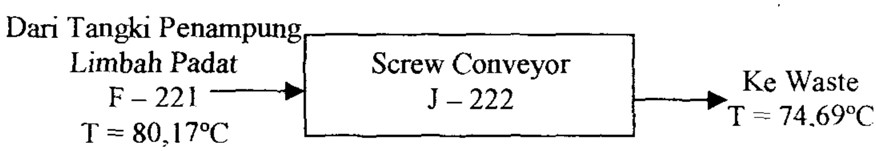
$$= 785{,}6035\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$= (120{,}3226 + 2572{,}4155 + 0{,}135 + 0{,}0285 + 0{,}0036 + 785{,}6035)\ \text{kJ}$$

$$= 2692{,}9053\ \text{kJ}$$

SCREW CONVEYOR J – 222



ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

Suhu masuk = 80,17°C = 353,17 K

- **Dari Centrifugal Separator H – 220**

$\Delta H_{Ca(OH)_2}$	= 120,3226 kJ
ΔH_{H_2O}	= 2572,4155 kJ
ΔH_{SiO_2}	= 0,135 kJ
$\Delta H_{Fe_2O_3}$	= 0,0285 kJ
ΔH_{MgO}	= 0,0036 kJ
ΔH_{HCl}	= 785,6035 kJ +
ΔH masuk	= 2692,9053 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

2692,9053 kJ = ΔH keluar + 10% (2692,9053 kJ)

ΔH keluar = 2423,6148 kJ

- **Ke Screw Conveyor J – 222**

  - $Ca(OH)_2$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{1{,}8098.10^3}{74} \text{mol} \left[21{,}4 \left(T_{out} - 298 \right) \right] \text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{11{,}1249}{18} \text{kmol.} \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298 \right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^2 + T_{out}.298 + 298^2 \right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^2 + 298^2 \right) \left(T_{out} + 298 \right) \right]$$

$$\left(T_{out} - 298 \right) \text{kJ/kmol}$$

  - SiO_2

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{2{,}2024}{60} \text{mol} \left[10{,}87 \left(T_{out} - 298 \right) + \frac{0{,}00871}{2} \left(T_{out}^2 - 298^2 \right) + \left(\frac{241200}{T_{out}} \right. \right.$$

$$\left. \left. - \frac{241200}{298} \right) \right] \text{cal/mol}$$

- Fe_2O_3

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0,7661}{160}mol\left[24,72(T_{out} - 298) + \frac{0,01604}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{-423400}{T_{out}} - \frac{-423400}{298}\right)\right] cal/mol$$

- MgO

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0,0479}{40}mol\left[10,86(T_{out} - 298) + \frac{0,0012}{2}\left(T_{out}^{\ 2} - 298^2\right) + \left(\frac{208700}{T_{out}} - \frac{208700}{298}\right)\right] cal/mol$$

- HCl

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3 + E.T^4\right)dT$$

$$\Delta H = \frac{6,7844}{36,5}kmol.\left[4,73.10^4.(T_{out} - 298) + 45.\left(T_{out}^{\ 2} - 298^2\right)\right] J/kmol$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$2423,6148\ kJ = \left(\frac{m}{BM}Cp.\Delta T\right)_{Ca(OH)_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O} + \left(\frac{m}{BM}Cp.\Delta T\right)_{SiO_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{Fe_2O_3} + \left(\frac{m}{BM}Cp.\Delta T\right)_{MgO} + \left(\frac{m}{BM}Cp.\Delta T\right)_{HCl}$$

Dengan cara trial diperoleh : T_{out} = 347,69 K = 74,69°C, maka :

- $\underline{Ca(OH)_2}$

$$\Delta H = \frac{1{,}8098.10^3}{74} \text{mol} \left[21{,}4\ (347{,}69 - 298)\right] \text{cal/mol}$$

$$= 108{,}3592 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{11{,}1249}{18} \text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(347{,}69 + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(347{,}69^2 + 347{,}69.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(347{,}69^2 + 298^2\right)$$

$$\left.(347{,}69 + 298)\right](347{,}69 - 298) \text{ kJ/kmol}$$

$$= 2315{,}1051 \text{ kJ}$$

- $\underline{SiO_2}$

$$\Delta H = \frac{2{,}2024}{60} \text{mol}\left[10{,}87(347{,}69 - 298) + \frac{0{,}00871}{2}\left(347{,}69^2 - 298^2\right) + \right.$$

$$\left.\left(\frac{241200}{347{,}69} - \frac{241200}{298}\right)\right] \text{cal/mol}$$

$$= 0{,}1217 \text{ kJ}$$

- $\underline{Fe_2O_3}$

$$\Delta H = \frac{0{,}7661}{160} \text{mol}\left[24.72(347{,}69 - 298) + \frac{0{,}01604}{2}\left(347.69^2 - 298^2\right) + \right.$$

$$\left.\left(\frac{-423400}{347{,}69} - \frac{-423400}{298}\right)\right] \text{cal/mol}$$

$$= 0{,}0256 \text{ kJ}$$

- MgO

$$\Delta H = \frac{0{,}0479}{40}\text{mol}\left[10{,}86(347{,}69-298)-\frac{0{,}0012}{2}(347{,}69^2-298^2)+\left(\frac{208700}{347{,}69}-\frac{208700}{298}\right)\right]\text{cal/mol}$$

$$= 0{,}0033 \text{ kJ}$$

- HCl

$$\Delta H = \frac{6{,}7844}{36{,}5}\text{kmol}\left[4{,}73.10^4(347{,}69-298)+45(347{,}69^2-298^2)\right]\text{J/kmol}$$

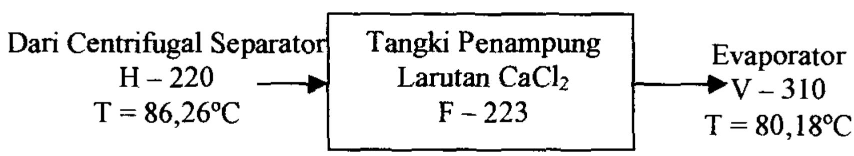
$$= 705{,}2123 \text{ kJ}$$

$$\Delta H_{keluar} = \Delta H_{Ca(OH)_2} + \Delta H_{H_2O} + \Delta H_{SiO_2} + \Delta H_{Fe_2O_3} + \Delta H_{MgO} + \Delta H_{HCl}$$

$$= (108{,}3592 + 2315{,}1051 + 0{,}1217 + 0{,}0256 + 0{,}0033 + 705{,}2123) \text{ kJ}$$

$$= 2423{,}6148 \text{ kJ}$$

TANGKI PENAMPUNG LARUTAN $CaCl_2$ F – 223



ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

Suhu masuk = 86,26°C = 359,26 K

- **Dari Centrifugal Separator H – 220**

ΔH_{CaCl_2}	= 2155,0543 kJ
ΔH_{H_2O}	= 75097,1957 kJ +
ΔH masuk	= 77252,25 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

77252,25 kJ = ΔH keluar + 10% (77252,25 kJ)

ΔH keluar = 69527,025 kJ

- **Ke Evaporator V – 310**

- $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right) dT$$

$$= \frac{51,5798.10^3}{111} \text{mol} \left[16,9\,(T_{out} - 298) + \frac{0,000386}{2}\left(T_{out}^{\ 2} - 298^2\right)\right] \text{cal/mol}$$

- H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3\right) dT$$

$$\Delta H = \frac{292,2856}{18} \text{kmol.}\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right)\right]$$

$$\left(T_{out} - 298\right) \text{kJ/kmol}$$

Dengan cara trial diperoleh : T_{out} = 353,18 K = 80,18°C, maka :

- $CaCl_2$

$$\Delta H = \frac{51,5798.10^3}{111} \text{mol} \left[16,9\,(353,18 - 298) + \frac{0,000386}{2}\left(353,18^2 - \right.\right.$$

$$\left.\left. - 298^2\right)\right] \text{cal/mol}$$

$$= 1939,7192 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{292{,}2856}{18}\text{kmol}.\Big[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(353{,}18+298) - \frac{133{,}88.10^{-5}}{3}$$

$$(353{,}18^2 + 353{,}18.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(353{,}18^2 + 298^2)$$

$$(353{,}18+298)\Big](353{,}18-298)\ \text{kJ/kmol}$$

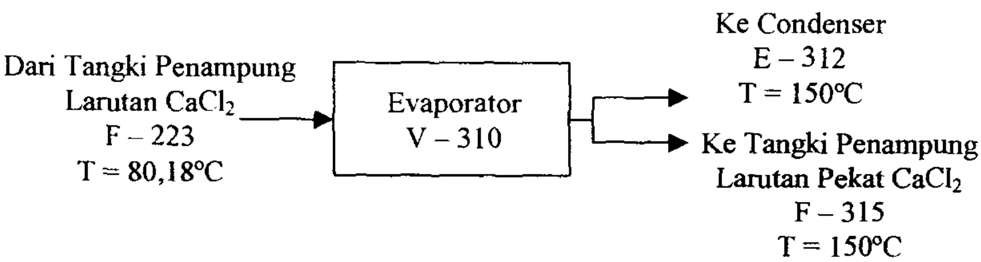
$$= 67587{,}3058\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (1939{,}7192 + 67587{,}3058)\ \text{kJ}$$

$$= 69527{,}025\ \text{kJ}$$

EVAPORATOR V – 310



ΔH masuk + Q_{suplai} = ΔH keluar + Q_{loss}

Entalpi masuk :

Suhu masuk = 80,18°C = 353,18 K

- **Dari Tangki Penampung Larutan $CaCl_2$ F – 223**

ΔH_{CaCl_2}	= 1939,7192 kJ
ΔH_{H_2O}	= 67587,3058 kJ
	+
ΔH masuk	= 69527,025 kJ

Entalpi keluar :

Asumsi : Suhu keluar = 423 K = 150°C

- **Ke Condenser E – 312**

Panas laten air menguap $= \frac{m}{BM} . \lambda$

$= \frac{274{,}7485.10^3}{18} \text{mol} . 40{,}65 \frac{kJ}{mol}$

$= 620{,}4737$ kJ

- $\underline{H_2O_{(g)}}$

$$\Delta H = \frac{m}{BM} . C_P . \Delta T$$

$$\Delta H = \frac{274{,}7485}{18} \text{kmol} \int_{25}^{150} \left(A + BT + CT^2 + DT^3\right) dT$$

$$\Delta H = \frac{274{,}7485}{18} \text{kmol} . \left[33{,}46 + \frac{0{,}688.10^{-2}}{2}(150 + 25) + \frac{0{,}7604.10^{-5}}{3}\right.$$

$$\left.\left(150^2 + 150.25 + 25^2\right) - \frac{3{,}593.10^{-9}}{4}\left(150^2 + 25^2\right)(150 + 25)\right]$$

$$(150 - 25) \text{ kJ/kmol}$$

$\Delta H = 65112{,}5017$ kJ

Total entalpi keluar ke Condenser E – 312

$= (620{,}4737 + 65112{,}5017)$ kJ

$= 65732{,}9754$ kJ

- **Ke Tangki Penampung Larutan Pekat $CaCl_2$ F – 315**

- $\underline{CaCl_2}$

$$\Delta H = \frac{m}{BM} . \int_{298}^{423} \left(A + B.T + \frac{C}{T^2}\right) dT$$

$$= \frac{51{,}5798.10^3}{111} \text{mol} \left[16{,}9 \,(423 - 298) + \frac{0{,}000386}{2}\left(423^2 - 298^2\right)\right] \text{cal/mol}$$

$= 4426{,}9604$ kJ

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} \int_{298}^{423} \left(A + B.T + C.T^2 + D.T^3\right) dT$$

$$\Delta H = \frac{17{,}5371}{18} \text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(423+298) - \frac{133{,}88.10^{-5}}{3}\left(423^2 + 423.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(423^2 + 298^2\right)(423+298)\right]$$

$$(423 - 298)\ \text{kJ/kmol}$$

$$= 9278{,}0545\ \text{kJ}$$

Total entalpi keluar ke Tangki Penampung Larutan Pekat $CaCl_2$ F – 315

= (4426,9604 + 9278,0545) kJ

= 13705,0149 kJ

Total entalpi keluar = entalpi keluar ke (E – 312 + F – 315)

= (65732,9754 + 13705,0149) kJ

= 79437,9903 kJ

ΔH masuk + Q_{suplai} = ΔH keluar + Q_{loss}

69527,025 kJ + Q_{suplai} = 79437,9903 kJ + 10% Q_{suplai}

$$Q_{suplai} = \frac{(79437{,}9903 - 69527{,}025)\ \text{kJ}}{0.9}$$

$$Q_{suplai} = 11012{,}1837\ \text{kJ}$$

TANGKI PENAMPUNG LARUTAN PEKAT $CaCl_2$ F – 315

Dari Evaporator
V – 310
T = 150°C

→ Tangki Penampung Larutan Pekat $CaCl_2$ F – 315 →

Ke Kristaliser
X – 320
T = 137,71°C

ΔH masuk $= \Delta H$ keluar + Q_{loss}

Entalpi masuk :

Suhu masuk = 150°C = 423 K

- **Dari Evaporator V – 310**

ΔH_{CaCl_2} = 4426,9604 kJ

ΔH_{H_2O} = 9278,0545 kJ

-- +

ΔH masuk = 13705,0149 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk $= \Delta H$ keluar + Q_{loss}

13705,0149 kJ $= \Delta H$ keluar + 10% (13705,0149 kJ)

ΔH keluar = 12334,5134 kJ

- **Ke Kristaliser X – 320**

  - $CaCl_2$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{51{,}5798.10^3}{111} \text{mol} \left[16{,}9 \left(T_{out} - 298 \right) + \frac{0{,}000386}{2} \left(T_{out}^{\ 2} - 298^2 \right) \right] \text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{17{,}5371}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right)\Bigg]$$

$$\left(T_{out} - 298\right)\text{ kJ / kmol}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$12334{,}5134 \text{ kJ} = \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 410,71 K = 137,71°C, maka :

- <u>$CaCl_2$</u>

$$\Delta H = \frac{51{,}5798.10^3}{111}\text{mol}\left[16{,}9\left(410{,}71 - 298\right) + \frac{0{,}000386}{2}\left(410{,}71^2 - \right.\right.$$

$$\left.\left.298^2\right)\right] \text{ cal / mol}$$

$$= 3986{,}4736 \text{ kJ}$$

- <u>H_2O</u>

$$\Delta H = \frac{17{,}5371}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(410{,}71 + 298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left(410{,}71^2 + 410{,}71.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(410{,}71^2 + 298^2\right)$$

$$\left.\left(410{,}71 + 298\right)\right]\left(410{,}71 - 298\right)\text{ kJ / kmol}$$

$$= 8348{,}0398 \text{ kJ}$$

Total entalpi keluar ke Kristaliser X – 320

= (3986,4736 + 8348,0398) kJ

= 12334,5134 kJ

KRISTALISER X – 320

Suhu operasi kristaliser = 50°C = 323 K

Cp $CaCl_2 . 2 H_2O$ = 0,983 kJ / kmol . K (Perry, 1999)

Dari Tangki Penampung Larutan Pekat $CaCl_2$ F – 315 T = 137,71°C → Kristaliser X – 320 → Ke Screw Conveyor J – 322 T = 50°C

ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Tangki Penampung Larutan Pekat $CaCl_2$ F – 315**

Suhu masuk = 137,71°C = 410,71 K

ΔH_{CaCl_2}	= 3986,4736 kJ
ΔH_{H_2O}	= 8348,0398 kJ
	+
ΔH masuk	= 12334,5134 kJ

Entalpi keluar :

Suhu keluar = 50°C = 323 K

- **Ke Screw Conveyor J – 322**

- $\underline{CaCl_2 . 2 H_2O}$

$$\Delta H = \frac{m}{BM} . Cp . dT$$

$$= \frac{68,2934}{147} \text{kmol} . 0,983 \text{ kJ / kmol.K.} (323 - 298) \text{K}$$

$$= 11,4171 \text{ kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{323} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0113}{111} mol \left[16{,}9\ (323 - 298) + \frac{0{,}000386}{2} (323^2 - 298^2) \right] cal/mol$$

$$= 0{,}1925\ kJ$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} \int_{298}^{323} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{0{,}8122}{18} kmol . \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} (323 + 298) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. (323^2 + 323.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4} (323^2 + 298^2)(323 + 298) \right]$$

$$(323 - 298)\ kJ/kmol$$

$$= 84{,}7768\ kJ$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O}$$

$$= (11{,}4171 + 0{,}1925 + 84{,}7768)\ kJ$$

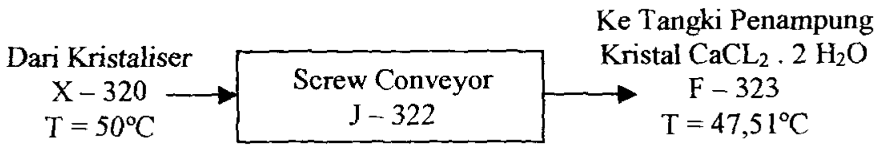
$$= 96{,}3864\ kJ$$

ΔH masuk $= \Delta H$ keluar $+ Q_{loss}$

12334,5134 kJ $= 96{,}3864$ kJ $+ Q_{loss}$

Q_{loss} $= 12238{,}1270$ kJ

SCREW CONVEYOR J – 322



ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

- **Dari Kristaliser X – 320**

  Suhu masuk = 50°C = 323 K

  $\Delta H_{CaCl_2.2H_2O}$ = 11,4171 kJ

  ΔH_{CaCl_2} = 84,7768 kJ

  ΔH_{H_2O} = 0,1925 kJ

  ———————————————— +

  ΔH masuk = 96,3864 kJ

<u>Entalpi keluar :</u>

<u>Asumsi</u> : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

96,3864 kJ = ΔH keluar + 10% (96,3864 kJ)

ΔH keluar = 86,7478 kJ

- **Ke Tangki Penampung Kristal $CaCl_2 . 2\ H_2O$ F – 323**

  - <u>$CaCl_2 . 2\ H_2O$</u>

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{68{,}2934}{147}\text{kmol}\ .0{,}983\ \text{kJ/kmol.K}.(T_{out} - 298)\text{K}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0113}{111} mol \left[16{,}9 \,(T_{out} - 298) + \frac{0{,}000386}{2} \left(T_{out}^{\ 2} - 298^2 \right) \right] cal/mol$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{0{,}8122}{18} kmol. \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} (T_{out} + 298) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2 \right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^{\ 2} + 298^2 \right) \left(T_{out} + 298 \right) \right]$$

$$(T_{out} - 298) \text{ kJ/kmol}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 321,51 K = 47,51°C, maka :

- $\underline{CaCl_2 \,.\, 2\, H_2O}$

$$\Delta H = \frac{68{,}2934}{147} kmol \,.\, 0{,}983 \text{ kJ/kmol.K} \,.(321{,}51 - 298)K$$

$$\Delta H = 10{,}2784 \text{ kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0{,}0113}{111} mol \left[16{,}9 \,(321{,}51 - 298) + \frac{0{,}000386}{2} \left(321{,}51^2 - 298^2 \right) \right] cal/mol$$

$$= 0{,}1733 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{0{,}8122}{18}\text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(321{,}51+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(321{,}51^2 + 321{,}51.298 + 298^2) + \frac{1314{,}2.10^{-9}}{4}(321{,}51^2 + 298^2)(321{,}51+298)\right]$$

$$(321{,}51 - 298)\ \text{kJ/kmol}$$

$$= 76{,}2961\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (10{,}2784 + 0{,}1733 + 76{,}2961)\ \text{kJ}$$

$$= 86{,}7478\ \text{kJ}$$

TANGKI PENAMPUNG KRISTAL $CaCl_2$. 2 H_2O F – 323

Dari Screw Conveyor J – 322 T = 47,51°C	→	Tangki Penampung Kristal $CaCl_2$.2 H_2O F – 323	→	Ke Screw Conveyor J – 324 T = 45,26°C

ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

Suhu masuk = 47,51°C = 320,51 K

- **Dari Screw Conveyor J – 322**

$\Delta H_{CaCl_2.2H_2O}$	= 10,2784 kJ
ΔH_{CaCl_2}	= 0,1733 kJ
ΔH_{H_2O}	= 76,2961 kJ
	+
ΔH masuk	= 86,7478 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

86,7478 kJ = ΔH keluar + 10% (86,7478 kJ)

ΔH keluar = 78,0730 kJ

- **Ke Screw Conveyor J – 324**

  - $CaCl_2 . 2 H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{68{,}2934}{147}\text{kmol} .0{,}983 \text{ kJ/kmol.K}.(T_{out} - 298)K$$

  - $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0{,}0113}{111}\text{mol}\left[16{,}9\,(T_{out} - 298) + \frac{0{,}000386}{2}\left(T_{out}{}^2 - 298^2\right)\right]\text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{0{,}8122}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out} + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}{}^2 + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}{}^2 + 298^2\right)\left(T_{out} + 298\right)\right]$$

$$(T_{out} - 298)\text{ kJ/kmol}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T\right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 318,26 K = 45,26°C, maka :

- $\underline{CaCl_2 . 2\ H_2O}$

$$\Delta H = \frac{68,2934}{147} \text{kmol } .0,983 \text{ kJ / kmol.K}.(318,26 - 298)\text{K}$$

$$\Delta H = 9,2531 \text{ kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0,0113}{111} \text{mol} \left[16,9\ (318,26 - 298) + \frac{0,000386}{2}\left(318,26^2 - 298^2\right)\right] \text{cal / mol}$$

$$= 0,156 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{0,8122}{18} \text{kmol}.\Bigg[18,2964 + \frac{47,212.10^{-2}}{2}(318,26 + 298) - \frac{133,88.10^{-5}}{3}$$

$$\left(318,26^2 + 318,26.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(318,26^2 + 298^2\right)(318,26 + 298)\Bigg]$$

$$(318,26 - 298) \text{ kJ / kmol}$$

$$= 68,6639 \text{ kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (9,2531 + 0,156 + 68,6639) \text{ kJ}$$

$$= 78,0730 \text{ kJ}$$

SCREW CONVEYOR J – 324

Dari Tangki Penampung Kristal $CaCl_2 . 2\ H_2O$ F – 323 T = 45,26°C	→	Screw Conveyor J – 324	→	Ke Tumbling Mill C – 330 T = 43,24°C

ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Tangki Penampung Kristal $CaCl_2.2\ H_2O$ F – 323**

  Suhu masuk = 45,26°C = 318,26 K

  $\Delta H_{CaCl_2.2H_2O}$ = 9,2531 kJ

  ΔH_{CaCl_2} = 0,1560 kJ

  ΔH_{H_2O} = 68,6639 kJ

  ——————————————— +

  ΔH masuk = 78,0730 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

78,0730 kJ = ΔH keluar + 10% (78,0730 kJ)

ΔH keluar = 70,2657 kJ

- **Ke Tumbling Mill C – 330**

  - $CaCl_2 . 2\ H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{68{,}2934}{147} kmol\ .0{,}983\ kJ/kmol.K.(T_{out} - 298)K$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{m}{BM} . \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0113}{111} mol \left[16{,}9 \left(T_{out} - 298\right) + \frac{0{,}000386}{2} \left(T_{out}^{\ 2} - 298^2\right) \right] cal/mol$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{0{,}8122}{18} kmol. \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298\right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right) \right]$$

$$\left(T_{out} - 298\right) kJ/kmol$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 316,24 K = 43,24°C, maka :

- $\underline{CaCl_2 . 2\ H_2O}$

$$\Delta H = \frac{68{,}2934}{147} kmol\ .0{,}983\ kJ/kmol.K.(316{,}24 - 298)K$$

$$\Delta H = 8{,}3298\ kJ$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0{,}0113}{111} mol \left[16{,}9 \left(316{,}24 - 298\right) + \frac{0{,}000386}{2} \left(316{,}24^2 - 298^2\right) \right] cal/mol$$

$$= 0{,}1404\ kJ$$

- $\underline{H_2O}$

$$\Delta H = \frac{0{,}8122}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(316{,}24+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(316{,}24^2+316{,}24.298+298^2)+\frac{1314{,}2.10^{-9}}{4}(316{,}24^2+298^2)(316{,}24+298)\right]$$

$$(316{,}24-298)\ \text{kJ / kmol}$$

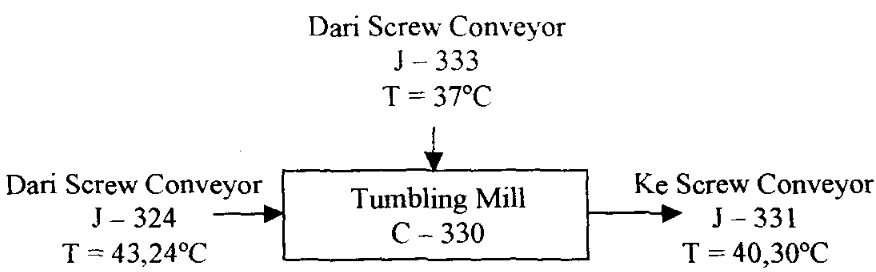
$$= 61{,}7955\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (8{,}3298 + 0{,}1404 + 61{,}7955)\ \text{kJ}$$

$$= 70{,}2657\ \text{kJ}$$

TUMBLING MILL C - 330



ΔH masuk $= \Delta H$ keluar + Q_{loss}

<u>Entalpi masuk :</u>

- **Dari Screw Conveyor J – 324**

  Suhu masuk = 43,24°C = 316,24 K

$\Delta H_{CaCl_2.2H_2O}$	= 8,3298 kJ
ΔH_{CaCl_2}	= 0,1404 kJ
ΔH_{H_2O}	= 61,7955 kJ
	+
ΔH dari J – 324	= 70,2657 kJ

- **Dari Screw Conveyor J – 333**

Asumsi : Q_{loss} pada Screw Conveyor J – 333 = ±10% sehingga suhu bahan masuk dari Screw Conveyor J – 333 = 37°C = 310 K, maka diperoleh :

- $CaCl_2 . 2\ H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{17{,}0733}{147} kmol .0{,}983\ kJ/kmol.K.(310 - 298)K$$

$$\Delta H = 1{,}3700\ kJ$$

- $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{310}\left(A + B.T + \frac{C}{T^2}\right) dT$$

$$= \frac{0{,}0028}{111} mol \left[16{,}9\ (310 - 298) + \frac{0{,}000386}{2}\left(310^2 - 298^2\right)\right] cal/mol$$

$$= 0{,}0231 kJ$$

- H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{310}\left(A + B.T + C.T^2 + D.T^3\right) dT$$

$$\Delta H = \frac{0.2031}{18} kmol.\left[18.2964 + \frac{47.212.10^{-2}}{2}(310 + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(310^2 + 310.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(310^2 + 298^2\right)(310 + 298)\right]$$

$$(310 - 298)\ kJ/kmol$$

$$\Delta H = 10{,}1548\ kJ$$

$$\Delta H_{\text{masuk dr J-333}} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T\right)_{H_2O}$$

$$= (1{,}37 + 0{,}0231 + 10{,}1548)\ kJ$$

$$= 11{,}5479\ kJ$$

Total entalpi masuk = entalpi masuk dari Screw Conveyor (J – 324 + J – 333)

= (70,2657 + 11,5479) kJ

= 81,8136 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

81,8136 kJ = ΔH keluar + 10% (81,8136 kJ)

ΔH keluar = 73,6323 kJ

- **Ke Screw Conveyor J – 331**

  - $CaCl_2 . 2\ H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{85{,}3667}{147} kmol\ .0{,}983\ kJ/kmol.K.(T_{out} - 298)K$$

  - $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right) dT$$

$$= \frac{0{,}0142}{111} mol \left[16{,}9\ (T_{out} - 298) + \frac{0{,}000386}{2}(T_{out}^{\ 2} - 298^2)\right] cal/mol$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{1{,}0153}{18}kmol.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(T_{out}+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^2 + T_{out}.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(T_{out}^2 + 298^2\right)\left(T_{out}+298\right)\right]$$

$$\left(T_{out} - 298\right) kJ/kmol$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 313,30 K = 40,30°C, maka :

- $\underline{CaCl_2 . 2 H_2O}$

$$\Delta H = \frac{85{,}3667}{147} kmol . 0{,}983\ kJ/kmol.K.(313{,}30 - 298)K$$

$$\Delta H = 8{,}7321\ kJ$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0{,}0142}{111} mol\left[16{,}9\ (313{,}30 - 298) + \frac{0{,}000386}{2}\left(313{,}30^2 - 298^2\right)\right] cal/mol$$

$$= 0{,}1471\ kJ$$

- H_2O

$$\Delta H = \frac{1{,}0153}{18}\,\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(313{,}30+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(313{,}30^2+313{,}30.298+298^2) + \frac{1314{,}2.10^{-9}}{4}(313{,}30^2+298^2)(313{,}30+298)\right]$$

$$(313{,}30-298)\ \text{kJ/kmol}$$

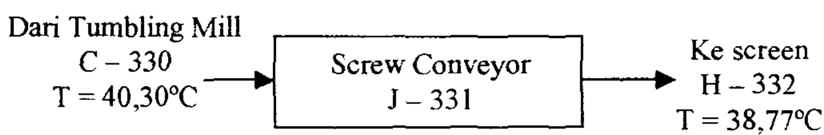
$$= 64{,}7531\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (8{,}7321 + 0{,}1471 + 64{,}7531)\ \text{kJ}$$

$$= 73{,}6323\ \text{kJ}$$

SCREW CONVEYOR J – 331



ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Tumbling Mill C – 330**

  Suhu masuk = 40,30°C = 313,30 K

  $\Delta H_{CaCl_2.2H_2O}$ = 8,7321 kJ

  ΔH_{CaCl_2} = 0,1471 kJ

  ΔH_{H_2O} = 64,7531 kJ

  ——————————————— +

  ΔH masuk = 73,6323 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk $= \Delta H$ keluar + Q_{loss}

73,6323 kJ $= \Delta H$ keluar + 10% (73,6323 kJ)

ΔH keluar $= 66,2691$ kJ

- **Ke Screw Conveyor J – 331**

- $CaCl_2 . 2\,H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{85,3667}{147} \text{kmol} .0,983 \text{ kJ/kmol.K}.(T_{out} - 298)K$$

- $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0,0142}{111} \text{mol} \left[16,9\,(T_{out} - 298) + \frac{0,000386}{2}\left(T_{out}^{\ 2} - 298^2\right) \right] \text{cal/mol}$$

- H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3\right) dT$$

$$\Delta H = \frac{1,0153}{18} \text{kmol.} \Big[18,2964 + \frac{47,212.10^{-2}}{2} (T_{out} + 298) - \frac{133,88.10^{-5}}{3}$$

$$\left(T_{out}^{\ 2} + T_{out}.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^{\ 2} + 298^2\right)\left(T_{out} + 298\right) \Big]$$

$$(T_{out} - 298) \text{ kJ/kmol}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 311,77 K = 38,77°C, maka :

- $\underline{CaCl_2 . 2\,H_2O}$

$$\Delta H = \frac{85{,}3667}{147}\,\text{kmol}\,.\,0{,}983\ \text{kJ/kmol.K}.(311{,}77 - 298)\,\text{K}$$

$$\Delta H = 7{,}8604\ \text{kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0{,}0142}{111}\,\text{mol}\left[16{,}9\,(311{,}77 - 298) + \frac{0{,}000386}{2}\left(311{,}77^2 - 298^2\right)\right]\text{cal/mol}$$

$$= 0{,}1324\ \text{kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{1{,}0153}{18}\,\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\,(311{,}77 + 298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(311{,}77^2 + 311{,}77.298 + 298^2\right) + \frac{1314{,}2.10^{-9}}{4}\left(311{,}77^2 + 298^2\right)(311{,}77 + 298)\right]$$

$$(311{,}77 - 298)\ \text{kJ/kmol}$$

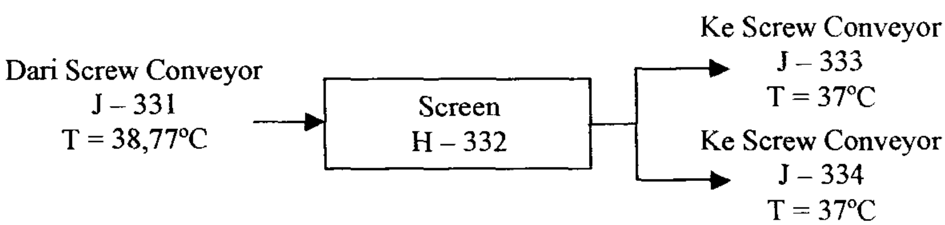
$$= 58{,}2763\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (7{,}8604 + 0{,}1324 + 58{,}2763)\ \text{kJ}$$

$$= 66{,}2691\ \text{kJ}$$

SCREEN H – 332



ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Screw Conveyor J – 331**

Suhu masuk = 38,77°C = 311,77 K

$\Delta H_{CaCl_2.2H_2O}$ = 7,8604 kJ

ΔH_{CaCl_2} = 0,1324 kJ

ΔH_{H_2O} = 58,2763 kJ

——————————————— +

ΔH masuk = 66,2691 kJ

Entalpi keluar :

- **Ke Screw Conveyor J – 333**

- $CaCl_2 . 2 H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{17{,}0733}{147}\text{kmol} .0{,}983\ \text{kJ/kmol.K}.(311-298)\text{K}$$

$$\Delta H = 1{,}37\ \text{kJ}$$

- $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{311}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0{,}0028}{111}\text{mol}\left[16{,}9\,(311-298) + \frac{0{,}000386}{2}\left(311^2 - 298^2\right)\right]\text{cal/mol}$$

$$= 0{,}0231\ \text{kJ}$$

- H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{311}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{0{,}2031}{18} kmol.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(311+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(311^2+311.298+298^2)+\frac{1314{,}2.10^{-9}}{4}(311^2+298^2)(311+298)\right]$$

$$(311-298)\ kJ/kmol$$

$$\Delta H = 10{,}1548\ kJ$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (1{,}37 + 0{,}0231 + 10{,}1548)\ kJ$$

$$= 11{,}5479\ kJ$$

- **Ke Screw Conveyor J – 333**

  - $CaCl_2 . 2\ H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{68{,}2934}{147} kmol\ .0{,}983\ kJ/kmol.K.(311-298)K$$

$$\Delta H = 5{,}4802\ kJ$$

  - $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{311}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0{,}0113}{111} mol\left[16{,}9\ (311-298)+\frac{0{,}000386}{2}(311^2-298^2)\right] cal/mol$$

$$= 0{,}0923\ kJ$$

  - H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{311}(A + B.T + C.T^2 + D.T^3)dT$$

$$\Delta H = \frac{0{,}8122}{18}\text{kmol.}\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(311+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(311^2+311.298+298^2)+\frac{1314{,}2.10^{-9}}{4}(311^2+298^2)(311+298)\right]$$

$$(311-298)\ \text{kJ/kmol}$$

$$\Delta H = 40{,}6191\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (5{,}4802 + 0{,}0923 + 40{,}6191)\ \text{kJ}$$

$$= 46{,}1915\ \text{kJ}$$

Total entalpi keluar = entalpi keluar ke Screw Conveyor (J – 333 + J – 334)

= (11,5479 + 46,1915) kJ

= 57,7394 kJ

Entalpi masuk = entalpi keluar + Q_{loss}

66,2691 kJ = 57,7394 kJ + Q_{loss}

Q_{loss} = 8,5297 kJ → 12,87 %

SCREW CONVEYOR J – 333

Dari Screen H – 332, T = 37°C → Screw Conveyor J – 333 → Ke Tumbling Mill C – 330, T = 35,80°C

ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Screen H – 332**

  Suhu masuk = 37°C = 311 K

$\Delta H_{CaCl_2.2H_2O}$ = 1,37 kJ

ΔH_{CaCl_2} = 0,0231 kJ

ΔH_{H_2O} = 10,1548 kJ

―――――――――――――――― +

ΔH masuk = 11,5479 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

11,5479 kJ = ΔH keluar + 10% (11,5479 kJ)

ΔH keluar = 10,3931 kJ

- **Ke Tumbling Mill C – 330**

  - $CaCl_2 . 2 H_2O$

$$\Delta H = \frac{m}{BM} . Cp . dT$$

$$\Delta H = \frac{17{,}0733}{147} \text{kmol} . 0{,}983 \text{ kJ/kmol.K} . (T_{out} - 298) K$$

  - $CaCl_2$

$$\Delta H = \frac{m}{BM} . \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0028}{111} \text{mol} \left[16.9 \, (T_{out} - 298) + \frac{0{,}000386}{2} \left(T_{out}^{\ 2} - 298^2 \right) \right] \text{cal/mol}$$

  - H_2O

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{0{,}2031}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(T_{out}+298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^{\ 2}+T_{out}.298+298^2\right)+\frac{1314{,}2.10^{-9}}{4}\left(T_{out}^{\ 2}+298^2\right)\left(T_{out}+298\right)\right]$$

$$\left(T_{out}-298\right)\text{ kJ / kmol}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM}Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM}Cp.\Delta T\right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 308,80 K = 35,80°C, maka :

- $\underline{CaCl_2 \,.\, 2\, H_2O}$

$$\Delta H = \frac{17{,}0733}{147}\text{kmol }.0{,}983\text{ kJ / kmol.K}.(308{,}80-298\ )\text{K}$$

$$\Delta H = 1{,}2332\text{ kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0{,}0028}{111}\text{mol}\left[16{,}9\ (308{,}80-298)+\frac{0{,}000386}{2}\left(308{,}80^2-298^2\right)\right]\text{ cal / mol}$$

$$= 0{,}0208\text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{0{,}2031}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}\left(308{,}80+298\right) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.\left(308{,}80^2+308{,}80.298+298^2\right)+\frac{1314{,}2.10^{-9}}{4}\left(308{,}80^2+298^2\right)\left(308{,}80+298\right)\right]$$

$$\left(308{,}80-298\right)\text{ kJ / kmol}$$

$$= 9{,}1391\text{ kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(1{,}2332 + 0{,}0208 + 9{,}1391\right)\text{ kJ}$$

$$= 10{,}3931\text{ kJ}$$

SCREW CONVEYOR J – 334

Dari Screen H – 332, T = 37°C	→	Screw Conveyor J – 334	→	Ke Tangki Penampung Produk F – 335, T = 35,80°C

ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Screen H – 332**

Suhu masuk = 37°C = 311 K

$\Delta H_{CaCl_2.2H_2O}$ = 5,4802 kJ

ΔH_{CaCl_2} = 0,0923 kJ

ΔH_{H_2O} = 40,6191 kJ
______________________________________ +

ΔH masuk = 46,1951 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

46,1951 kJ = ΔH keluar + 10% (46,1951 kJ)

ΔH keluar = 41,5724 kJ

- **Ke Tangki Penampung Produk F – 335**

  - $CaCl_2 . 2 H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{68{,}2934}{147} kmol .0{,}983\ kJ/kmol.K.(T_{out} - 298)K$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{m}{BM} \cdot \int_{298}^{T_{out}} \left(A + B.T + \frac{C}{T^2} \right) dT$$

$$= \frac{0{,}0113}{111} mol \left[16{,}9 \left(T_{out} - 298 \right) + \frac{0{,}000386}{2} \left(T_{out}^{\ 2} - 298^2 \right) \right] cal/mol$$

- $\underline{H_2O}$

$$\Delta H = \frac{m}{BM} \int_{298}^{T_{out}} \left(A + B.T + C.T^2 + D.T^3 \right) dT$$

$$\Delta H = \frac{0{,}8122}{18} kmol. \left[18{,}2964 + \frac{47{,}212.10^{-2}}{2} \left(T_{out} + 298 \right) - \frac{133{,}88.10^{-5}}{3} \right.$$

$$\left. \left(T_{out}^{\ 2} + T_{out}.298 + 298^2 \right) + \frac{1314{,}2.10^{-9}}{4} \left(T_{out}^{\ 2} + 298^2 \right) \left(T_{out} + 298 \right) \right]$$

$$\left(T_{out} - 298 \right) kJ/kmol$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T \right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T \right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 308,80 K = 35,80°C, maka :

- $\underline{CaCl_2 . 2\ H_2O}$

$$\Delta H = \frac{68{,}2934}{147} kmol \ .0{,}983\ kJ/kmol.K.\left(308{,}80 - 298 \right) K$$

$$\Delta H = 4{,}9329\ kJ$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0{,}0113}{111} mol \left[16{,}9 \left(308{,}80 - 298 \right) + \frac{0{,}000386}{2} \left(308{,}80^2 - 298^2 \right) \right] cal/mol$$

$$= 0{,}0831\ kJ$$

- $\underline{H_2O}$

$$\Delta H = \frac{0{,}8122}{18}\text{kmol}.\left[18{,}2964 + \frac{47{,}212.10^{-2}}{2}(308{,}80+298) - \frac{133{,}88.10^{-5}}{3}\right.$$

$$\left.(308{,}80^2+308{,}80.298+298^2)+\frac{1314{,}2.10^{-9}}{4}(308{,}80^2+298^2)(308{,}80+298)\right]$$

$$(308{,}80-298)\ \text{kJ/kmol}$$

$$= 36{,}5564\ \text{kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (4{,}9329 + 0{,}0831 + 36{,}5564)\ \text{kJ}$$

$$= 41{,}5724\ \text{kJ}$$

TANGKI PENAMPUNG PRODUK F – 335

Dari Screw Conveyor J – 334, T = 35,8°C → [Tangki Penampung Produk F – 335] → Ke Unit Pengepakan, T = 34.72°C

ΔH masuk = ΔH keluar + Q_{loss}

Entalpi masuk :

- **Dari Screw Conveyor J – 334**

Suhu masuk = 35,8°C = 308,8 K

$\Delta H_{CaCl_2.2H_2O}$	= 4,9329 kJ
ΔH_{CaCl_2}	= 0,0831 kJ
ΔH_{H_2O}	= 36,5564 kJ
	+
ΔH masuk	= 41,5724 kJ

Entalpi keluar :

Asumsi : Q_{loss} = 10% total entalpi masuk

ΔH masuk = ΔH keluar + Q_{loss}

41,5724 kJ = ΔH keluar + 10% (41,5724 kJ)

ΔH keluar = 37,4152 kJ

- **Ke Unit Pengepakan**

- $CaCl_2 . 2 H_2O$

$$\Delta H = \frac{m}{BM}.Cp.dT$$

$$\Delta H = \frac{68,2934}{147} kmol . 0,983\ kJ/kmol.K.(T_{out} - 298)K$$

- $CaCl_2$

$$\Delta H = \frac{m}{BM}.\int_{298}^{T_{out}}\left(A + B.T + \frac{C}{T^2}\right)dT$$

$$= \frac{0,0113}{111} mol \left[16,9\ (T_{out} - 298) + \frac{0,000386}{2}\left(T_{out}^2 - 298^2\right)\right] cal/mol$$

- H_2O

$$\Delta H = \frac{m}{BM}\int_{298}^{T_{out}}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{0,8122}{18} kmol.\left[18,2964 + \frac{47,212.10^{-2}}{2}(T_{out} + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.\left(T_{out}^2 + T_{out}.298 + 298^2\right) + \frac{1314,2.10^{-9}}{4}\left(T_{out}^2 + 298^2\right)(T_{out} + 298)\right]$$

$$(T_{out} - 298)\ kJ/kmol$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2.2H_2O} + \left(\frac{m}{BM} Cp.\Delta T\right)_{CaCl_2} + \left(\frac{m}{BM} Cp.\Delta T\right)_{H_2O}$$

Dengan cara trial diperoleh : T_{out} = 307,72 K = 34,72°C, maka :

- $\underline{CaCl_2 . 2\ H_2O}$

$$\Delta H = \frac{68,2934}{147} \text{kmol} .0,983 \text{ kJ / kmol.K}.(307,72 - 298)\text{K}$$

$$\Delta H = 4,4430 \text{ kJ}$$

- $\underline{CaCl_2}$

$$\Delta H = \frac{0,0113}{111} \text{mol} \left[16,9\ (307,72 - 298) + \frac{0,000386}{2}(307,72^2 - 298^2)\right] \text{cal / mol}$$

$$= 0,0748 \text{ kJ}$$

- $\underline{H_2O}$

$$\Delta H = \frac{0,8122}{18} \text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(307,72 + 298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(307,72^2 + 307,72.298 + 298^2) + \frac{1314,2.10^{-9}}{4}(307,72^2 + 298^2)(307,72 + 298)\right]$$

$$(307,72 - 298) \text{ kJ / kmol}$$

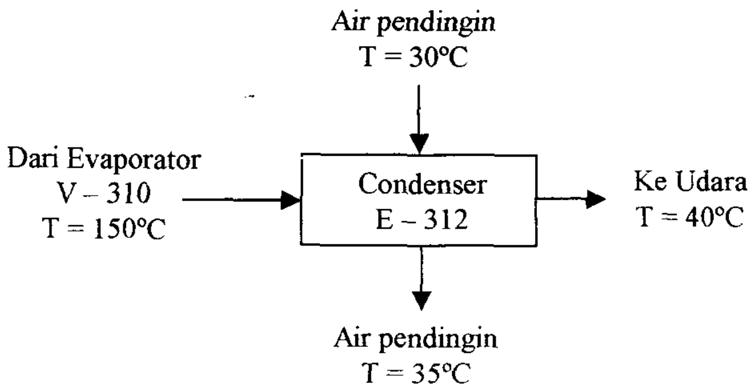
$$= 32,9002 \text{ kJ}$$

$$\Delta H_{keluar} = \Delta H_{CaCl_2.2H_2O} + \Delta H_{CaCl_2} + \Delta H_{H_2O}$$

$$= (4,4403 + 0,0748 + 32,9002)\text{ kJ}$$

$$= 37,4152 \text{ kJ}$$

CONDENSER E – 312



ΔH masuk = ΔH keluar + Q_{loss}

<u>Entalpi masuk :</u>

- **Dari Evaporator V – 310**

  Suhu masuk = 423 K = 150°C

  $\Delta H_{H_2O_{(g)}} = 65112{,}5017$ kJ

  Panas laten uap air mengembun $= \dfrac{m}{BM} . \lambda$

  $= \dfrac{274{,}7485 \text{ kg}}{18 \text{ kg/kmol}} . 6{,}009 \text{ kJ/kmol}$

  $= 91{,}7202$ kJ

Total entalpi masuk = 65112,5017 kJ + 91,7202 kJ = 65204,2219 kJ

<u>Entalpi keluar :</u>

- **Ke udara**

  - <u>$H_2O_{(l)}$</u>

    $$\Delta H = \frac{m}{BM} . C_p . \Delta T$$

$$\Delta H = \frac{m}{BM}\int_{298}^{313}\left(A + B.T + C.T^2 + D.T^3\right)dT$$

$$\Delta H = \frac{274,7485}{18}\text{kmol}.\left[18,2964 + \frac{47,212.10^{-2}}{2}(313+298) - \frac{133,88.10^{-5}}{3}\right.$$

$$\left.(313^2 + 313.298 + 298^2) + \frac{1314,2.10^{-9}}{4}(313^2+298^2)(313+298)\right]$$

$$(313-298)\ \text{kJ/kmol}$$

$$\Delta H = 17182,5392\ \text{kJ}$$

- **Air pendingin**

Suhu masuk = 303 K = 30°C

<u>Asumsi</u> : suhu keluar air pendingin = 35°C

Cp H_2O pada : T = 30°C = 303 K ➔ 4,181 kJ / kg . K

T = 35°C = 308 K ➔ 4,181 kJ / kg . K

(Geankoplis, 1993, pp.856, A.2-5)

Cp rata-rata = 4,181 kJ / kg . K

$$\Delta H = \frac{m}{BM}.Cp.\Delta T$$

$$(65204,2219 - 17182,5392)\ \text{kJ} = \frac{m}{18}.4,181\frac{\text{kJ}}{\text{kg.K}}.(308-303)\text{K}$$

m = 41348,4950 kg

APPENDIX C

PERHITUNGAN SPESIFIKASI PERALATAN

APPENDIX C

PERHITUNGAN SPESIFIKASI PERALATAN

Data massa jenis zat :

Zat	Sg	Massa Jenis (kg / lt)	Massa Jenis (lb / ft^3)
$CaCl_2$	2,152	2,152	134,3829
$Ca(OH)_2$	2,2	2,2	137,3803
HCl	1,46	1,46	91,1706
CO_2	1,53	1,53	95,5418
Fe_2O_3	5,12	5,12	319,7215
MgO	3,65	3,65	227,9264
SiO_2	2,32	2,32	144,8738
$CaCl_2.2H_2O$	1,87	1,87	116,7733

(Perry, 1999)

ρ H_2O pada 30°C = 0,99568 kg / lt = 62,1758 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

1. Tangki Penampung Waste $Ca(OH)_2$ F – 110

Fungsi : menampung waste $Ca(OH)_2$ sebelum dimasukkan ke Reaktor R – 210

Tipe : Tangki silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan slurry seperti waste $Ca(OH)_2$

Jumlah : 1 buah

Perhitungan :

Suhu = 30°C

Jumlah = 1 buah

Waste :

Massa H_2O dalam waste = 200,1812 kg

Massa waste = 239,3939 kg

Fraksi H_2O $= \dfrac{\text{massa } H_2O}{\text{massa waste}} = \dfrac{200{,}1812 \text{ kg}}{239{,}3939 \text{ kg}} = 0{,}8362$

Volume H_2O $= \dfrac{\text{massa } H_2O}{\rho_{H_2O}} = \dfrac{200{,}1812 \text{ kg}}{0{,}99568 \text{ kg/lt}} = 201{,}0497 \text{ lt}$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
H_2O	200,1812	0,8362	201,0497
$Ca(OH)_2$	36,1964	0,1512	16,4529
SiO_2	2,2024	0,0092	0,9493
Fe_2O_3	0,7661	0,0032	0,1496
MgO	0,0479	0,0002	0,0131
	239,3939	1	218,6147

Sehingga :

$$\rho_{waste} = \frac{1}{\left(\dfrac{X_{H_2O}}{\rho_{H_2O}} + \dfrac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}} + \dfrac{X_{SiO_2}}{\rho_{SiO_2}} + \dfrac{X_{Fe_2O_3}}{\rho_{Fe_2O_3}} + \dfrac{X_{MgO}}{\rho_{MgO}}\right) \text{lt/kg}}$$

$$\rho_{waste} = \frac{1}{\left(\dfrac{0{,}8362}{0{,}99568} + \dfrac{0{,}1512}{2{,}2} + \dfrac{0{,}0092}{2{,}32} + \dfrac{0{,}0032}{5{,}12} + \dfrac{0{,}0002}{3{,}65}\right) \text{lt/kg}}$$

$\rho_{waste} = 1{,}0950 \text{ kg/lt}$

ρ_{waste} = 1,0950 kg / lt = 68,3810 lb / ft^3

Tangki dirancang untuk menyimpan waste $Ca(OH)_2$ selama 1 hari.

Volume waste $Ca(OH)_2$ total = 218,6147 lt / jam . 24 jam

= 5246,7528 lt = 185,2667 ft^3

Asumsi : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 185{,}2667 \text{ ft}^3$$

$$= 231{,}5834 \text{ ft}^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4} . D^2 . H$

$$231{,}5834 \text{ ft}^3 = \frac{\pi}{4} . D^2 . D$$

$$D^3 = 294{,}7425 \text{ ft}^3$$

$$D = 6{,}6550 \text{ ft} \approx 6{,}7 \text{ ft} = 2{,}0422 \text{ m}$$

$$H = 6{,}7 \text{ ft} = 2{,}0422 \text{ m}$$

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$185{,}2667\ ft^3 = \frac{\pi}{4}.D^2.H_l$$

$$185{,}2667\ ft^3 = \frac{\pi}{4}.(6{,}7\ ft)^2.H_l$$

$$H_l = 5{,}2527\ ft$$

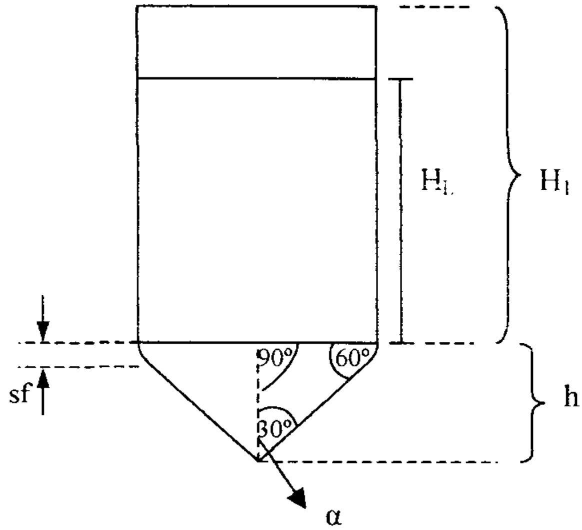
$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{68{,}3810\ lb/ft^3.(5{,}2527\ ft).(12.6{,}7)in}{2.18750\ lb/in^2.0{,}80.(144\ in^2/ft^2)} + \frac{1}{8}\ in$$

$t_S = 0{,}1317$ in → diambil $t_S\ \frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in



Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)

Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60°.0{,}5.D + sf$$

$$h = \tan 60° \,.\, 0{,}5 \,.\, 6{,}7 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 5{,}9747 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(6{,}7 \text{ ft})^2.5{,}9747 \text{ ft}$$

$$= 70{,}2439 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$185{,}2667 \text{ ft}^3 - 70{,}2439 \text{ ft}^3 = \frac{1}{4}.\pi.(6{,}7 \text{ ft})^2.H_L$$

$$H_L = 3{,}2611 \text{ ft}$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 3{,}2611 \text{ ft} + 5{,}9747 \text{ ft}$$

$$H = 9{,}2358 \text{ ft} \approx 9{,}3 \text{ ft}$$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{68{,}3810\ lb/ft^3 .9{,}2358\ ft}{144} = 4{,}3858\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk $\alpha \leq 30°$ dapat dipakai rumus

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{4{,}3858\ lb/in^2 .6{,}7\ ft}{2.\cos 30°.(18750\ lb/in^2 .0{,}80 - 0{,}6.4{,}3858\ lb/in^2)} + \frac{1}{8}$$

$t_k = 0{,}1261$ in → diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 6,7 ft + 5,9747 ft + 0,1875 ft + 3 ft

= 15,8622 ft

Perancangan Pengaduk

$$\frac{H_{liquid}}{D_{tangki}} = \frac{9{,}2358\ ft}{6{,}7\ ft} = 1{,}3785$$

μ H_2O pada 30°C = 0,8007 cp (Geankoplis, 1993, pp.855, A.2-4)

μ $Ca(OH)_2$ = 15,32 cp

μ SiO_2 = 26,54 cp

μ Fe_2O_3 = 41,2 cp

μ MgO = 32,65 cp

(Perry, 1999)

$$\mu_{campuran}{}^{1/3} = X_{H_2O} \cdot (\mu_{H_2O})^{1/3} + X_{Ca(OH)_2} \cdot (\mu_{Ca(OH)_2})^{1/3} + X_{SiO_2} \cdot (\mu_{SiO_2})^{1/3} +$$
$$X_{Fe_2O_3} \cdot (\mu_{Fe_2O_3})^{1/3} + X_{MgO} \cdot (\mu_{MgO})^{1/3}$$ (Perry,1999)

$$\mu_{campuran}{}^{1/3} = 0{,}8362.(0{,}8007\ cp)^{1/3} + 0{,}1512.(15{,}32\ cp)^{1/3} + 0{,}0092.(26{,}54\ cp)^{1/3}$$
$$+ 0{,}0032.(41{,}2\ cp)^{1/3} + 0{,}0002.(32{,}65\ cp)^{1/3}$$

$\mu_{campuran}$ = 1,69 cp

$$\left.\begin{array}{l} \mu_{campuran} = 1{,}69\,cp \\ \dfrac{H_{liquid}}{D_{tangki}} = 1{,}3785 \end{array}\right\}$$ Walas, 1990, pp.288 diperoleh :

Jumlah impeller = 2

Letak impeller 1 = $D_t/3$

Letak impeller 2 = (2/3) H

Letak impeller 1 = $\dfrac{D_t}{3} = \dfrac{6{,}7\ ft}{3} = 2{,}2333\ ft$

Letak impeller 2 = $\dfrac{2}{3}\ H = \dfrac{2}{3} 9{,}2358\ ft = 6{,}1572\ ft$

Ukuran impeller

$\dfrac{d}{D_t} = 0{,}3 - 0{,}6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0,5$, sehingga : $d = 0,5 \ . \ 6,7 \ ft$

$d = 3,35 \ ft$

Ukuran baffle

$W = \frac{D_t}{12}$ Dimana : W : lebar baffle

$Offset = \frac{d}{2}$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{6,7 \ ft}{12} = 0,5583 \ ft$

$Offset = \frac{3,35 \, ft}{2} = 1,675 \ ft$

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 3,35 \ ft = 1,0211 \ m$

$N = 110 \ rpm = 1,8333 \ rps$

$$N_{Re} = \frac{D_a^{\ 2}.N.\rho}{\mu} = \frac{(1,0211 \, m)^2 .1,8333 \ rps.1095,05 \ kg/m^3}{1,69.10^{-3} \ kg/m.s} = 1238547,8466$$

(Walas, 1990, pp. 290)

Untuk flat six-blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P \,.\, \rho \,.\, N^3 \,.\, D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5 \,.\, 1095{,}05\ kg/m^3 \,.\, 1{,}8333\ rps \,.\, 1{,}0211\ m$

$P = 34450{,}3114\ Watt = 46{,}18\ hp$

Efisiensi motor = 85% (Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{46{,}18\ hp}{0{,}85} = 54{,}3295\ hp \approx 54{,}5\ hp$$

2. Tangki Penampung Larutan HCl 32% F – 120

Fungsi : menampung larutan HCl 32% sebelum dimasukkan ke Reaktor R – 210

Tipe : Tangki silinder dengan tutup bagian bawah dan atas berbentuk datar (flat bottomed dan flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan liquid seperti larutan HCl

Jumlah : 1 buah

Perhitungan :

Suhu = 30°C

Jumlah = 1 buah

Larutan HCl :

Massa H_2O dalam larutan = 86,5007 kg

Massa HCl dalam larutan = 40,7062 kg

Massa larutan = 127,2070 kg

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{86{,}5007 \text{ kg}}{0{,}99568 \text{ kg/lt}} = 86{,}8761 \text{ lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Volume (lt)
H_2O	86,5007	86,8761
HCl	40,7062	27,8810
	127,2070	114,7570

Sehingga :

$$\rho_{larutan} = \frac{1}{\left(\dfrac{X_{H_2O}}{\rho_{H_2O}} + \dfrac{X_{HCl}}{\rho_{HCl}}\right) \text{lt/kg}}$$

$$\rho_{larutan} = \frac{1}{\left(\dfrac{0{,}68}{0{,}99568} + \dfrac{0{,}32}{1{,}46}\right) \text{lt/kg}}$$

$$\rho_{larutan} = 1{,}1085 \text{ kg/lt}$$

$$\rho_{larutan\ HCl} = 1{,}1085 \text{ kg / lt} = 69{,}2203 \text{ lb / ft}^3$$

Tangki dirancang untuk menyimpan larutan HCl selama 1 hari.

Volume larutan HCl total = 114,7570 lt / jam . 24 jam

= 2754,1689 lt = 97,2517 ft^3

<u>Asumsi</u> : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 97{,}2517 \text{ ft}^3$$

$$= 121{,}5647 \text{ ft}^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4} . D^2 . H$

$121,5647 \text{ ft}^3 = \frac{\pi}{4} . D^2 . D$

$D^3 = 154,7187 \text{ ft}^3$

$D = 5,3684 \text{ ft} \approx 5,4 \text{ ft} = 1,6459 \text{ m}$

$H = 5,4 \text{ ft} = 1,6459 \text{ m}$

Bahan konstruksi : Stainless Steel SA-240 grade A type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$97,2517 \text{ ft}^3 = \frac{\pi}{4} . D^2 . H_l$

$97,2517 \text{ ft}^3 = \frac{\pi}{4} . (5,4 \text{ ft})^2 . H_l$

$H_l = 4,2447 \text{ ft}$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{69{,}2203\,lb/ft^3 \,.\, (4{,}2447\ ft).\,(12\,.5{,}4)\ in}{2.18750\,lb/in^2\,.0{,}80.(144\ in^2/ft^2)} + \frac{1}{8}\ in$$

$t_S = 0{,}1294$ in → diambil $t_S\ \frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

Tutup bawah berbentuk datar

Tebal tutup flat-bottomed = tebal shell = $\frac{3}{16}$ in

H total = tebal head + tinggi silinder + tebal tutup bawah + jarak pemasangan pipa

= 0,1875 ft + 5,4 ft + 0,1875 ft + 3 ft

= 8,7750 ft

3. Reaktor R – 210

Fungsi : mereaksikan waste $Ca(OH)_2$ dari Tangki Penampung Waste F – 110 dengan larutan HCl dari Tangki Penampung Larutan HCl F – 120

Tipe : Tangki silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan slurry

Jumlah : 1 buah

Perhitungan :

Reaktor bekerja secara batch pada suhu 99,6°C dan tekanan 1 atm

Waste :

Dengan komposisi sebagai berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
H_2O	200,1812	0,8362	201,0497
$Ca(OH)_2$	36,1964	0,1512	16,4529
SiO_2	2,2024	0,0092	0,9493
Fe_2O_3	0,7661	0,0032	0,1496
MgO	0,0479	0,0002	0,0131
	239,3939	1	218,6147

ρ_{waste} = 1,0950 kg / lt = 68,3810 lb / ft^3

Larutan HCl :

Dengan komposisi sebagai berikut :

Zat	Massa (kg)	Volume (lt)
H_2O	86,5007	86,8761
HCl	40,7062	27,8810
	127,2070	114,7570

$\rho_{larutan\ HCl}$ = 1,1085 kg / lt = 69,2203 lb / ft^3

Sehingga :

$$\text{Fraksi waste} = \frac{\text{massa waste}}{\text{massa bahan masuk}} = \frac{239{,}3939\ \text{kg}}{239{,}3939\ \text{kg} + 127{,}207\ \text{kg}} 100\% = 65{,}30\%$$

$$\text{Fraksi HCl} = \frac{\text{massa larutan HCl}}{\text{massa bahan masuk}} = \frac{127{,}2070\ \text{kg}}{239{,}3939\ \text{kg} + 127{,}2070\ \text{kg}} 100\% = 34{,}70\%$$

$$\rho_{campuran} = \frac{1}{\dfrac{\text{fraksi waste}}{\text{densitas waste}} + \dfrac{\text{fraksi HCl}}{\text{densitas HCl}}}$$

$$\rho_{campuran} = \frac{1}{\dfrac{0{,}653}{1{,}0950\ kg/lt} + \dfrac{0{,}347}{1{,}1085\ kg/lt}} = 10{,}9968\ kg/lt$$

Asumsi : Ruang kosong = 20 % volume tangki

Volume total bahan masuk = volume waste + volume larutan HCl

= 218,6147 lt + 114,7570 lt

= 333,3717 lt = 11,7716 ft^3

Volume tangki $= \dfrac{100\%}{80\%} 11{,}7716\ ft^3$

$= 14{,}7145\ ft^3$

$\dfrac{H}{D} = 1$, sehingga : Volume tangki $= \dfrac{\pi}{4}.D^2.H$

$14{,}7145\ ft^3 = \dfrac{\pi}{4}.D^2.D$

$D^3 = 18{,}7275\ ft^3$

$D = 2{,}6556\ ft \approx 2{,}7\ ft = 0{,}8230\ m$

$H = 2{,}7\ ft = 0{,}8230\ m$

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$11{,}7716\ ft^3 = \frac{\pi}{4} . D^2 . H_l$$

$$11{,}7716\ ft^3 = \frac{\pi}{4} . (2{,}7\ ft)^2 . H_l$$

$$H_l = 2{,}0551\ ft$$

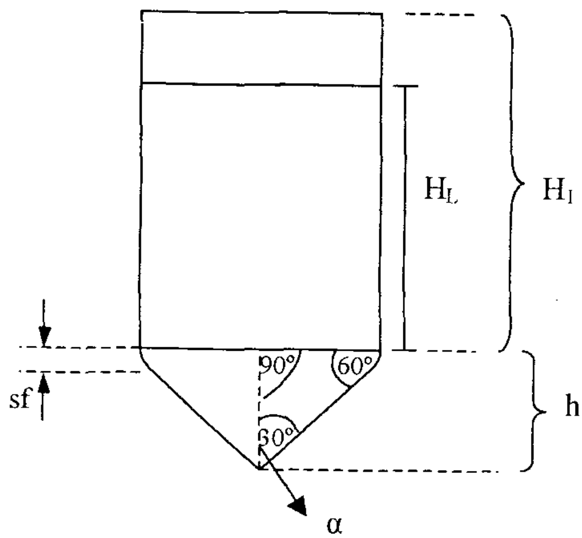
$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{10{,}9968\ lb/ft^3 . (2{,}0551\ ft).(12.2{,}7)\ in}{2.18750\ lb/in^2 . 0{,}80.(144\ in^2/ft^2)} + \frac{1}{8} in$$

$t_S = 0{,}1252$ in → diambil $t_S\ \frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in



Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)

Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60°.0{,}5.D + sf$$

$$h = \tan 60° \,.\, 0{,}5 \,.\, 2{,}7 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 2{,}5072 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(2{,}7 \text{ ft})^2.2{,}5072 \text{ ft}$$

$$= 4{,}7870 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$11{,}7716\ ft^3 - 4{,}7870\ ft^3 = \frac{1}{4}.\pi.(2{,}7\ ft)^2.H_L$$

$$H_L = 1{,}2194\ ft$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 1{,}2194\ ft + 2{,}5072\ ft$$

$$H = 3{,}7266\ ft \approx 3{,}8\ ft$$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{686{,}6993\ lb/ft^3.3{,}8\ ft}{144} = 17{,}7713\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{17{,}7713\ lb/in^2.2{,}7\ ft}{2.\cos 30°.(18750\ lb/in^2.0{,}80 - 0{,}6.17{,}7713\ lb/in^2)} + \frac{1}{8}$$

$t_k = 0{,}1268$ in → diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 2,7 ft + 2,5072 ft + 0,1875 ft + 3 ft

= 8,3947 ft

Perancangan Pengaduk

$$\frac{H_{liquid}}{D_{tangki}} = \frac{3,7266 \text{ ft}}{2,7 \text{ ft}} = 1,3802$$

μ H_2O pada 30°C = 0,8007 cp (Geankoplis, 1993, pp.855, A.2-4)

μ $Ca(OH)_2$ = 15,32 cp

μ SiO_2 = 26,54 cp

μ Fe_2O_3 = 41,2 cp

μ MgO = 32,65 cp

(Perry, 1999)

$$\mu_{waste}{}^{1/3} = X_{H_2O} \cdot (\mu_{H_2O})^{1/3} + X_{Ca(OH)_2} \cdot (\mu_{Ca(OH)_2})^{1/3} + X_{SiO_2} \cdot (\mu_{SiO_2})^{1/3} + X_{Fe_2O_3} \cdot (\mu_{Fe_2O_3})^{1/3} + X_{MgO} \cdot (\mu_{MgO})^{1/3}$$ (Perry,1999)

$$\mu_{waste}{}^{1/3} = 0,8362.(0,8007 \text{ cp})^{1/3} + 0,1512.(15,32 \text{ cp})^{1/3} + 0,0092.(26,54 \text{ cp})^{1/3} + 0,0032.(41,2 \text{ cp})^{1/3} + 0,0002.(32,65 \text{ cp})^{1/3}$$

$$\mu_{waste} = 1,69 \text{ cp}$$

μ HCl = 1,8 cp (Geankoplis, 1993, pp.876)

$$\mu_{lar.HCl}{}^{1/3} = X_{H_2O} \cdot (\mu_{H_2O})^{1/3} + X_{HCl} \cdot (\mu_{HCl})^{1/3}$$ (Perry,1999)

$$\mu_{lar.HCl}{}^{1/3} = 0,68.(0,8007 \text{ cp})^{1/3} + 0,32.(1,8 \text{ cp})^{1/3}$$

$$\mu_{lar.HCl} = 1,0634 \text{ cp}$$

$$\mu_{campuran}{}^{1/3} = X_{waste} \cdot (\mu_{waste})^{1/3} + X_{lar.HCl} \cdot (\mu_{lar.HCl})^{1/3} \qquad \text{(Perry,1999)}$$

$$\mu_{campuran}{}^{1/3} = 0{,}653.(1{,}69\ cp)^{1/3} + 0{,}347.(1{,}0634\ cp)^{1/3}$$

$$\mu_{campuran} = 1{,}4506\ cp$$

$$\left.\begin{aligned} \mu_{campuran} &= 1{,}4506\,cp \\ \frac{H_{liquid}}{D_{tangki}} &= 1{,}3802 \end{aligned}\right\} \text{Walas, 1990, pp.288 diperoleh :}$$

Jumlah impeller = 2

Letak impeller 1 = D_t /3

Letak impeller 2 = (2/3) H

$$\text{Letak impeller 1} = \frac{D_t}{3} = \frac{2{,}7\ ft}{3} = 0{,}9\ ft$$

$$\text{Letak impeller 2} = \frac{2}{3}\ H = \frac{2}{3}\ 3{,}7266\ ft = 2{,}4844\ ft$$

<u>Ukuran impeller</u>

$\frac{d}{D_t} = 0{,}3 - 0{,}6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\frac{d}{D_t} = 0{,}5$, sehingga : d = 0,5 . 2,7 ft

d = 1,35 ft

Ukuran baffle

$$W = \frac{D_t}{12}$$ Dimana : W : lebar baffle

$$Offset = \frac{d}{2}$$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $W = \frac{2,7\ ft}{12} = 0,225\ ft$

$$Offset = \frac{1,35\ ft}{2} = 0,675\ ft$$

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 1,35\ ft = 0,4115\ m$

N = 110 rpm = 1,8333 rps

$$N_{Re} = \frac{D_a^{\ 2}.N.\rho}{\mu} = \frac{(0,4115\,m)^2\,.1,8333\ rps.10996,76\ kg/m^3}{1,4506.10^{-3}\ kg/m.s} = 2353276,1618$$

(Walas, 1990, pp. 290)

Untuk flat six-blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P = N_P\ .\ \rho\ .\ N^3\ .\ D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P = 5\ .\ 10996,76\ kg/m^3\ .\ 1,8333\ rps\ .\ 0,4115\ m$

P = 139416,1545 Watt = 186,8849 hp

Efisiensi motor = 85% (Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{186{,}8849\ \text{hp}}{0{,}85} = 219{,}8646\ \text{hp} \approx 220\ \text{hp}$$

4. Tangki Penampung Hasil Reaksi F – 211

Fungsi : menampung hasil reaksi dari Reaktor R – 210 sebelum dimasukkan ke Centrifugal Separator H – 220

Tipe : Tangki silinder dengan tutup bagian bawah berbentuk konis dan atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan berfase slurry

Jumlah : 1 buah

Perhitungan :

Suhu = 99,69°C

Jumlah = 1 buah

ρ H_2O pada 99,69°C = 0,963 kg / lt (Geankoplis, 1993, pp. 855, A.2-3)

Massa H_2O dalam hasil reaksi = 303,4106 kg

Massa hasil reaksi = 366,6009 kg

$$\text{Fraksi } H_2O \text{ dalam hasil reaksi} = \frac{\text{massa } H_2O}{\text{massa hasil reaksi}} = \frac{303{,}4106\ \text{kg}}{366{,}6009\ \text{kg}} = 0{,}8276$$

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{303{,}4106\ \text{kg}}{0{,}963\ \text{kg/lt}} = 315{,}0681\ \text{lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$Ca(OH)_2$	1,8098	0,0049	0,8226
$CaCl_2$	51,5798	0,1407	23,9683
H_2O	303,4106	0,8276	315,0681
SiO_2	2,2024	0,0060	0,9493
Fe_2O_3	0,7661	0,0021	0,1496
MgO	0,0479	0,0001	0,0131
HCl	6,7844	0,0185	4,6468
	366,6009	1	345,6179

Volume total bahan masuk = 345,6179 lt = 12,2040 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}} + \frac{X_{SiO_2}}{\rho_{SiO_2}} + \frac{X_{Fe_2O_3}}{\rho_{Fe_2O_3}} + \frac{X_{MgO}}{\rho_{MgO}} + \frac{X_{HCl}}{\rho_{HCl}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,0049}{2,2} + \frac{0,1407}{2,152} + \frac{0,8276}{0,963} + \frac{0,006}{2,32} + \frac{0,0021}{5,12} + \frac{0,0001}{3,65} + \frac{0,0185}{1,46}\right) lt/kg}$$

$$\rho_{campuran} = 1,0607 \ kg/lt$$

$$\rho_{campuran} = 1,0607 \ kg / lt = 66,2368 \ lb / ft^3$$

Asumsi : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 12,2040 \ ft^3$$

$$= 15,2550 \ ft^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4} . D^2 . H$

$15{,}2550 \ ft^3 = \frac{\pi}{4} . D^2 . D$

$D^3 = 19{,}4155 \ ft^3$

$D = 2{,}6877 \ ft \approx 2{,}7 \ ft = 0{,}8230 \ m$

$H = 2{,}7 \ ft = 0{,}8230 \ m$

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$12{,}2040 \ ft^3 = \frac{\pi}{4} . D^2 . H_l$

$12{,}2040 \ ft^3 = \frac{\pi}{4} . (2{,}7 \ ft)^2 . H_l$

$H_l = 2{,}1306 \ ft$

$t_S = \frac{\rho . (H_l) . (12 . D)}{2 . f . E . (144)} + C$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{66{,}2368\,lb/ft^3\,.\,(2{,}1306\ ft).\,(12\,.2{,}7)\ in}{2.18750\,lb/in^2\,.0{,}80.(144\ in^2/ft^2)} + \frac{1}{8}\,in$$

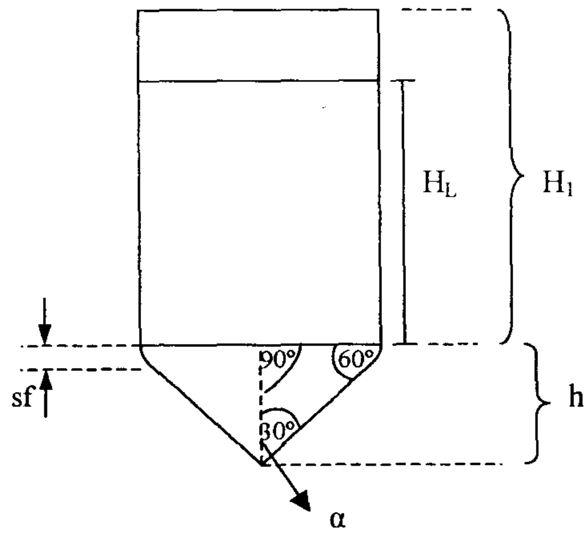
t_S = 0,1261 in → diambil t_S $\frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)



Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60°.0{,}5.D + sf$$

$$h = \tan 60°\,.\,0{,}5\,.\,2{,}7\ ft + (2/12)\ ft$$

$$h = 2{,}5072\ ft$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(2{,}7\ \text{ft})^2.2{,}5072\ \text{ft}$$

$$= 4{,}7870\ \text{ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$12{,}2040\ \text{ft}^3 - 4{,}7870\ \text{ft}^3 = \frac{1}{4}.\pi.(2{,}7\ \text{ft})^2.H_L$$

$$H_L = 1{,}2949\ \text{ft}$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 1{,}2949\ \text{ft} + 2{,}5072\ \text{ft}$$

$$H = 3{,}8021\ \text{ft} \approx 3{,}9\ \text{ft}$$

Mencari tebal konis (t_K)

$$P_{\text{hidrostatik}} = \frac{\rho.H}{144} = \frac{66{,}2368\ \text{lb/ft}^3.3{,}8021\ \text{ft}}{144} = 1{,}7489\ \text{lb/in}^2$$

Sudut konis = 60° → $\alpha = 30°$

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{1{,}7489\ lb/in^2 . 2{,}7\ ft}{2.\cos 30°.\left(18750\ lb/in^2 .0{,}80 - 0{,}6.1{,}7489\ lb/in^2\right)} + \frac{1}{8}$$

$t_k = 0{,}1252$ in $\rightarrow$ diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 2,7 ft + 2,5072 ft + 0,1875 ft + 3 ft

= 8,3947 ft

5. Centrifugal Separator H – 220

Fungsi : untuk memisahkan larutan $CaCl_2$ dari hasil reaksi lainnya

Tipe : Centrifuge sedimentation

Jumlah : 1 buah

Dasar pemilihan : dapat digunakan untuk memisahkan fase solid dan liquid, design sederhana, dapat digunakan untuk kapasitas besar, serta dapat digunakan untuk liquid yang viskos

Perhitungan :

ρ H_2O pada 92,28°C = 0,9651 kg / lt = 60,2662 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam bahan masuk = 303,4106 kg

Massa bahan masuk = 366,6009 kg

Fraksi H_2O dalam hasil reaksi = $\frac{\text{massa } H_2O}{\text{massa hasil reaksi}} = \frac{303{,}4106\ kg}{366{,}6009\ kg} = 0{,}8276$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$Ca(OH)_2$	1,8098	0,0049
$CaCl_2$	51,5798	0,1407
H_2O	303,4106	0,8276
SiO_2	2,2024	0,0060
Fe_2O_3	0,7661	0,0021
MgO	0,0479	0,0001
HCl	6,7844	0,0185
	366,6009	1

$$\rho_{\text{bahan masuk}} = \frac{1}{\frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}} + \frac{X_{SiO_2}}{\rho_{SiO_2}} + \frac{X_{Fe_2O_3}}{\rho_{Fe_2O_3}} + \frac{X_{MgO}}{\rho_{MgO}} + \frac{X_{HCl}}{\rho_{HCl}}}$$ (Perry, 1

$$\rho_{\text{bahan masuk}} = \frac{1}{\frac{0,0049}{2,2} + \frac{0,1407}{2,152} + \frac{0,8276}{0,9651} + \frac{0,006}{2,32} + \frac{0,0021}{5,12} + \frac{0,0001}{3,65} + \frac{00185}{1,46}} \text{kg/lt}$$

$$\rho_{\text{bahan masuk}} = 1,0628 \text{ kg/lt} = 66,3684 \text{ lb/ft}^3 = 1062,8198 \text{ kg/m}^3$$

Kapasitas $= 366,6009$ kg / jam

$$= \frac{366,6009 \text{ kg/jam}}{1062,8198 \text{ kg/m}^3} \cdot \frac{1 \text{ jam}}{3600 \text{ s}}$$

$$= 9,5815.10^{-5} \text{ m}^3/\text{s}$$

Power $= 1000$. kapasitas (Ulrich, 1984, pp. 220, table 4-23)

$$= 1000 . 9,5815.10^{-5} \text{ m}^3/\text{dt}$$

$$= 0,0958 \text{ kW} = 0,1285 \text{ hp} \approx 0,5 \text{ hp}$$

Bahan konstruksi : carbon steel

6. Tangki Penampung Limbah Padat F – 221

Fungsi : menampung limbah padat dari Centrifugal Separator H – 220 sebelum dibuang

Tipe : Tangki silinder dengan tutup bagian bawah berbentuk konis dan atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan slurry

Jumlah : 1 buah

Perhitungan :

Suhu = 86,26°C

Jumlah = 1 buah

ρ H_2O pada 86,26°C = 0,9679 kg / lt (Geankoplis, 1993, pp. 855, A.2-3)

Massa H_2O dalam limbah padat = 11,1249 kg

Massa hasil reaksi = 22,7355 kg

$$\text{Fraksi } H_2O \text{ dalam hasil reaksi} = \frac{\text{massa } H_2O}{\text{massa hasil reaksi}} = \frac{11{,}1249 \text{ kg}}{22{,}7355 \text{ kg}} = 0{,}4893$$

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{11{,}1249 \text{ kg}}{0{,}9679 \text{ kg/lt}} = 11{,}4939 \text{ lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$Ca(OH)_2$	1,8098	0,0796	0,8226
H_2O	11,1249	0,4893	11,4939
SiO_2	2,2024	0,0969	0,9493
Fe_2O_3	0,7661	0,0337	0,1496
MgO	0,0479	0,0021	0,0131
HCl	6,7844	0,2984	4,6468
	22,7355	1	18,0754

Volume total bahan masuk = 18,0754 lt = 0,6383 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}} + \frac{X_{H_2O}}{\rho_{H_2O}} + \frac{X_{SiO_2}}{\rho_{SiO_2}} + \frac{X_{Fe_2O_3}}{\rho_{Fe_2O_3}} + \frac{X_{MgO}}{\rho_{MgO}} + \frac{X_{HCl}}{\rho_{HCl}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,0796}{2,2} + \frac{0,4893}{0,963} + \frac{0,0969}{2,32} + \frac{0,0337}{5,12} + \frac{0,0021}{3,65} + \frac{0,2984}{1,46}\right) lt/kg}$$

$$\rho_{campuran} = 1,2578 \text{ kg/lt}$$

$\rho_{campuran}$ = 1,2578 kg / lt = 78,5449 lb / ft^3

Asumsi : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 0.6383 \text{ ft}^3$$

$$= 0,7978 \text{ ft}^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4} . D^2 . H$

$$0{,}7978 \text{ ft}^3 = \frac{\pi}{4} . D^2 . D$$

$$D^3 = 1{,}0154 \text{ ft}^3$$

$$D = 1{,}0051 \text{ ft} \approx 1{,}1 \text{ ft} = 0{,}3353 \text{ m}$$

$$H = 1{,}1 \text{ ft} = 0{,}3353 \text{ m}$$

<u>Bahan konstruksi</u> : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

<u>Penentuan tebal shell (t_S)</u> :

Tinggi liquida (H_l),

$$0{,}6383 \text{ ft}^3 = \frac{\pi}{4} . D^2 . H_l$$

$$0{,}6383 \text{ ft}^3 = \frac{\pi}{4} . (1{,}1 \text{ ft})^2 . H_l$$

$$H_l = 0{,}6713 \text{ ft}$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{78{,}5449\,lb/ft^3 \,.\, (0{,}6713\ ft).\,(12\,.1{,}1)\ in}{2.18750\,lb/in^2 .0{,}80.(144\ in^2/ft^2)} + \frac{1}{8}\ in$$

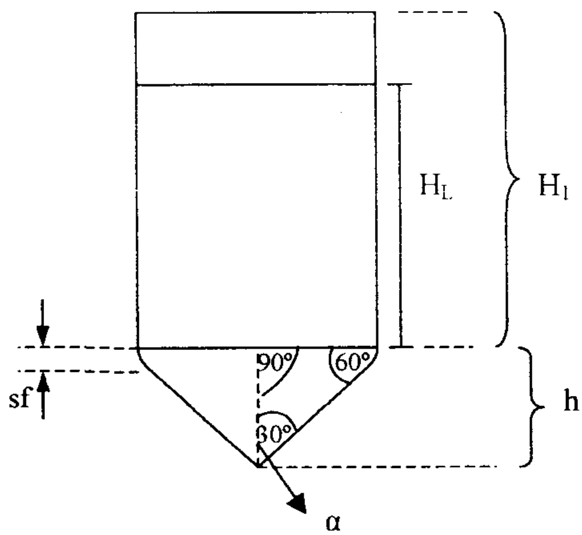
$t_S = 0{,}1252$ in $\rightarrow$ diambil $t_S\ \frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)



Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$\tan 60° = \frac{h - sf}{0{,}5.D}$ $\rightarrow$ $h = \tan 60°.0{,}5.D + sf$

$h = \tan 60°\ .\ 0{,}5\ .\ 1{,}1\ ft + (2/12)\ ft$

$h = 1{,}1202$ ft

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(1{,}1\,ft)^2.1{,}1202\ ft$$

$$= 0{,}3550\ ft^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$0{,}6383\ ft^3 - 0{,}3550\ ft^3 = \frac{1}{4}.\pi.(1{,}1\ ft)^2.H_L$$

$$H_L = 0{,}2979\ ft$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 0{,}2979\ ft + 1{,}1202\ ft$$

$$H = 1{,}4182\ ft \approx 1{,}5\ ft$$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{78{,}5449\ lb/ft^3.1{,}4182\ ft}{144} = 0{,}7735\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{0{,}7735\ lb/in^2 . 1{,}1\ ft}{2.\cos 30°.\left(18750\ lb/in^2 . 0{,}80 - 0{,}6 . 0{,}7735\ lb/in^2\right)} + \frac{1}{8}$$

$t_k = 0{,}1250$ in $\rightarrow$ diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 1,1 ft + 1,1202 ft + 0,1875 ft + 3 ft

= 5,4077 ft

7. Screw Conveyor J – 222

Fungsi : mengangkut limbah padat dari Tangki Penampung Limbah Padat F – 221 ke tempat pembuangan limbah

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

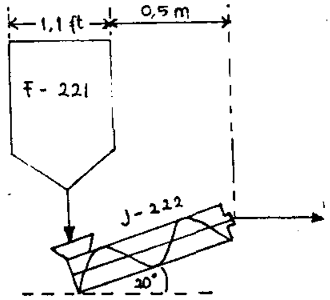
Perhitungan :

Kapasitas = 22,7355 kg / jam

Jarak F – 221 ke pembuangan = ½ Diameter F – 221 + 0,5 m

= ½ . 1,1 ft + 0,5 m

= 2,1904 ft



Asumsi : sudut Screw Conveyor J – 222 = 20°C

Panjang Screw Conveyor J – 134 = $\dfrac{2,1904 \text{ ft}}{\cos 20^o} = 2,3311$ ft

Suhu = 80,17°C

ρ H_2O pada 80,17°C = 0,97183 kg / lt (Geankoplis, 1993, pp. 855, A.2-3)

Massa H_2O dalam limbah padat = 11,1249 kg

Massa hasil reaksi = 22,7355 kg

Fraksi H_2O dalam hasil reaksi = $\dfrac{\text{massa } H_2O}{\text{massa hasil reaksi}} = \dfrac{11,1249 \text{ kg}}{22,7355 \text{ kg}} = 0,4893$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$Ca(OH)_2$	1,8098	0,0796
H_2O	11,1249	0,4893
SiO_2	2,2024	0,0969
Fe_2O_3	0,7661	0,0337
MgO	0,0479	0,0021
HCl	6,7844	0,2984
	22,7355	1

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{Ca(OH)_2}}{\rho_{Ca(OH)_2}} + \frac{X_{H_2O}}{\rho_{H_2O}} + \frac{X_{SiO_2}}{\rho_{SiO_2}} + \frac{X_{Fe_2O_3}}{\rho_{Fe_2O_3}} + \frac{X_{MgO}}{\rho_{MgO}} + \frac{X_{HCl}}{\rho_{HCl}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0{,}0796}{2{,}2} + \frac{0{,}4893}{0{,}97183} + \frac{0{,}0969}{2{,}32} + \frac{0{,}0337}{5{,}12} + \frac{0{,}0021}{3{,}65} + \frac{0{,}2984}{1{,}46}\right) lt/kg}$$

$$\rho_{campuran} = 1{,}2611 \ kg/lt$$

$$\rho_{campuran} = 1{,}2611 \ kg/lt = 78{,}7474 \ lb/ft^3$$

$$\text{Massa yang dipindahkan} = 22{,}7355 \frac{kg}{jam} . 2{,}205 \frac{lb}{kg} . \frac{1 \ jam}{60 \ menit} = 0{,}8355 \ lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{22{,}7355 \ kg/jam}{1{,}2611 \ kg/lt} = 18{,}0289 \ lt/jam = 0{,}6366 \ ft^3/jam$$

Maka kapasitas Screw Conveyor J – 134 = 0,6366 ft^3 / jam

Diameter Screw Conveyor = 3 in (untuk abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

<u>Power</u> :

$hp = \frac{Co . Ca . L}{33000}$, dimana : Co : koefisien (Co = 1,3)

Ca : kapasitas Screw Conveyor (= 0,8355 lb / menit)

L : panjang Screw Conveyor (= 2,3311 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\ .0{,}8355\ lb/menit.2{,}3311\ ft}{33000} = 7{,}6727.10^{-5}\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{7{,}6727.10^{-5}\ hp}{0{,}8} = 9{,}5909.10^{-5}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = $9{,}5909.10^{-5}$ hp × 2 = $1{,}9182.10^{-4}$ hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

8. Tangki Penampung Larutan $CaCl_2$ F – 223

Fungsi : menampung larutan $CaCl_2$ dari Centrifugal Separator H – 220 sebelum dimasukkan ke Evaporator V – 310

Tipe : Tangki silinder dengan tutup bagian bawah berbentuk konis dan atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan liquid

Jumlah : 1 buah

Perhitungan :

Suhu = 86,26°C

Jumlah = 1 buah

ρ H_2O pada 86,26°C = 0,9679 kg / lt (Geankoplis, 1993, pp. 855, A.2-3)

Massa H_2O dalam larutan $CaCl_2$ = 292,2856 kg

Massa larutan $CaCl_2$ = 343,8655 kg

Fraksi H_2O dalam larutan $CaCl_2$ = $\dfrac{\text{massa } H_2O}{\text{massa larutan } CaCl_2} = \dfrac{292{,}2856 \text{ kg}}{343{,}8655 \text{ kg}} = 0{,}85$

Volume H_2O $= \dfrac{\text{massa } H_2O}{\rho_{H_2O}} = \dfrac{292{,}2856 \text{ kg}}{0{,}9679 \text{ kg/lt}} = 301{,}9792 \text{ lt}$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
H_2O	292,2856	0,85	301,9792
$CaCl_2$	51,5798	0,15	23,9683
	343,8655	1	325,9475

Volume total bahan masuk = 325,9475 lt = 11,5094 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\dfrac{X_{CaCl_2}}{\rho_{CaCl_2}} + \dfrac{X_{H_2O}}{\rho_{H_2O}}\right) \text{lt/kg}}$$

$$\rho_{campuran} = \frac{1}{\left(\dfrac{0{,}15}{2{,}152} + \dfrac{0{,}85}{0{,}9679}\right) \text{lt/kg}}$$

$$\rho_{campuran} = 1{,}0550 \text{ kg/lt}$$

$$\rho_{campuran} = 1{,}0550 \text{ kg / lt} = 65{,}8784 \text{ lb / ft}^3$$

<u>Asumsi</u> : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 11{,}5094 \text{ ft}^3$$

$$= 14{,}3868 \text{ ft}^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4} . D^2 . H$

$$14{,}3868\ ft^3 = \frac{\pi}{4} . D^2 . D$$

$$D^3 = 18{,}3105\ ft^3$$

$$D = 2{,}6357\ ft \approx 2{,}7\ ft = 0{,}823\ m$$

$$H = 2{,}7\ ft = 0{,}823\ m$$

Bahan konstruksi : Stainless Steel SA-240 grade A type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$11{,}5094\ ft^3 = \frac{\pi}{4} . D^2 . H_l$$

$$11{,}5094\ ft^3 = \frac{\pi}{4} . (2{,}7\ ft)^2 . H_l$$

$$H_l = 2{,}0094\ ft$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{65{,}8784\ lb/ft^3 . (2{,}0094\ ft).(12 .2{,}7)\ in}{2.18750\ lb/in^2 .0{,}80.(144\ in^2/ft^2)} + \frac{1}{8} in$$

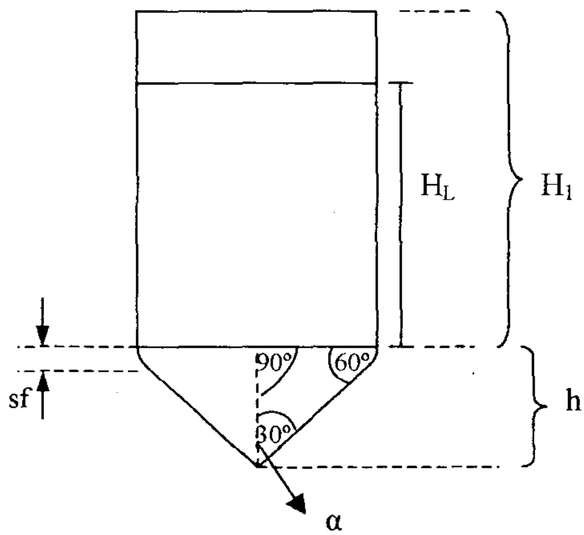
$t_S = 0{,}1260$ in → diambil t_S $\frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)



Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60°.0{,}5.D + sf$$

$$h = \tan 60° \;.\; 0{,}5 \;.\; 2{,}7 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 2{,}5072 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(2{,}7 \text{ ft})^2.2{,}5072 \text{ ft}$$

$$= 4{,}7870 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$11{,}5094\ ft^3 - 4{,}7870\ ft^3 = \frac{1}{4}.\pi.(2{,}7\ ft)^2.H_L$$

$$H_L = 1{,}1736\ ft$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 1{,}1736\ ft + 2{,}5072\ ft$$

$$H = 3{,}6809\ ft \approx 3{,}7\ ft$$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{65{,}8784\ lb/ft^3.3{,}6809\ ft}{144} = 1{,}6839\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C \quad \text{(Brownell \& Young, 1959, pp. 118, eq. 6.154)}$$

$$t_k = \frac{1{,}6839\ lb/in^2.2{,}7\ ft}{2.\cos 30°.(18750\ lb/in^2.0{,}80 - 0{,}6.1{,}6839\ lb/in^2)} + \frac{1}{8}$$

$$t_k = 0{,}1252\ in \quad \rightarrow \text{diambil } t_k = \frac{3}{16}\ in$$

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 2,7 ft + 2,5072 ft + 0,1875 ft + 3 ft

= 8,3947 ft

9. Evaporator V – 310

Fungsi : untuk memekatkan larutan $CaCl_2$

Tipe : single effect vertical forced circulation evaporator

Dasar pemilihan : dapat beroperasi secara kontinyu, forced circulation supaya koefisien perpindahan panas besar, digunakan single effect karena kapasitas kecil

Jumlah : 1 buah

Kondisi operasi :

T larutan (fluida dingin) : t_1 = 80,18°C = 176,32°F

t_2 = 150°C = 302°F

T steam (fluida panas) : T = 180°C = 356°F

T operasi = 150°C = 302°F

Asumsi : steam yang digunakan adalah saturated steam 180°C

Dari App. B didapat : Kebutuhan panas = 11012,1837 kJ / jam

= 10437,4952 Btu / jam

H_L = 763,22 kJ / kg

H_V = 2778,2 kJ / kg

(Geankoplis, 1993, pp. 858, A.2-9)

$\lambda = H_V - H_L$

λ = 2778,2 kJ / kg – 763,22 kJ / kg

λ = 2014,98 kJ / kg

$$\text{Kebutuhan steam} = \frac{\text{kebutuhan panas}}{\lambda}$$

$$= \frac{11012{,}1837 \text{ kJ / jam}}{2014{,}98 \text{ kJ / kg}}$$

$$= 5{,}4652 \text{ kg / jam} = 12{,}0507 \text{ lb / jam}$$

Untuk perancangan dipakai faktor keamanan 80% (untuk mengatasi kebocoran dan kehilangan panas), maka jumlah steam yang harus disediakan :

$$= \frac{100\%}{80\%} \text{ jumlah steam yang dibutuhkan}$$

$$= \frac{100\%}{80\%} \, 12{,}0507 \text{ lb / jam}$$

$$= 15{,}0633 \text{ lb / jam}$$

Dari App. A didapat : massa uap air = 274,7485 kg / jam = 605,8204 lb / jam

<u>Perhitungan</u> :

$\Delta T = 356°F - 302°F = 54°F$

T_d larutan = 150°C = 302°F → U_D = 30 Btu / ft^2 . jam . °F

(Badger, 1995, pp. 209, fig. 5-26)

$$A = \frac{Q}{U_D . \Delta T} = \frac{10437{,}4952 \text{ Btu / jam}}{30 \text{ Btu / ft}^2 . \text{jam} . °F . 54°F} = 6{,}4429 \text{ ft}^2$$

Untuk jenis evaporator vertical forced circulation, tube ditentukan :

OD < 2 in (Kern, 1965, pp.406)

L = 48 in = 4 ft (Badger, 1995, pp. 208)

Ditentukan ukuran tube pipa diameter nominal :

1½ in sch. 40

OD = 1,9 in

ID = 1,61 in

a" = 0,106 ft^2 / ft

(Kern, 1965, pp.843, table 10)

$$N_t = \frac{A}{a''.L} = \frac{6{,}4429\ ft^2}{0{,}106\ ft^2/ft.4\ ft} = 15{,}1955 \approx 16$$

<u>Menghitung ρ liquid (ρ_L)</u>

ρ H_2O pada 150°C = 0,94356 kg / lt = 58,9212 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam larutan $CaCl_2$ = 292,2856 kg

Massa larutan $CaCl_2$ = 343,8655 kg

Fraksi H_2O dalam larutan $CaCl_2$ = $\dfrac{\text{massa}\ H_2O}{\text{massa larutan}\ CaCl_2} = \dfrac{292{,}2856\ kg}{343{,}8655\ kg} = 0{,}85$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
H_2O	292,2856	0,85
$CaCl_2$	51,5798	0,15
	343,8655	1

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,15}{2,152} + \frac{0,85}{0,94356}\right) lt/kg}$$

$$\rho_{campuran} = 1,0303\ kg/lt$$

$\rho_{campuran} = 1,0303\ kg / lt = 64,3407\ lb / ft^3 = 1030,3476\ kg / m^3$

$\rho_V = 0,4891\ kg / m^3$

T steam = 356°F → P = 145,564 psia, V = 3,115 ft^3 / lb

(Geankoplis, 1993, pp. 858, A.2-9)

Laju volumetrik uap = massa uap air. V

= 605,8204 lb/ jam.3,115 ft^3 / lb

= 1887,1307 ft^3 / jam = 0,0148 m^3 / dt

$$\text{Kec. uap max.} = V_V = 0,035.\left(\frac{\rho_L}{\rho_V}\right)^{0,5} = 0,035.\left(\frac{1030,3476\,kg/m^3}{0,4891\,kg/m^3}\right)^{0,5} = 1,6064\ m/dt$$

$$A_S = \frac{Q}{V_V} = \frac{0,0148\ m^3/dt}{1,6064\ m/dt} = 0,0092\ m^2$$

$$A_S = \frac{\pi}{4} D_S^{\ 2}$$

$$D_S = \sqrt{\frac{A_S}{\pi/4}} = \sqrt{\frac{0,0092\ m^2}{\pi/4}} = 0,1084\ m = 0,3558\ ft$$

Menentukan tinggi evaporator

Tinggi badan silinder = 1,5 – 2 dari panjang tube (Hugot, pp. 500)

Diambil $H_S = 2 . L = 2 . 4$ ft = 8 ft

Menghitung tebal shell

Asumsi : $t_S = ¼$ in

ID = 5,9481 ft = 71,3772 in

OD = ID + 2 . t_S = 71,3772 in + 2 . ¼ in = 71,7882 in

$$\frac{H_S}{OD} = \frac{8.12 \text{ in}}{71{,}7882 \text{ in}} = 1{,}3356$$

$$\frac{OD}{t_S} = \frac{71{,}8772 \text{ in}}{0{,}25 \text{ in}} = 287{,}5088$$

Dari fig. 8.7 dan 8.8 Brownell & Young diperoleh : A = 0,00014

B = 3900 psi

$$P_{allowable} = \frac{4.B}{3\left(\frac{OD}{t_S}\right)} = \frac{4.3900}{3.287{,}5088} = 18{,}0864 \text{ psi} > 14{,}7 \text{ psi (memenuhi)}$$

$$t_S' = t_S + C = ¼ + \frac{1}{8} = \frac{3}{8} \text{ in}$$

Digunakan tebal plate = $\frac{3}{8}$ in

Bahan konstruksi : carbon steel

10. Tangki Penampung Larutan Pekat $CaCl_2$ F – 315

Fungsi : menampung larutan $CaCl_2$ pekat dari Evaporator V – 310 sebelum dimasukkan ke Kristaliser X – 320

Tipe : Tangki silinder dengan tutup bagian bawah berbentuk konis dan atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan liquid pekat

Jumlah : 1 buah

Perhitungan :

Suhu = 150°C

Jumlah = 1 buah

ρ H_2O pada 150°C = 0,94356 kg / lt (Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam larutan $CaCl_2$ = 17,5371 kg

Massa larutan $CaCl_2$ = 69,1170 kg

$$\text{Fraksi } H_2O \text{ dalam larutan } CaCl_2 = \frac{\text{massa } H_2O}{\text{massa larutan } CaCl_2} = \frac{17{,}5371 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}2537$$

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{17{,}5371 \text{ kg}}{0{,}94356 \text{ kg/lt}} = 18{,}5861 \text{ lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$CaCl_2$	51,5798	0,7463	23,9683
H_2O	17,5371	0,2537	18,5861
	69,1170	1	42,5545

Volume total bahan masuk = 42,5545 lt = 1,5206 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,7463}{2,152} + \frac{0,2537}{0,94356}\right) lt/kg}$$

$$\rho_{campuran} = 1,6242\ kg/lt$$

$\rho_{campuran}$ = 1,6242 kg / lt = 101,4242 lb / ft^3

<u>Asumsi</u> : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 1,5206\ ft^3$$

$$= 1,8783\ ft^3$$

$\frac{H}{D}$ = 1, sehingga : Volume tangki $= \frac{\pi}{4}.D^2.H$

$$1,8783\ ft^3 = \frac{\pi}{4}.D^2.D$$

$$D^3 = 2,3905\ ft^3$$

$$D = 1,3371\ ft \approx 1,4\ ft = 0,4267\ m$$

$$H = 1,4\ ft = 0,4267\ m$$

<u>Bahan konstruksi</u> : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$1,5026\ ft^3 = \frac{\pi}{4} . D^2 . H_l$

$1,5026\ ft^3 = \frac{\pi}{4} . (1,4\ ft)^2 . H_l$

$H_l = 0,9757\ ft$

$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$ (Brownell & Young, 1959, pers 3.18)

$t_S = \frac{13,2682\ lb/ft^3 . (0,9757\ ft).(12 . 1,4)\ in}{2.18750\ lb/in^2 . 0,80.(144\ in^2/ft^2)} + \frac{1}{8}\ in$

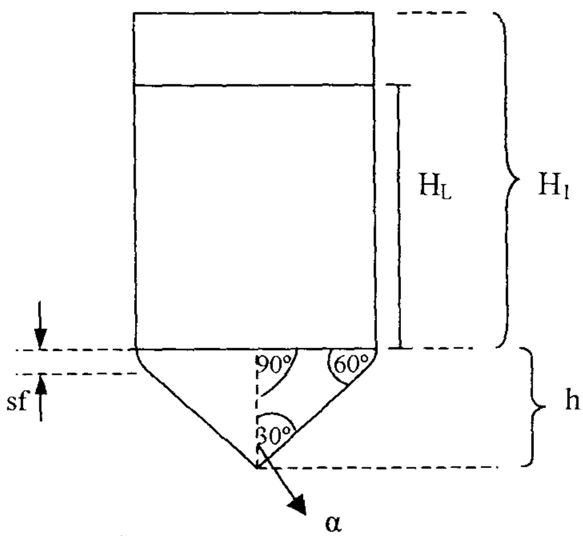
$t_S = 0,1254$ in → diambil $t_S\ \frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)



Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60° = \frac{h - sf}{0{,}5 . D} \rightarrow h = \tan 60° . 0{,}5 . D + sf$$

$$h = \tan 60° \,.\, 0{,}5 \,.\, 1{,}4 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 1{,}3803 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3} . \frac{1}{4} . \pi . D^2 . h$$

$$= \frac{1}{3} . \frac{1}{4} . \pi . (1{,}4 \text{ ft})^2 . 1{,}3803 \text{ ft}$$

$$= 0{,}7085 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4} . \pi . D^2 . H_L$$

$$1{,}5026\ ft^3 - 0{,}7085\ ft^3 = \frac{1}{4}.\pi.(1{,}4\ ft)^2.H_L$$

$$H_L = 0{,}5156\ ft$$

<u>Tinggi liquid total (H)</u>

$H = H_L + h$

$H = 0{,}5156\ ft + 1{,}3803\ ft$

$H = 1{,}8959\ ft \approx 1{,}9\ ft$

<u>Mencari tebal konis (t_K)</u>

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{101{,}4242\ lb/ft^3.1{,}8959\ ft}{144} = 1{,}3354\ lb/in^2$$

Sudut konis = 60° → $\alpha = 30°$

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{1{,}3354\ lb/in^2.1{,}4\ ft}{2.\cos 30°.(18750\ lb/in^2.0{,}80 - 0{,}6.1{,}3354\ lb/in^2)} + \frac{1}{8}$$

$t_k = 0{,}1251$ in → diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 1,4 ft + 1,3803 ft + 0,1875 ft + 3 ft

= 5,9678 ft

11. Kristaliser X – 320

Fungsi : untuk menghasilkan kristal $CaCl_2$

Tipe : tangki silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk datar (flat-head) yang dilengkapi dengan baffle dan pengaduk tipe flat six-blade turbine with disk, dan jaket pendingin.

Dasar pemilihan : jaket pendingin untuk menurunkan suhu operasi sampai dengan 50°C, cocok digunakan untuk mencampur dan menampung bahan yang berbentuk slurry.

Jumlah : 1 buah

Perhitungan :

Mencari ρ campuran

ρ H_2O pada 137,71°C = 928,2 kg / m^3 = 0,9282 kg / lt

(Geankoplis, 1993, pp.856, A.2-5)

Massa H_2O dalam larutan $CaCl_2$ = 17,5371 kg

Massa larutan $CaCl_2$ = 69,1170 kg

$$\text{Fraksi } H_2O \text{ dalam larutan } CaCl_2 = \frac{\text{massa } H_2O}{\text{massa larutan } CaCl_2} = \frac{17{,}5371 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}2537$$

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{17{,}5371 \text{ kg}}{0{,}9282 \text{ kg/lt}} = 18{,}8937 \text{ lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$CaCl_2$	51,5798	0,7463	23,9683
H_2O	17,5371	0,2537	18,8937
	69,1170	1	42,8620

Volume total bahan masuk = 42,8620 lt = 1,5135 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right)} \text{ lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,7463}{2,152} + \frac{0,2537}{0,9282}\right)} \text{ lt/kg}$$

$$\rho_{campuran} = 1,6125 \text{ kg/lt}$$

$$\rho_{campuran} = 1,6125 \text{ kg / lt} = 100,6964 \text{ lb / ft}^3$$

<u>Asumsi</u> : Ruang kosong = 20% volume tangki

$$\text{Volume tangki} = \frac{1,5135 \text{ ft}^3}{80\%} = 1,8919 \text{ ft}^3$$

$$\frac{H_1}{D} = 1,5 \quad \rightarrow H_1 = 1,5 \text{ D}$$

$$\text{Volume tangki} = \frac{\pi}{4}.D^2.H_1$$

$$1,8919 \text{ ft}^3 = \frac{\pi}{4}.D^2.1,5D$$

$$D^3 = 1,6052 \text{ ft}^3$$

$D = 1{,}1709 \text{ ft} \approx 1{,}2 \text{ ft} = 0{,}3658 \text{ m}$

$H_l = 1{,}8 \text{ ft} = 0{,}5486 \text{ m}$

Tinggi bahan pada shell (H_b)

$$\text{Volume total} = \frac{1}{4}.\pi.D^2.H_b$$

$$1{,}5135 \text{ ft}^3 = \frac{1}{4}.\pi.(1{,}2 \text{ ft})^2.H_b$$

$$H_b = 1{,}3377 \text{ ft}$$

Suhu operasi = 50°C (App. B)

Tekanan (P_0) = 12,349 kPa (Geankoplis, 1993, pp.857, A.2-9)

= 1,7911 psia

$$P_{hidrostatis} = \frac{\rho.H_b}{144} = \frac{100{,}6964 \text{ lb/ft}^3.1{,}3377 \text{ ft}}{144} = 0{,}9354 \text{ psia}$$

$P_{operasi} = P_0 + P_{hidrostatis} = 1{,}7911 \text{ psia} + 0{,}9354 \text{ psia} = 2{,}7265 \text{ psia}$

$P_{design} = 1{,}5 \,.\, P_{operasi}$

$= 1{,}5 \,.\, 2{,}7265 \text{ psia}$

$= 4{,}0897 \text{ psia}$

Bahan konstruksi :

Stainless steel SA – 240 Grade M tipe 316

$F_{allowable}$ (T = -20°C – 100°C) = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342, App. D, item 4)

Pengelasan menggunakan double welded butt joint → efisiensi = 80%

(Brownell & Young, 1959, pp. 254, table 13.2)

$$C = \frac{1}{8}$$

Mencari tebal shell (t_S)

$$t_S = \frac{P.r_i}{f.E - 0,6.P} + C \qquad \text{(Brownell \& Young, 1959, pp.254, eq. 13.1)}$$

$$t_S = \frac{4,0897\ lb/in^2 . \frac{1}{2} . 1,2.12\, in}{18750\ lb/in^2 . 0,80 - 0,6 . 4,0897\ lb/in^2} + \frac{1}{8}$$

$$t_S = 0,1270\ in \qquad \rightarrow \text{ diambil } t_S = \frac{3}{16}\ in$$

Penentuan tebal head (t_h)

Rc = D – 0,1 = (1,2 – 0,1) ft = 1,1 ft

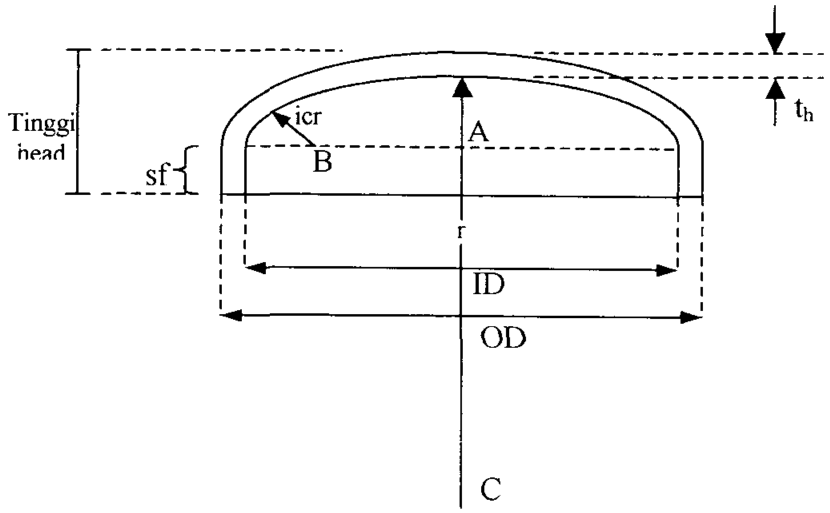
sf = 2 in

$$t_h = \frac{0,885 . P . rc}{f E - 0,1.P} + C \qquad \text{(Brownell \& Young, 1959, pp. 258, pers.13.12)}$$

$$= \frac{0,885 . 4,0897\ lb/in^2 . 1,1 ft . 12\ in/ft}{18750\ lb/in^2 . 0,8 - 0,1 . 4,0897\ lb/in^2} + \frac{1}{8}\ in$$

$$= 0,1253\ in \qquad \rightarrow \text{ diambil } t_h = \frac{3}{16}\ in = 0,1875\ in$$

Menentukan tinggi head



ID = 1,2 ft = 14,4001 in

OD = ID + 2 t_S

$= 14{,}4001 \text{ in} + 2 \cdot \frac{3}{16} \text{ in}$

$= 14{,}6541$ in

r = 7,25 in

icr = 2 in

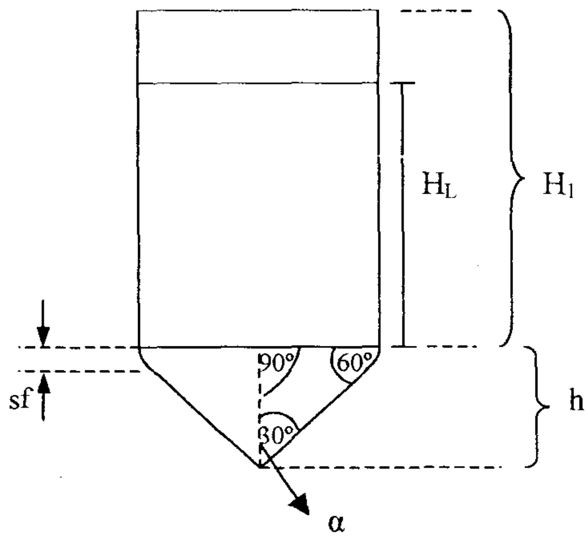
(Brownell & Young, 1959, pp. 91, table 5.7)

$$\text{Tinggi head} = t_h + sf + \left(r - \sqrt{(BC)^2 - (AB)^2} \right)$$

$$= \frac{3}{16} \text{ in} + 2 \text{ in} + \left(7{,}25 - \sqrt{(7{,}25 - 2)^2 - \left(\frac{14{,}4001}{2} - 2 \right)^2} \right)$$

$$= 8{,}7125 \text{ in} = 0{,}7263 \text{ ft}$$

Penentuan tebal konis (t_k)



$$\tan x = \frac{h - sf}{0{,}5.D} \quad ; \; h : \text{tinggi konis, ft}$$

$$h = \tan 60°.0{,}5.1{,}2\,ft + \frac{2}{12}ft$$

$$h = 1{,}2069 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(1{,}2 \text{ ft})^2.1{,}2069 \text{ ft}$$

$$= 0{,}4552 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$1{,}5135 \text{ ft}^3 - 0{,}4552 \text{ ft}^3 = \frac{1}{4}.\pi.(1{,}2\,ft)^2.H_L$$

$$H_L = 0{,}9354 \text{ ft}$$

<u>Tinggi liquid total (H)</u>

$H = H_L + h$

$H = 0{,}9354 \text{ ft} + 1{,}2069 \text{ ft}$

$H = 2{,}1423 \text{ ft} \approx 2{,}2 \text{ ft}$

$$P_{hidrostatis} = \frac{\rho.H}{144} = \frac{100{,}6964 \text{ lb/ft}^3 .2{,}2 \text{ ft}}{144 \text{ in}^2/\text{ft}^2} = 1{,}5384 \text{ psia}$$

$$t_k = \frac{P.D}{2.\cos\alpha(f.E - 0{,}6.P)} + C$$ (Brownell & Young, 1959, pp.254, eq. 13.1)

$$t_k = \frac{1{,}5384 \text{ lb/in}^2 .1{,}2.12 \text{ in}}{2.\cos 30^\circ (18750 \text{ lb/in}^2 .0{,}8 - 0{,}6.1{,}5384 \text{ lb/in}^2)} + \frac{1}{8} \text{ in}$$

$t_k = 0{,}1251$ in $\rightarrow$ diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi head + tinggi silinder + tinggi konis + jarak pemasangan pipa

= 0,7263 ft + 1,8 ft + 1,2069 ft + 3 ft

= 6,7332 ft

<u>Perancangan pengaduk</u>

$$\frac{H_{liquid}}{D_{tangki}} = \frac{2{,}2 \text{ ft}}{1{,}2 \text{ ft}} = 1{,}8333$$

μ H_2O pada 137,71°C = 0,2115 cp

(Geankoplis, 1993, pp.862, A.2-11)

$\mu_{CaCl_2} = 12{,}3$ cp (Perry, 1999, pp. 2-105)

Menghitung μ campuran

$$\mu_{campuran}^{1/3} = X_{CaCl_2} \cdot (\mu_{CaCl_2})^{1/3} + X_{H_2O} \cdot (\mu_{H_2O})^{1/3}$$

$$\mu_{campuran}^{1/3} = 0{,}7463.(12{,}3\ cp)^{1/3} + 0{,}2537.(0{,}2115\ cp)^{1/3}$$

$$\mu_{campuran} = 6{,}5794\ cp$$

$$\left.\begin{array}{l} \mu_{campuran} = 6{,}5794\,cp \\ \dfrac{H_{liquid}}{D_{tangki}} = 1{,}8333 \end{array}\right\} \text{Walas, 1990, pp.288 diperoleh :}$$

Jumlah impeller = 2

Letak impeller 1 = $D_t/3$

Letak impeller 2 = (2/3) H

Letak impeller 1 = $\dfrac{D_t}{3} = \dfrac{1{,}2\ ft}{3} = 0{,}4\ ft$

Letak impeller 2 = $\dfrac{2}{3}\ H = \dfrac{2}{3}\ 2{,}2\ ft = 1{,}4667\ ft$

Ukuran impeller

$\dfrac{d}{D_t} = 0{,}3 - 0{,}6$; dimana : d : diameter impeller

D_t : diameter tangki

(Walas, 1990, pp. 287)

Dipilih $\dfrac{d}{D_t} = 0{,}5$, sehingga : d = 0,5 . 1,2 ft

d = 0,6 ft

Ukuran baffle

$$W = \frac{D_t}{12}$$ Dimana : W : lebar baffle

$$Offset = \frac{d}{2}$$ D_t : diameter tangki

d : diameter impeller

(Walas, 1990, pp. 287)

Sehingga : $$W = \frac{1{,}2\ ft}{12} = 0{,}1\ ft$$

$$Offset = \frac{0{,}6\ ft}{2} = 0{,}3\ ft$$

Jumlah baffle = 4 buah (Walas, 1990, pp. 287)

Perhitungan power pengaduk

$d = D_a = 0{,}6\ ft = 0{,}1829\ m$

$N = 110\ rpm = 1{,}8333\ rps$

$$N_{Re} = \frac{D_a^{\ 2}.N.\rho}{\mu} = \frac{(0{,}1829\,m)^2.1{,}8333\ rps.1612{,}5454\,kg/m^3}{6{,}5794.10^{-3}\ kg/m.s} = 15028{,}3136$$

(Walas, 1990, pp. 290)

Untuk Flat six-blade turbine with disk (Walas, 1990, pp. 292, Fig. 10.6) :

$N_P = 5$

$P\ = N_P\ .\ \rho\ .\ N^3\ .\ D_a$ (Walas, 1990, pp. 292, Fig. 10.6)

$P\ = 5\ .\ 1612{,}5454\ kg/m^3\ .\ 1{,}8333\ rps\ .\ 0{,}1829\ m$

$P\ = 9086{,}1048\ Watt = 12{,}1798\ hp$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{12{,}1798\ \text{hp}}{0{,}85} = 14{,}3291\ \text{hp} \approx 14{,}5\ \text{hp}$$

Perancangan jaket pendingin

L = d = 0,6 ft

N = 110 rpm = 6600 rph

$\rho_{campuran} = 100{,}6964\ \text{lb}/\text{ft}^3$

$$N_{Re} = \frac{L^2 . N . \rho_{campuran}}{\mu_{campuran}} = \frac{(0{,}6\ \text{ft})^2 . 6600\ \text{rph} . 100{,}6964\ \text{lb}/\text{ft}^3}{6{,}5794\ \text{cp} . 2{,}4191 \dfrac{\text{lb}}{\text{ft.h.cp}}} = 15032{,}1217$$

Asumsi : $\mu = \mu_W = \mu_{air\ pendingin} = 0{,}8007$ cp (T = 30°C)

(Geankoplis, 1993, pp. 855, A.2-4)

J untuk jaket = 30

(Kern, 1965, pp. 718, Fig. 20.2)

Cp H2O (T = 50°C) = 4,183 kJ / kg . K

(Geankoplis, 1993, pp. 856, A.2-5)

Cp CaCl2 = 125,3233 kJ / kmol . K = 1,1290 kJ / kg . K

(Perry, 1999)

$$Cp_{campuran} = X_{CaCl_2} . Cp_{CaCl_2} + X_{H_2O} . Cp_{H_2O}$$

$$Cp_{campuran} = 0{,}7463 . 1{,}1290\ \text{kJ}/\text{kg.K} + 0{,}2537 . 4{,}183\ \text{kJ}/\text{kg.K}$$

$$Cp_{campuran} = 1{,}9039\ \text{kJ}/\text{kg.K}$$

Diambil k = k air pada T = 50°C = 122°F, maka :

$$k = 0{,}3726\ \frac{\text{Btu}}{\text{jam.ft}^2.\frac{^\circ\text{F}}{\text{ft}}}$$ (Kern, 1965, pp. 800)

Dari Perhitungan Neraca Panas Appendix B diperoleh data sebagai berikut :

- Q_{loss} = 12238,1270 kJ = 11599,4607 Btu
- Suhu bahan keluar ke Centrifugal Separator H – 172 = 50°C = 122°F

$$\left(\frac{C_P.\mu}{k}\right)^{1/3} = \left(\frac{1{,}9039\frac{\text{Btu}}{\text{lb.}^\circ\text{F}}\ .\ 6{,}5794\ \text{cp}\ .\ 2{,}4191\frac{\text{lb}}{\text{ft.jam.cp}}}{0{,}3726\frac{\text{Btu}}{\text{jam.ft}^2\frac{^\circ\text{F}}{\text{ft}}}}\right)^{1/3} = 4{,}3326$$

$$\left(\frac{\mu_{campuran}}{\mu_W}\right)^{0,14} = 1$$

Water → h_o = 150 Btu / (jam) (ft^2) (°F) (Kern, 1965, pp. 726)

<u>Jaket pendingin</u>

$$h_{i\,jaket} = J_{jaket}\cdot\frac{k}{D_i}\cdot\left(\frac{C_P.\mu}{k}\right)^{1/3}\cdot\left(\frac{\mu}{\mu_W}\right)^{0,14}$$ (Kern, 1965, pp. 112, eq. 6.15b)

$$h_{i\,jaket} = 30.\frac{0{,}3726\frac{\text{Btu}}{\text{jam.ft}^2.\frac{^\circ\text{F}}{\text{ft}}}}{1{,}2\,\text{ft}}.4{,}3326.1$$

$$h_{i\,jaket} = 40{,}3582\frac{\text{Btu}}{\text{jam.ft}^2.^\circ\text{F}}$$

$$h_{io} = h_i \cdot \frac{ID}{OD} = 40{,}3582 \frac{Btu}{jam.ft^2.^\circ F} \cdot \frac{1{,}2\ ft}{1{,}2212\ ft} = 39{,}6589 \frac{Btu}{jam.ft^2.^\circ F}$$

$$U_C = \frac{h_o \cdot h_{io}}{h_o + h_{io}} = \frac{150 \frac{Btu}{jam.ft^2.^\circ F} \cdot 39{,}6589 \frac{Btu}{jam.ft^2.^\circ F}}{(150 + 39{,}6589) \frac{Btu}{jam.ft^2.^\circ F}} = 31{,}3659 \frac{Btu}{jam.ft^2.^\circ F}$$

(Kern, 1965, pp. 121, eq. 6.38)

Rd = 0,001 (Kern, 1965, pp. 845, table 12)

$$h_d = \frac{1}{0{,}001} = 1000$$

$$U_D = \frac{U_C \cdot h_d}{U_C + h_d} = \frac{31{,}3659 \frac{Btu}{jam.ft^2.^\circ F} \cdot 1000}{31{,}3659 \frac{Btu}{jam.ft^2.^\circ F} + 1000} = 30{,}4120 \frac{Btu}{jam.ft^2.^\circ F}$$

(Kern, 1965, pp. 107, eq. 6.10)

A = luas sisi liquida + luas kerucut

$$= \pi \cdot D_{tangki} \cdot H_L + \pi \cdot \left[\left(\frac{1}{2} D_{tangki} \right)^2 + h^2 \right]$$

$$= \pi \cdot 1{,}2\ ft \cdot 2{,}2\ ft + \pi \cdot \left[(1{,}2\ ft)^2 + (1{,}2069\ ft)^2 \right]$$

$$= 11{,}1938\ ft^2$$

$$\Delta T_{LMTD} = \frac{(137{,}71 - 35) - (50 - 30)}{\ln\left(\frac{137{,}71 - 35}{50 - 30} \right)} = 50{,}55^\circ C = 122{,}99^\circ F$$

$Q = U_D \cdot A \cdot \Delta T$

$= 30{,}4120 \dfrac{\text{Btu}}{\text{jam.ft}^2.^\circ\text{F}} \cdot 11{,}1938 \text{ ft}^2 \cdot 122{,}99^\circ\text{F}$

$= 41869{,}1299$ Btu

12. Tangki Penampung Kristal $CaCl_2.2H_2O$ F – 323

Fungsi : menampung kristal $CaCl_2.2H_2O$ dari Kristaliser X – 320 sebelum dimasukkan ke Tumbling Mill C – 330

Tipe : Tangki silinder dengan tutup bagian bawah berbentuk konis dan atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan berbentuk padat

Jumlah : 1 buah

Perhitungan :

Suhu = 47,51°C

Jumlah = 1 buah

ρ H_2O pada 47,51°C = 0,9866 kg / lt (Geankoplis, 1993, pp. 855, A.2-3)

Massa H_2O dalam campuran = 0,8122 kg

Massa campuran = 69,1170 kg

Fraksi H_2O dalam campuran $= \dfrac{\text{massa } H_2O}{\text{massa campuran}} = \dfrac{0{,}8122 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}0118$

Volume H_2O $= \dfrac{\text{massa } H_2O}{\rho_{H_2O}} = \dfrac{0{,}8122 \text{ kg}}{0{,}9866 \text{ kg/lt}} = 0{,}8233$ lt

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$CaCl_2.2H_2O$	68,2934	0,9881	36,5205
$CaCl_2$	0,0113	$1,64.10^{-4}$	$5,2678.10^{-3}$
H_2O	0,8122	0,0118	0,8233
	69,1170	1	37,3491

Volume total bahan masuk = 37,3491 lt = 1,3188 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,9881}{1,87} + \frac{1,64.10^{-4}}{2,152} + \frac{0,0118}{0,9866}\right) lt/kg}$$

$$\rho_{campuran} = 1,8506 \ kg/lt$$

$$\rho_{campuran} = 1,8506 \ kg/lt = 115,5597 \ lb/ft^3$$

<u>Asumsi</u> : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 1,3188 \ ft^3$$

$$= 1,6485 \ ft^3$$

$\frac{H}{D} = 1$, sehingga : Volume tangki $= \frac{\pi}{4}.D^2.H$

$$1,6485 \ ft^3 = \frac{\pi}{4}.D^2.D$$

$$D^3 = 2,0981 \ ft^3$$

$D = 1{,}2802\ ft \approx 1{,}3\ ft = 0{,}3962\ m$

$H = 1{,}3\ ft = 0{,}3962\ m$

Bahan konstruksi : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

Penentuan tebal shell (t_S) :

Tinggi liquida (H_l),

$$1{,}3188\ ft^3 = \frac{\pi}{4}.D^2.\ H_l$$

$$1{,}3188\ ft^3 = \frac{\pi}{4}.\left(1{,}3\ ft\right)^2.\ H_l$$

$$H_l = 0{,}9932\ ft$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{115{,}5597\,lb/ft^3\ .\ (0{,}9932\ ft).\ (12\ .1{,}3)\ in}{2.18750\,lb/in^2\ .0{,}80.(144\ in^2\ /ft^2)} + \frac{1}{8}\,in$$

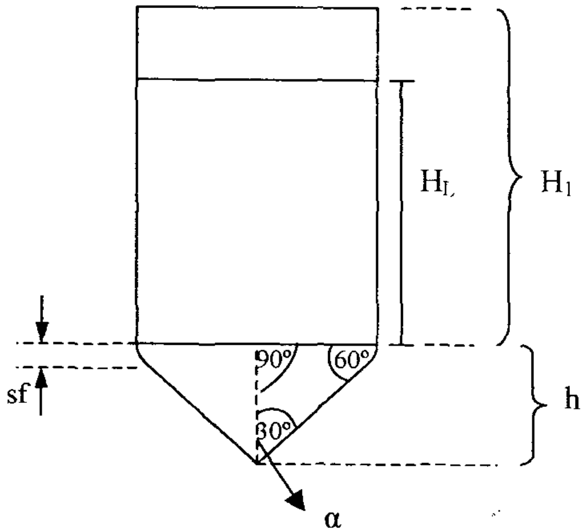
$t_S = 0{,}1254$ in $\rightarrow$ diambil t_S $\frac{3}{16}$ in

Tutup atas berbentuk datar

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

Perancangan konis

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)



Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60^\circ = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60^\circ.0{,}5.D + sf$$

$$h = \tan 60^\circ \,.\, 0{,}5 \,.\, 1{,}3\ ft + (2 / 12)\ ft$$

$$h = 1{,}2936\ ft$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(1{,}3\,ft)^2.1{,}2936\ ft$$

$$= 0{,}5726\ ft^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$1{,}3188\ ft^3 - 0{,}5726\ ft^3 = \frac{1}{4}.\pi.(1{,}3\ ft)^2.H_L$$

$$H_L = 0{,}5620\ ft$$

Tinggi liquid total (H)

$$H = H_L + h$$

$$H = 0{,}5620\ ft + 1{,}2936\ ft$$

$$H = 1{,}8556\ ft \approx 1{,}9\ ft$$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{115{,}5597\ lb/ft^3.1{,}8556\ ft}{144} = 1{,}4891\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{1{,}4891\ lb/in^2.1{,}3\ ft}{2.\cos30°.(18750\ lb/in^2.0{,}80 - 0{,}6.1{,}4891\ lb/in^2)} + \frac{1}{8}$$

$t_k = 0{,}1251$ in → diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 1,3 ft + 1,2936 ft + 0,1875 ft + 3 ft

= 5,7811 ft

13. Screw Conveyor J – 322

Fungsi : mengangkut kristal $CaCl_2$ dari Kristaliser X – 320 menuju ke Tangki Penampung Kristal $CaCl_2$ F – 323

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

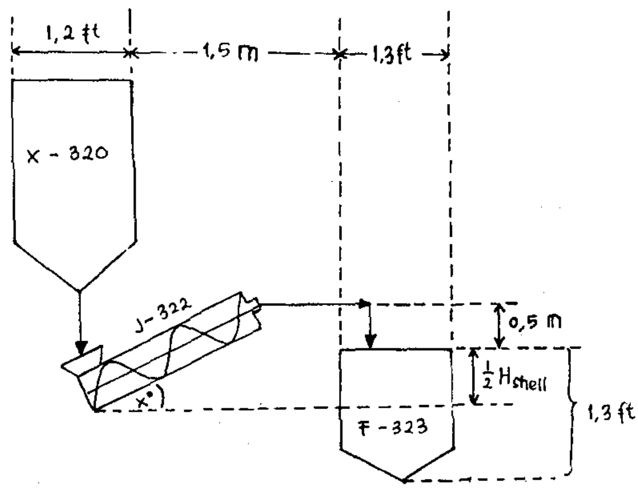
Perhitungan :

Kapasitas = 69,1170 kg / jam

Jarak X – 320 ke F – 323 = ½ D_{X-320} + 1,5 m + ½ D_{F-323}

= ½ . 1,2 ft + 1,5 m + ½ . 1,3 ft

= 6,1712 ft



h = ½ H shell + ½ m

H = 0,5 . 1,3 ft + ½ m

H = 2,2904 ft

Panjang Screw Conveyor J – 322 = $\sqrt{2{,}2904^2 + 6{,}1712^2}$ ft = 6,5825 ft ≈ 7 ft

Sudut Screw Conveyor J – 322 :

$$\tan x = \frac{2{,}2904 \text{ ft}}{6{,}1712 \text{ ft}} = 0{,}3480$$

$$x = 19{,}19°$$

ρ H_2O pada 50°C = 0,98807 kg / lt = 61,7006 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam campuran = 0,8122 kg

Massa campuran = 69,1170 kg

Fraksi H_2O dalam campuran = $\dfrac{\text{massa } H_2O}{\text{massa campuran}} = \dfrac{0{,}8122 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}0118$

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{0{,}8122 \text{ kg}}{0{,}98807 \text{ kg/lt}} = 0{,}8220 \text{ lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$CaCl_2.2H_2O$	68,2934	0,9881	69,2505
$CaCl_2$	0,0113	$1{,}64.10^{-4}$	$5{,}2678.10^{-3}$
H_2O	0,8122	0,0118	0,822
	69,1170	1	37,3478

Volume total bahan masuk = 37,3478 lt = 1,3819 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) \text{lt/kg}}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0{,}9881}{1{,}87} + \frac{1{,}64.10^{-4}}{2{,}152} + \frac{0{,}0118}{0{,}98807}\right) \text{lt/kg}}$$

$$\rho_{campuran} = 1{,}8506 \text{ kg/lt}$$

$$\rho_{campuran} = 1{,}8506 \text{ kg/lt} = 115{,}5636 \text{ lb/ft}^3$$

$$\text{Massa yang dipindahkan} = 69{,}1170 \frac{\text{kg}}{\text{jam}} . 2{,}205 \frac{\text{lb}}{\text{kg}} . \frac{1 \text{ jam}}{60 \text{ menit}} = 2{,}54 \text{ lb/menit}$$

$$\text{Volume yg dipindahkan} = \frac{69{,}1170 \text{ kg/jam}}{1{,}8506 \text{ kg/lt}} = 37{,}3478 \text{ lt/jam} = 1{,}3189 \text{ ft}^3\text{/jam}$$

Maka kapasitas Screw Conveyor J – 322 = 1,3189 ft^3 / jam

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

<u>Power</u> :

$$hp = \frac{Co\,.Ca.L}{33000}$$, dimana : Co : koefisien (Co = 1,3)

Ca : kapasitas Screw Conveyor (= 2,54 lb/menit)

L : panjang Screw Conveyor (= 7 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\,.2{,}54\,lb/menit.7\ ft}{33000} = 7{,}0044.10^{-4}\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{7{,}0044.10^{-4}\ hp}{0{,}8} = 8{,}7555.10^{-4}\ hp \qquad \rightarrow \text{power} < 2\ hp$$

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = $8{,}7555.10^{-4}$ hp × 2 = $1{,}7511.10^{-3}$ hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

14. Tumbling Mill C – 330

<u>Fungsi</u> : mengecilkan ukuran kristal $CaCl_2.2H_2O$ dari Tangki Penampung Kristal $CaCl_2.2H_2O$ F – 323

Dasar pemilihan : cocok untuk material keras dan abrasif, dapat memberikan hasil dengan ukuran merata

Jumlah : 1 buah

Kapasitas bahan : 86,3962 kg / jam = 0,024 kg / s

Kapasitas alat maksimum : 15 kg / s

Reduction ratio(R) : 20

(Ulrich, 1984, pp. 77, table 4-5)

Tinggi : 2 m

Perhitungan :

$D_P = 500\ \mu m = 5 . 10^{-4}$ m

$$Power = 0{,}008\ \frac{m}{D_P} = 0{,}008\ \frac{0{,}024\ kg/s}{5.10^{-4}\ m} = 0{,}3840\ kW = 0{,}5149\ hp$$

(Ulrich, 1984, pp. 77, table 4-5)

Maka dipilih motor 1 hp

Bahan konstruksi = carbon steel

15. Screw Conveyor J – 324

Fungsi : mengangkut kristal $CaCl_2$ dari Tangki Penampung Kristal $CaCl_2$ F – 323 menuju ke Tumbling Mill C – 330

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

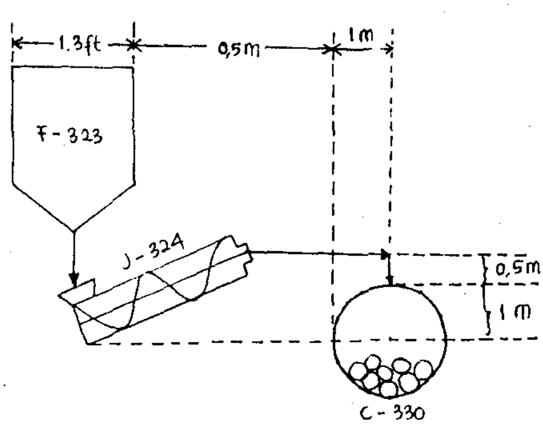
Perhitungan :

Kapasitas = 69,1170 kg / jam

Jarak F – 323 ke C – 330 $= \frac{1}{2} D_{F-323} + 0,5 \text{ m} + \frac{1}{2} D_{C-330}$

$= \frac{1}{2} \cdot 1,3 \text{ ft} + 0,5 \text{ m} + \frac{1}{2} \cdot 2 \text{ m}$

$= 5,5712 \text{ ft}$



h = ½ H C – 330 + ½ m

H = 0,5 . 2 m + ½ m

H = 1,5 m = 4,9212 ft

Panjang Screw Conveyor J – 324 = $\sqrt{5,5712^2 + 4,9212^2}$ ft = 7,4335 ft = 8 ft

Sudut Screw Conveyor J – 324 :

$$\tan x = \frac{5,5712 \text{ ft}}{4,9212 \text{ ft}} = 1,1321 \quad \Rightarrow \quad x = 48,55^\circ$$

ρ H_2O pada 45,26°C = 0,9899 kg / lt = 61,8149 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam campuran = 0,8122 kg

Massa campuran = 69,1170 kg

$$\text{Fraksi } H_2O \text{ dalam campuran} = \frac{\text{massa } H_2O}{\text{massa campuran}} = \frac{0{,}8122 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}0118$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$CaCl_2.2H_2O$	68,2934	0,9881
$CaCl_2$	$1{,}1336.10^{-2}$	$1{,}64.10^{-4}$
H_2O	0,8122	0,0118
	69,1170	1

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) \text{lt/kg}}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0{,}9881}{1{,}87} + \frac{1{,}64.10^{-4}}{2{,}152} + \frac{0{,}0118}{0{,}9899}\right) \text{lt/kg}}$$

$$\rho_{campuran} = 1{,}8507 \text{ kg/lt}$$

$$\rho_{campuran} = 1{,}8507 \text{ kg / lt} = 115{,}5683 \text{ lb / ft}^3$$

$$\text{Massa yang dipindahkan} = 69{,}1170 \frac{\text{kg}}{\text{jam}} . 2{,}205 \frac{\text{lb}}{\text{kg}} . \frac{1 \text{ jam}}{60 \text{ menit}} = 2{,}54 \text{ lb/menit}$$

$$\text{Volume yg dipindahkan} = \frac{69{,}1170 \text{ kg/jam}}{1{,}8506 \text{ kg/lt}} = 37{,}3463 \text{ lt/jam} = 1{,}3189 \text{ ft}^3\text{/jam}$$

Maka kapasitas Screw Conveyor J – 324 = 1,3189 ft^3 / jam

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

<u>Power</u> :

$$hp = \frac{Co \, . \, Ca \, . \, L}{33000}$$, dimana : Co : koefisien (Co = 1,3)

Ca : kapasitas Screw Conveyor (= 2,54 lb/menit)

L : panjang Screw Conveyor (= 8 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3 \, . \, 2{,}54 \text{ lb/menit} \, . \, 8 \text{ ft}}{33000} = 8{,}005 . 10^{-4} \text{ hp}$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{8{,}005 . 10^{-4} \text{ hp}}{0{,}8} = 0{,}001 \text{ hp} \quad \rightarrow \text{power} < 2 \text{ hp}$$

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,001 hp × 2 = 0,002 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

16. Screen H – 332

Fungsi : untuk memisahkan bahan yang berukuran tidak sama

Tipe : Vibrating screen

Dasar pemilihan : kapasitas besar, efisiensi pemisahan tinggi

Jumlah : 1 buah

Perhitungan :

Kapasitas = 86,3962 kg / jam

Data-data :

Kapasitas aktual screen = 0,2 – 0,8 kg / ft^2. h . mm mesh size

(Mc. Cabe, 1985, pp.1001)

Diameter partikel = 50 – 50000 μm

Panjang Screen (L) = 2 – 5 m

Lebar Screen (D) = 0,5 – 1,5 m

Luas area (A) = 1 – 7,5 m^2

(Ulrich, 1984, pp. 223, table 4-23)

Dari data di atas diambil :

Kapasitas aktual screen = 0,2 kg / ft^2. jam . mm mesh size

Diameter partikel = 50 μm = 5.10^{-2} mm

Panjang screen (L) = 4 m

Lebar screen (D) = 1,5 m ; maka :

Ukuran ayakan = 270 mesh → (Diameter lubang screen = 53 μm)

(Brown, 1961, pp. 17, tabel 4)

$$\text{Luas screen yang dibutuhkan (A)} = \frac{86{,}3962\ \text{kg / jam}}{0{,}2\ \dfrac{\text{kg}}{\text{ft}^2.\text{jam.mm}}.0{,}053\,\text{mm}}$$

$$= 8{,}1506\ \text{ft}^2$$

Luas area (A) $= L\ .\ D$

$= 5\ m\ .\ 1{,}5\ m$

$= 7{,}5\ m^2 = 80{,}727\ ft^2$

$$ms = 86{,}3962\ \text{kg / jam} = \frac{86{,}3962\ \text{kg/ jam}}{3600\ \dfrac{\text{s}}{\text{jam}}.7{,}5\ \text{m}^2} = 0{,}0032\ \frac{\text{kg}}{\text{m}^2.\text{s}}$$

$$\text{Power} = 1600\ \frac{ms}{Dp} = 1600\ \frac{0{,}0032\ \dfrac{\text{kg}}{\text{m}^2.\text{s}}}{53\ \mu\text{m}} = 0{,}0966\ \text{hp} \rightarrow \text{power} < 2\ \text{hp}$$

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0966 hp × 2 = 0,1932 hp → dipilih motor 0,5 hp

Bahan konstruksi = carbon steel

12. Screw Conveyor J – 331

Fungsi : mengangkut tulang dari Tumbling Mill C – 330 ke Screen H – 332

Tipe : standart pitch screw conveyor

Dasar pemilihan : membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

Jumlah : 1 buah

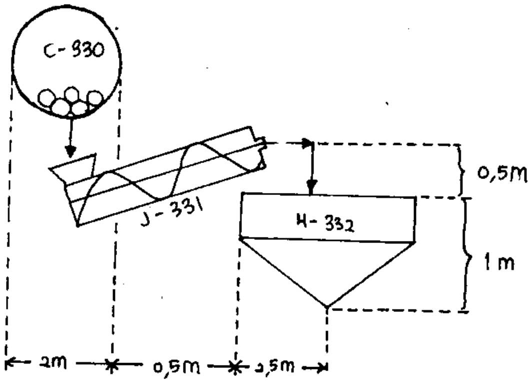
Perhitungan :

Kapasitas = 86,3962 kg / jam

Jarak Tumbling Mill ke screen = ½ D_{C-330} + 0,5 m + ½ panjang screen

= ½ . 1 m + 0,5 m + ½ 5 m

= 3,5 m = 11,4828 ft



H = 1,5 m = 4,9212 ft

Panjang Screw Conveyor J – 331 = $\sqrt{11{,}4828^2 + 4{,}9212^2}$ ft = 12,4929 ft ≈ 13 ft

Sudut Screw Conveyor J – 331 :

$$\tan x = \frac{4{,}9212 \text{ ft}}{11{,}4828 \text{ ft}} = 0{,}4286$$

$$x = 23{,}2°$$

ρ H_2O pada 40,30°C = 0,99223 kg / lt = 61,9604 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam campuran = 1,0153 kg

Massa campuran = 86,3962 kg

Fraksi H_2O dalam campuran = $\dfrac{\text{massa}\,H_2O}{\text{massa campuran}} = \dfrac{1{,}0153\ \text{kg}}{86{,}3962\ \text{kg}} = 0{,}0118$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$CaCl_2.2H_2O$	85,3667	0,9881
$CaCl_2$	0,0142	$1{,}64.10^{-4}$
H_2O	1,0153	0,0118
	86,3962	1

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\dfrac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \dfrac{X_{CaCl_2}}{\rho_{CaCl_2}} + \dfrac{X_{H_2O}}{\rho_{H_2O}}\right) \text{lt/kg}}$$

$$\rho_{campuran} = \frac{1}{\left(\dfrac{0{,}9881}{1{,}87} + \dfrac{1{,}64.10^{-4}}{2{,}152} + \dfrac{0{,}0118}{0{,}99223}\right) \text{lt/kg}}$$

$$\rho_{campuran} = 1{,}8508\ \text{kg/lt}$$

$$\rho_{campuran} = 1{,}8508\ \text{kg / lt} = 115{,}5743\ \text{lb / ft}^3$$

Massa yg dipindahkan = $86{,}3962\ \dfrac{\text{kg}}{\text{hari}} .\ 2{,}205\ \dfrac{\text{lb}}{\text{kg}} . \dfrac{1\ \text{jam}}{60\ \text{menit}} = 3{,}1751\ \text{lb/menit}$

Volume yang dipindahkan = $\dfrac{86{,}3962\,\text{kg / jam}}{1{,}8508\,\text{kg / lt}} = 46{,}6805\,\text{lt / jam} = 1{,}6485\,\text{ft}^3\text{ / jam}$

Maka kapasitas Screw Conveyor J – 331 = 1,6485 ft^3 / jam

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co \, . Ca . L}{33000}$$, dimana : Co : koefisien (Co = 1,3)

Ca : kapasitas Screw Conveyor (= 3,1751 lb/menit)

L : panjang Screw Conveyor (= 13 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1,3 \, . 3,1751 \text{ lb/menit} . 13 \text{ ft}}{33000} = 0,0016 \text{ hp}$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0,0016 \text{ hp}}{0,8} = 0,0020 \text{ hp} \qquad \rightarrow \text{power} < 2 \text{ hp}$$

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0020 hp × 2 = 0,0041 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

13. Screw Conveyor J – 333

Fungsi : mengangkut tulang dari Screen H – 332 ke Tumbling Mill C – 330

<u>Dasar pemilihan</u> : *membutuhkan ruang yang kecil,* ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar

<u>Jumlah</u> : 1 buah

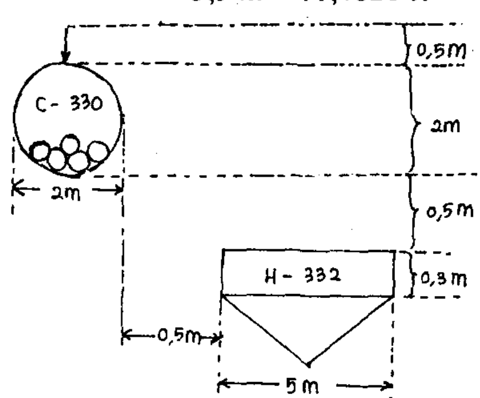
<u>Perhitungan</u> :

Kapasitas = 17,2792 kg / jam

Jarak screen ke Tumbling Mill = ½ panjang screen + 0,5 m + ½ D_{C-330}

= ½ . 5 m + 0,5 m + ½ 1 m

= 3,5 m = 11,4828 ft



H = tinggi Tumbling Mill C – 130 + 0,5 m + jarak C – 330 ke H – 332 + tinggi Screen

H = 2 m + ½ m + ½ m + 0,3 m

H = 3,3 m = 10,8266 ft

Panjang Screw Conveyor J – 333 = $\sqrt{11{,}4828^2 + 10{,}8266^2}$ ft = 15,782 ft ≈ 16 ft

Sudut Screw Conveyor J – 333 :

Sudut Screw Conveyor J – 333 :

$$\tan x = \frac{10,8266 \text{ ft}}{11,4828 \text{ ft}} = 0,9429$$

$$x = 43,32^{\circ}$$

ρ H_2O pada 37°C = 0,99318 kg / lt = 62,0197 lb / ft^3

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam campuran = 0,2031 kg

Massa campuran = 17,2792 kg

$$\text{Fraksi } H_2O \text{ dalam campuran} = \frac{\text{massa } H_2O}{\text{massa campuran}} = \frac{0,2031 \text{ kg}}{17,2792 \text{ kg}} = 0,0118$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$CaCl_2.2H_2O$	17,0733	0,9881
$CaCl_2$	0,0028	$1,64.10^{-4}$
H_2O	0,2031	0,0118
	17,2792	1

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\frac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \frac{X_{CaCl_2}}{\rho_{CaCl_2}} + \frac{X_{H_2O}}{\rho_{H_2O}}\right) \text{lt/kg}}$$

$$\rho_{campuran} = \frac{1}{\left(\frac{0,9881}{1,87} + \frac{1,64.10^{-4}}{2,152} + \frac{0,0118}{0,99318}\right) \text{lt/kg}}$$

$$\rho_{campuran} = 1,8508 \text{ kg/lt}$$

$\rho_{campuran}$ = 1,8508 kg / lt = 115,5767 lb / ft^3

$$\text{Massa yg dipindahkan} = 17{,}2792\frac{kg}{jam}.\ 2{,}205\frac{lb}{kg}.\frac{1\ jam}{60\ menit} = 0{,}6350\ lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{17{,}2792\ kg/jam}{1{,}8508\ kg/lt} = 9{,}33591\ lt/jam = 0{,}3297\ ft^3/jam$$

Maka kapasitas Screw Conveyor J – 333 = 0,3297 ft^3 / hari

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

Power :

$$hp = \frac{Co\,.Ca\,.L}{33000}$$, dimana : Co : koefisien (Co = 1,3)

Ca : kapasitas Screw Conveyor (= 0,6350 lb/menit)

L : panjang Screw Conveyor (= 16 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\ .0{,}635\ lb/menit.16\ ft}{33000} = 0{,}0004\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0{,}0004\ hp}{0{,}8} = 0{,}0005\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0005 hp × 2 = 0,0010 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

14. Tangki Penampung Produk F – 335

Fungsi : menampung bubuk $CaCl_2.2H_2O$ dari Screen H – 332 sebelum dibawa ke bagian pengepakan

Tipe : Tangki silinder dengan tutup bagian bawah berbentuk konis dan atas berbentuk datar (flat head)

Dasar pemilihan : cocok digunakan untuk menampung bahan berbentuk bubuk

Jumlah : 1 buah

Perhitungan :

Suhu = 35,8°C

Jumlah = 1 buah

ρ H_2O pada 35,8°C = 0,99354 kg / lt (Geankoplis, 1993, pp. 855, A.2-3)

Massa H_2O dalam campuran = 0,8122 kg

Massa campuran = 69,1170 kg

$$\text{Fraksi } H_2O \text{ dalam campuran} = \frac{\text{massa } H_2O}{\text{massa campuran}} = \frac{0{,}8122 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}0118$$

$$\text{Volume } H_2O = \frac{\text{massa } H_2O}{\rho_{H_2O}} = \frac{0{,}8122 \text{ kg}}{0{,}99354 \text{ kg / lt}} = 0{,}8175 \text{ lt}$$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi	Volume (lt)
$CaCl_2.2H_2O$	68,2934	0,9881	36,5205
$CaCl_2$	0,0113	$1{,}64.10^{-4}$	0,0053
H_2O	0,8122	0,0118	0,8175
	69,1170	1	37,3433

Volume total bahan masuk = 37,3433 lt = 1,3186 ft^3

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\dfrac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \dfrac{X_{CaCl_2}}{\rho_{CaCl_2}} + \dfrac{X_{H_2O}}{\rho_{H_2O}}\right) lt/kg}$$

$$\rho_{campuran} = \frac{1}{\left(\dfrac{0,9881}{1,87} + \dfrac{1,64.10^{-4}}{2,152} + \dfrac{0,0118}{0,99354}\right) lt/kg}$$

$$\rho_{campuran} = 1,8509\ kg/lt$$

$\rho_{campuran}$ = 1,8509 kg / lt = 115,5776 lb / ft^3

<u>Asumsi</u> : Ruang kosong = 20 % volume tangki

$$\text{Volume tangki} = \frac{100\%}{80\%} 1,3186\ ft^3$$

$$= 1,6483\ ft^3$$

$\frac{H}{D}$ = 1, sehingga : Volume tangki $= \frac{\pi}{4}.D^2.H$

$1,6483\ ft^3 = \frac{\pi}{4}.D^2.D$

$D^3 = 2,0978\ ft^3$

$D = 1,2801\ ft \approx 1,3\ ft = 0,3962\ m$

$H = 1,3\ ft = 0,3962\ m$

<u>Bahan konstruksi</u> : Stainless Steel SA-240 grade M type 316

F allowable = 18750 lb / in^2

(Brownell & Young, 1959, pp. 342)

Efisiensi pengelasan doubled welded butt joint = 0,80

(Brownell & Young, 1959, pp. 254)

$C = \frac{1}{8}$ in

<u>Penentuan tebal shell (t_S)</u> :

Tinggi liquida (H_l),

$$1{,}3186\ ft^3 = \frac{\pi}{4} . D^2 . H_l$$

$$1{,}3186\ ft^3 = \frac{\pi}{4} . (1{,}3\ ft)^2 . H_l$$

$$H_l = 0{,}9930\ ft$$

$$t_S = \frac{\rho.(H_l).(12.D)}{2.f.E.(144)} + C$$ (Brownell & Young, 1959, pers 3.18)

$$t_S = \frac{115{,}5597\ lb/ft^3 . (0{,}9930\ ft).(12 .1{,}3)\ in}{2.18750\ lb/in^2 .0{,}80.(144\ in^2/ft^2)} + \frac{1}{8} in$$

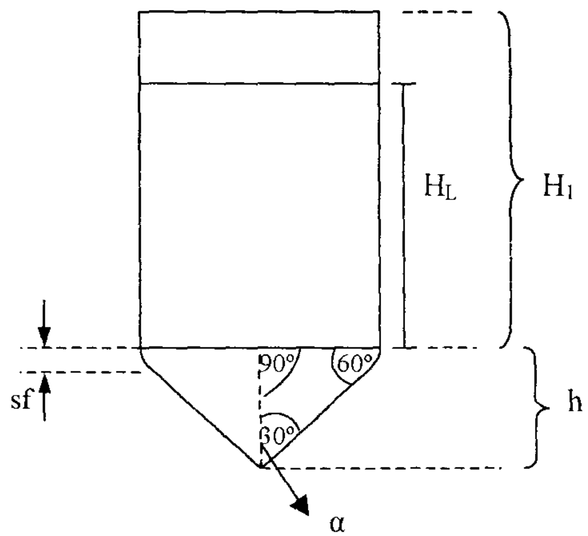
$t_S = 0{,}1254$ in → diambil t_S $\frac{3}{16}$ in

<u>Tutup atas berbentuk datar</u>

Tebal tutup flat-head = tebal shell = $\frac{3}{16}$ in

<u>Perancangan konis</u>

sf = 2 in (Brownell & Young, 1959, pp. 87, table 5.4)



Mencari tinggi liquid pada konis (h)

Sudut konis = 60°

$$\tan 60^\circ = \frac{h - sf}{0{,}5.D} \rightarrow h = \tan 60^\circ.0{,}5.D + sf$$

$$h = \tan 60^\circ . 0{,}5 . 1{,}3 \text{ ft} + (2 / 12) \text{ ft}$$

$$h = 1{,}2936 \text{ ft}$$

$$\text{Volume konis} = \frac{1}{3}.\frac{1}{4}.\pi.D^2.h$$

$$= \frac{1}{3}.\frac{1}{4}.\pi.(1{,}3 \text{ ft})^2 .1{,}2936 \text{ ft}$$

$$= 0{,}5726 \text{ ft}^3$$

Mencari tinggi liquida pada shell (H_L)

$$\text{Volume total} - \text{Volume konis} = \frac{1}{4}.\pi.D^2.H_L$$

$$1{,}3186\ ft^3 - 0{,}5726\ ft^3 = \frac{1}{4}.\pi.(1{,}3\ ft)^2.H_L$$

$$H_L = 0{,}5618\ ft$$

Tinggi liquid total (H)

$H = H_L + h$

$H = 0{,}5618\ ft + 1{,}2936\ ft$

$H = 1{,}8554\ ft$

Mencari tebal konis (t_K)

$$P_{hidrostatik} = \frac{\rho.H}{144} = \frac{115{,}5776\ lb/ft^3.1{,}8554\ ft}{144} = 1{,}4892\ lb/in^2$$

Sudut konis = 60° → α = 30°

Untuk $\alpha \leq 30°$ dapat dipakai rumus :

$$t_k = \frac{P.D}{2.\cos\alpha.(f.E - 0{,}6.P)} + C$$

(Brownell & Young, 1959, pp. 118, eq. 6.154)

$$t_k = \frac{1{,}4892\ lb/in^2.1{,}3\ ft}{2.\cos 30°.(18750\ lb/in^2.0{,}80 - 0{,}6.1{,}4892\ lb/in^2)} + \frac{1}{8}$$

$t_k = 0{,}1251$ in → diambil $t_k = \frac{3}{16}$ in

Jarak untuk pemasangan pipa dan perawatan = 3 ft

H total = tinggi silinder + tinggi konis + tebal head + jarak pemasangan pipa

= 1,3 ft + 1,2936 ft + 0,1875 ft + 3 ft

= 5,7811 ft

15. Screw Conveyor J – 334

Fungsi	: mengangkut tulang dari Screen H – 332 ke Tangki Penampung Produk F – 335
Tipe	: standart pitch screw conveyor
Dasar pemilihan	: membutuhkan ruang yang kecil, ekonomis dalam harga dan pemeliharaan, dapat dipasang vertikal, miring atau mendatar
Jumlah	: 1 buah

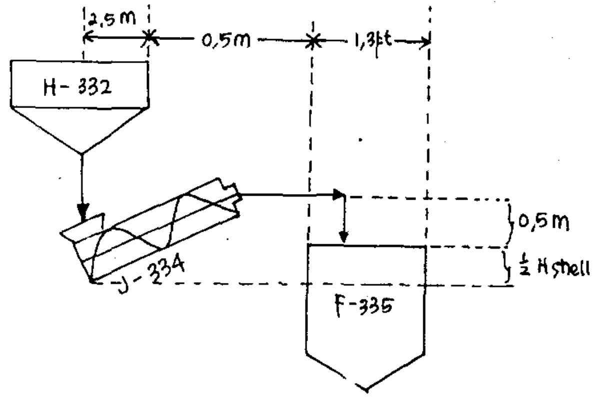
Perhitungan :

Kapasitas = 69,1170 kg / jam

Jarak screen ke Tumbling Mill = ½ panjang screen + 0,5 m + ½ D_{F-335}

= ½ . 5 m + 0,5 m + ½ 1,3 ft

= 4,7904 ft



H = 0,5 m + ½ H shell F – 335

H = 0,5 m + ½ . 1,3 ft

H = 2,2904 ft

Panjang Screw Conveyor J – 334 = $\sqrt{4{,}7904^2 + 2{,}2904^2}$ ft = 5,3098 ft ≈ 6 ft

Sudut Screw Conveyor J – 334 :

$$\tan x = \frac{2{,}2904 \text{ ft}}{4{,}7904 \text{ ft}} = 0{,}4781$$

$$x = 25{,}55^\circ$$

ρ H_2O pada 37°C = 0,99318 kg / lt = 62,0197 lb / ft³

(Geankoplis, 1993, pp.855, A.2-3)

Massa H_2O dalam campuran = 0,8122 kg

Massa campuran = 69,1170 kg

Fraksi H_2O dalam campuran = $\dfrac{\text{massa } H_2O}{\text{massa campuran}} = \dfrac{0{,}8122 \text{ kg}}{69{,}1170 \text{ kg}} = 0{,}0118$

Dengan cara yang sama dapat diperoleh seperti berikut :

Zat	Massa (kg)	Fraksi
$CaCl_2.2H_2O$	68,2934	0,9881
$CaCl_2$	0,0113	$1{,}64.10^{-4}$
H_2O	0,8122	0,0118
	69,1170	1

Sehingga :

$$\rho_{campuran} = \frac{1}{\left(\dfrac{X_{CaCl_2.2H_2O}}{\rho_{CaCl_2.2H_2O}} + \dfrac{X_{CaCl_2}}{\rho_{CaCl_2}} + \dfrac{X_{H_2O}}{\rho_{H_2O}}\right) \text{lt/kg}}$$

$$\rho_{campuran} = \frac{1}{\left(\dfrac{0{,}9881}{1{,}87} + \dfrac{1{,}64.10^{-4}}{2{,}152} + \dfrac{0{,}0118}{0{,}99318}\right) \text{lt/kg}}$$

$$\rho_{campuran} = 1{,}8508 \text{ kg/lt}$$

$\rho_{campuran}$ = 1,8508 kg / lt = 115,5767 lb / ft^3

$$\text{Massa yg dipindahkan} = 69{,}1170\frac{kg}{jam}.\ 2{,}205\frac{lb}{kg}.\frac{1\ jam}{60\,menit} = 2{,}54\ lb/menit$$

$$\text{Volume yang dipindahkan} = \frac{69{,}1170\,kg/jam}{1{,}8508\,kg/lt} = 37{,}3436\,lt/jam = 1{,}3188\,ft^3/jam$$

Maka kapasitas Screw Conveyor J – 334 = 1,3188 ft^3 / jam

Diameter Screw Conveyor = 3 in (untuk heavy abbrasive material dengan kapasitas kurang dari 37 ft^3 / jam)

(Brown, 1961, pp. 53, table 13)

<u>Power</u> :

$$hp = \frac{Co\,.Ca\,.L}{33000}$$, dimana : Co : koefisien (Co = 1,3)

Ca : kapasitas Screw Conveyor (= 2,54lb/menit)

L : panjang Screw Conveyor (= 5 ft)

(Brown, 1961, pp. 53)

$$hp = \frac{1{,}3\,.2{,}54\ lb/menit.6\ ft}{33000} = 0{,}0006\ hp$$

Efisiensi = 80% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$hp = \frac{0{,}0005\ hp}{0{,}8} = 0{,}0006\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0006 hp × 2 = 0,0015 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

27. Pompa (L – 111)

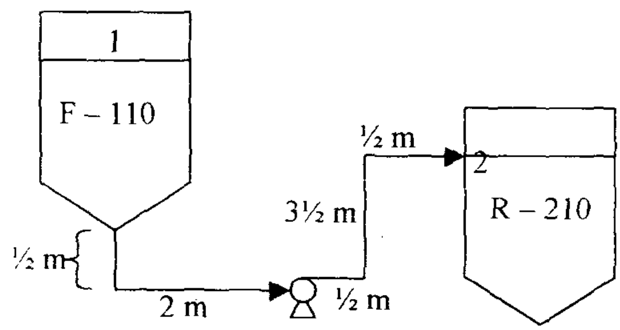
Fungsi : memompa waste $Ca(OH)_2$ dari Tangki Penampung Waste $Ca(OH)_2$ F – 110 menuju ke Reaktor R – 210

Tipe : gear pump

Dasar pemilihan : dapat digunakan untuk viskositas tinggi (2,5 sampai dengan 100.000 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 2 m + ½ m + 1½ m + ½ m

= 5 m = 16,404 ft ≈ 16,5 ft

Jumlah elbow = 3 buah

Jumlah valve = 2 (Gate Valve dan Globe Valve)

Tinggi feed masuk (Z_2) = 3,5 m = 11,4828 ft

Tinggi liquid pada Tangki Penampung Waste $Ca(OH)_2$ F – 110 = 9,2358 ft

Z_1 = ½ m + 9,2358 ft = 1,6404 ft + 9,2358 ft = 10,8762 ft

$\Delta Z \quad = Z_2 - Z_1$

$= 11{,}4828 \text{ ft} - 9{,}8762 \text{ ft}$

$= 0{,}6066 \text{ ft} = 0{,}1849 \text{ m}$

$\rho_{waste} = 1{,}0950 \text{ kg / lt} = 68{,}3810 \text{ lb / ft}^3 = 1095{,}05 \text{ kg / m}^3$

Volume bahan masuk R – 210 = 218,6147 lt / jam = 7,7194 ft^3 / jam

μ bahan masuk F – 110 = 1,69 cp

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk R} - 210}{3600 \text{ dt / jam}}$$

$$\text{Rate pemompaan (Q)} = \frac{7{,}7194 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0021 \text{ ft}^3 \text{ / dt}$$

$\text{ID optimum} = 3{,}9 \, . \, Q^{0,36} \, . \, \rho^{0,18}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \, . \, (0{,}0021 \text{ ft}^3 \text{ / dt})^{0,36} \, . \, (68{,}3810 \text{ lb / ft}^3)^{0,18}$

$= 0{,}4253 \text{ in}$

Maka dipilih pipa 3/8 in sch. 40 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,493 in = 0,0411 ft = 0,0125 m

OD = 0,675 in = 0,0563 ft = 0,0171 m

Luas penampang (A) = 0,00133 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{0{,}0021 \text{ ft}^3 \text{ / dt}}{0{,}00133 \text{ ft}^2} = 1{,}6122 \text{ ft / dt}$$

$$N_{Re} = \frac{ID.v_2.\rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0411\ ft.1{,}6122\ ft/dt.68{,}3810\ lb/ft^3}{1{,}69 cp.\ 6{,}72.10^{-4} lb/ft.dt.cp} = 3988{,}1498$$

N_{Re} > 2100 → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 . 10^{-5} → $\frac{e}{ID} = \frac{4{,}6.10^{-5} m}{0{,}0125 m} = 0{,}0037$

Sehingga : f = 0,009

Elbow 90° : 3 buah → $\frac{L_e}{ID} = 35$ → $L_e = 3.35.0{,}0411\ ft = 4{,}3138\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 1 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 9 . 0,0411 ft = 0,3698 ft

Globe valve : 1 buah → $\frac{L_e}{ID} = 300$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 300 . 0,0411 ft = 12,3250 ft

Panjang total = 13,5 ft + 4,3138 ft + 0,3698 ft + 12,3250 ft = 30,5085 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}009.(1{,}6122\ ft/dt)^2.30{,}5085\ ft}{32{,}1740 lb.ft/lb_f.dt^2\ 0{,}0411\ ft}$$

$$f = 1{,}0799\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C . v^2}{2 . g_c . \alpha} \rightarrow \text{ untuk aliran turbulen } \alpha = 1 \text{ dan } K_C = 0,55$$

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55.(1,6122 \text{ ft/dt})^2}{2.32,1740 \text{ lb.ft/lb}_f.\text{dt}^2.1}$$

$$f_C = 0,0222 \text{ ft.lb}_f/\text{lb}$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2 . g_c . \alpha}$$

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 1,6122 \text{ ft/dt})^2}{2.32,1740 \text{ lb.ft/lb}_f.\text{dt}^2.1}$$

$$f_e = 0,0404 \text{ ft.lb}_f/\text{lb}$$

$\Sigma F = f + f_C + f_e = (1,0799 + 0,0222 + 0,0404) \text{ ft . lb}_f/\text{lb}$

$= 1,1425 \text{ ft . lb}_f/\text{lb}$

<u>Asumsi</u> : $\Delta P = 1,5 \text{ atm} = 22,04 \text{ lb/in}^2 = 3174,4005 \text{ lb/ft}^2$

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$0,6066 \text{ ft} + \frac{0^2 - (1,6122 \text{ ft/dt})^2}{2.32,1740 \text{ lb.ft/lb}_f.\text{dt}^2} - \frac{3174,4005 \text{ lb/ft}^2}{68,381 \text{ lb/ft}^3} - 1,1425 \text{ ft.lb}_f/\text{lb} = W_S$$

$$W_S = -46,9986 \text{ ft.lb}_f/\text{lb}$$

$$m_1 = \frac{239,3939 \text{ kg/jam}}{3600 \text{ dt/jam}} = 0,0665 \text{ kg/dt} = 0,1466 \text{ lb/dt}$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S \cdot m_l}{\eta \cdot 550} = \frac{46{,}9986\,\text{ft.lb}_f/\text{lb} \cdot 0{,}1466\,\text{lb/dt}}{0{,}20 \cdot 550} = 0{,}0626\ \text{ft.lb}_f/\text{dt}$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}0626\ \text{hp} = 0{,}0737\ \text{hp}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0737 hp × 2 = 0,1466 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

28. Pompa (L – 121)

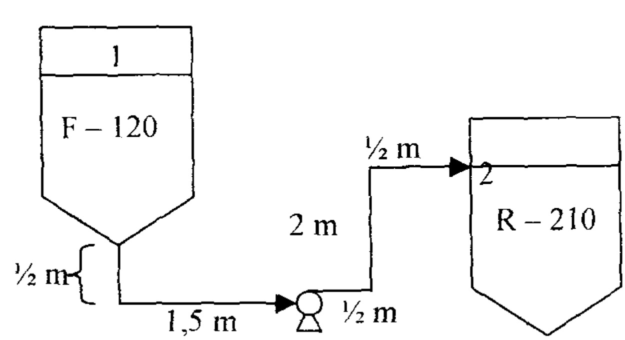
Fungsi : memompa larutan HCl dari Tangki Penampung larutan HCl F – 120 menuju ke Reaktor R – 210

Tipe : centrifugal pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas rendah (< 2,5 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1½ m + ½ m + 2 m + ½ m

= 5 m = 16,404 ft ≈ 16,5 ft

Jumlah elbow = 3 buah

Jumlah valve = 2 (Gate Valve dan Globe Valve)

Tinggi feed masuk (Z_2) = 2 m = 6,5616 ft

Tinggi liquid pada Tangki Penampung Larutan HCl F –120 = 4,2447 ft

Z_1 = ½ m + 4,2447 ft = 1,6404 ft + 4,2447 ft = 5,8851 ft

$\Delta Z = Z_2 - Z_1$

= 6,5616 ft – 5,8851 ft

= 0,6765 ft = 0,2062 m

$\rho_{larutan\ HCl}$ = 1,1085 kg / lt = 69,2203 lb / ft³ = 1108,4896 kg / m³

Volume bahan masuk R – 210 = 114,7570 lt / jam = 4,0522 ft³ / jam

μ bahan masuk F – 120 = 1,0634 cp

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk R} - 210}{3600\ \text{dt / jam}}$$

$$\text{Rate pemompaan (Q)} = \frac{4{,}0522\ \text{ft}^3\ /\ \text{jam}}{3600\ \text{dt / jam}} = 0{,}0011\ \text{ft}^3\ /\ \text{dt}$$

ID optimum $= 3{,}9\ .\ Q^{0{,}36}\ .\ \rho^{0{,}18}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9\ .\ (0{,}0011\ \text{ft}^3\ /\ \text{dt})^{0{,}36}\ .\ (69{,}2203\ \text{lb / ft}^3)^{0{,}18}$

= 0,3187 in

Maka dipilih pipa 1/4 in sch. 40 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,364 in = 0,0303 ft = 0,0092 m

OD = 0,540 in = 0,0450 ft = 0,0137 m

Luas penampang (A) = 0,00072 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{0{,}0011\ ft^3/dt}{0{,}00072\ ft^2} = 1{,}5633\ ft/dt$$

$$N_{Re} = \frac{ID.v_2.\rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0303\ ft.1{,}5633\ ft/dt.69{,}2203\ lb/ft^3}{1{,}0634\,cp.\ 6{,}72.10^{-4}\ lb/ft.dt.cp} = 4593{,}4575$$

N_{Re} > 2100 → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 . 10^{-5}, $\frac{e}{ID} = \frac{4{,}6.10^{-5}\,m}{0{,}0092\,m} = 0{,}0050$

Sehingga : f = 0,009

Elbow 90°: 3 buah → $\frac{L_e}{ID} = 35$ → $L_e = 3.35.0{,}0303$ ft = 3,1850 ft

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 1 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 9 . 0,0303 ft = 0,2730 ft

Globe valve : 1 buah → $\frac{L_e}{ID} = 300$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 300 . 0,0303 ft = 9,100 ft

Panjang total = 16,5 ft + 3,1850 ft + 0,2730 ft + 9,1 ft = 29,058 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}18.(1{,}5633\ ft/dt)^2.29{,}058\ ft}{32{,}1740\ lb.ft/lb_f.dt^2\ 0{,}0303\ ft}$$

$$f = 13{,}0983\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar $\alpha = 1$ dan $K_C = 0{,}55$

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55.(1{,}5633\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1}$$

$$f_C = 0{,}0209\ ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0-1{,}5633\ ft/dt)^2}{2.32{,}1740\,lb.ft/lb_f.dt^2.1}$$

$$f_e = 0{,}038\ ft.lb_f/lb$$

$$\Sigma F = f + f_C + f_e = (13{,}0983 + 0{,}0209 + 0{,}038)\ ft.lb_f/lb$$

$$= 13{,}1572\ ft.lb_f/lb$$

<u>Asumsi</u> : $\Delta P = 1{,}5$ atm $= 22{,}04\ lb/in^2 = 3174{,}4005\ lb/ft^2$

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$0{,}6765\ ft + \frac{0^2 - 1{,}5633^2}{2.32{,}1740\ lb.ft/lb_f.dt^2} - \frac{3174{,}4005\ lb/ft^2}{69{,}2203\ lb/ft^3} - 13{,}1572\ ft.lb_f/lb = W_S$$

$$W_S = -58{,}3780\ ft.lb_f/lb$$

$$m_1 = \frac{127{,}2070\ kg/jam}{3600\ dt/jam} = 0{,}0353\ kg/dt = 0{,}0779\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_1}{\eta.550} = \frac{58{,}3780\,ft.lb_f/lb.0{,}0779\,lb/dt}{0{,}20.550} = 0{,}0414\,ft.lb_f/dt$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}0414\ hp = 0{,}0486\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0486 hp × 2 = 0,0973 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

29. Pompa (L – 212)

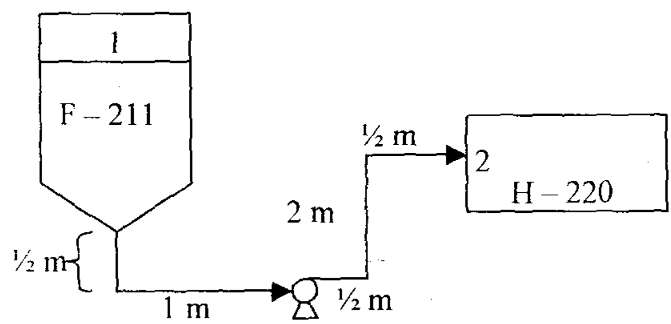
Fungsi : memompa hasil reaksi dari Tangki Penampung Hasil Reaksi F – 211 menuju ke Centrifugal Separator H – 220

Tipe : centrifugal pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas rendah (< 2,5 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1 m + ½ m + 2 m + ½ m

= 4,5 m = 14,7636 ft ≈ 15 ft

Jumlah elbow = 3 buah

Jumlah valve = 2 (Gate Valve dan Globe Valve)

Tinggi feed masuk (Z_2) = 2 m = 6,5616 ft

Tinggi liquid pada Tangki Penampung Hasil Reaksi F – 211 = 3,8021 ft

Z_1 = ½ m + 3,8021 ft = 1,6404 ft + 3,8021 ft = 5,4425 ft

$\Delta Z = Z_2 - Z_1$

= 6,5616 ft – 5,4425 ft

= 1,1191 ft = 0,3411 m

$\rho_{hasil\ reaksi}$ = 1,0607 kg / lt = 66,2368 lb / ft^3 = 1060,712 kg / m^3

Volume bahan masuk F – 211 = 345,6179 lt / jam = 12,2040 ft^3 / jam

μ bahan masuk F – 211 = 1,0338 cp

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk F} - 211}{3600 \text{ dt / jam}}$$

$$\text{Rate pemompaan (Q)} = \frac{12{,}2040 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0034 \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3{,}9 \cdot Q^{0,36} \cdot \rho^{0,18}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \cdot (0{,}0034 \text{ ft}^3 / \text{dt})^{0,36} \cdot (66{,}2368 \text{ lb / ft}^3)^{0.18}$

$= 0{,}5205$ in

Maka dipilih pipa ½ in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,546 in = 0,0455 ft = 0,0139 m

OD = 0,84 in = 0,07 ft = 0,0213 m

Luas penampang (A) = 0,00163 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{0{,}0034 \text{ ft}^3 \text{ / dt}}{0{,}00163 \text{ ft}^2} = 2{,}0798 \text{ ft / dt}$$

$$N_{Re} = \frac{ID \cdot v_2 \cdot \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0455 \text{ ft} \cdot 2{,}0798 \text{ ft / dt} \cdot 66{,}2368 \text{ lb / ft}^3}{1{,}0338 \text{cp} \cdot 6{,}72 \cdot 10^{-4} \text{ lb / ft.dt.cp}} = 9022{,}1916$$

N_{Re} > 2100 → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 . 10^{-5} , $\frac{e}{ID} = \frac{4{,}6.10^{-5}\,m}{0{,}0139\,m} = 0{,}0033$

Sehingga : f = 0,009

Elbow 90° : 3 buah → $\frac{L_e}{ID} = 35 \rightarrow L_e = 3.35.0{,}0455\ ft = 4{,}7775\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 1 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 9 . 0,0455 ft = 0,4095 ft

Globe valve : 1 buah → $\frac{L_e}{ID} = 300$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 300 . 0,0455 ft = 13,65 ft

Panjang total = 15 ft + 4,7775 ft + 0,4095 ft + 13,65 ft = 33,8370 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}009.(2{,}0798\ ft/dt)^2.33{,}8370\ ft}{32{,}1740\,lb.ft/lb_f.dt^2\ 0{,}0455\ ft}$$

$$f = 17{,}9959\ ft.lb_f/lb$$

b. *Friksi karena kontraksi dari tangki ke pipa*

$$f_C = \frac{K_C . v^2}{2.g_c.\alpha} \rightarrow \text{untuk aliran laminar } \alpha = 1 \text{ dan } K_C = 0{,}55$$

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55.(2{,}0798 \text{ ft/dt})^2}{2.32{,}1740 \text{ lb.ft/lb}_f.\text{dt}^2.1}$$

$$f_C = 0{,}0370 \text{ ft.lb}_f/\text{lb}$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 2{,}0798 \text{ ft/dt})^2}{2.32{,}1740 \text{ lb.ft/lb}_f.\text{dt}^2.1}$$

$$f_e = 0{,}0672 \text{ ft.lb}_f/\text{lb}$$

$\Sigma F = f + f_C + f_e = (17{,}9959 + 0{,}0370 + 0{,}0672)$ ft . lb_f/ lb

$= 18{,}1001$ ft . lb_f/ lb

<u>Asumsi</u> : $\Delta P = 1{,}5$ atm $= 22{,}04$ lb / in^2 $= 3174{,}4005$ lb / ft^2

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$1{,}1191 \text{ ft} + \frac{0^2 - (2{,}0798 \text{ ft/dt})^2}{2.32{,}1740 \text{ lb.ft/lb}_f.\text{dt}^2} - \frac{3174{,}4005 \text{ lb/ft}^2}{66{,}2368 \text{ lb/ft}^3} - 18{,}1001 \text{ ft.lb}_f/\text{lb} = W_S$$

$$W_S = -64{,}9733 \text{ ft.lb}_f/\text{lb}$$

$$m_1 = \frac{366{,}6009 \text{ kg/jam}}{3600 \text{ dt/jam}} = 0{,}1018 \text{ kg/dt} = 0{,}2245 \text{ lb/dt}$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_1}{\eta.550} = \frac{64{,}9733\,\text{ft.lb}_f/\text{lb}.0{,}2245\,\text{lb/dt}}{0{,}20.550} = 0{,}1326\,\text{ft.lb}_f/\text{dt}$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%}0{,}1326 \text{ hp} = 0{,}1560 \text{ hp}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,1560 hp × 2 = 0,3121 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

30. Pompa (L – 224)

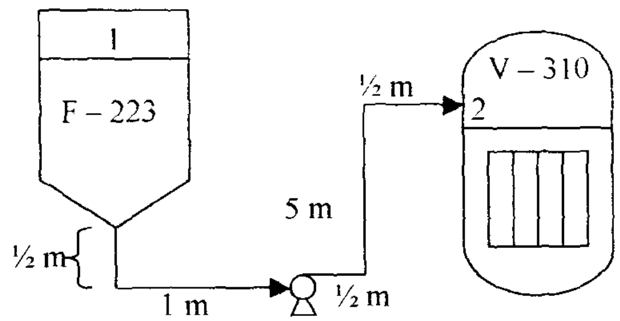
Fungsi : memompa larutan $CaCl_2$ dari Tangki Penampung Larutan $CaCl_2$ F – 223 menuju ke Evaporator V – 310

Tipe : centrifugal pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas rendah (< 2,5 cp)

Jumlah : 1 buah

Sketsa :



<u>Perhitungan</u> :

Perkiraan panjang pipa lurus = ½ m + 1 m + ½ m + 5 m + ½ m

= 7,5 m = 24,606 ft ≈ 25 ft

Jumlah elbow = 3 buah

Jumlah valve = 2 (Gate Valve dan Globe Valve)

Tinggi feed masuk (Z_2) = 5 m = 16,404 ft

Tinggi liquid pada Tangki Penampung Larutan $CaCl_2$ F – 223 = 3,6809 ft

Z_1 = ½ m + 3,6809 ft = 1,6404 ft + 3,6809 ft = 5,3213 ft

$\Delta Z \;= Z_2 - Z_1$

$= 16{,}404 \text{ ft} - 5{,}3213 \text{ ft}$

$= 11{,}0827 \text{ ft} = 3{,}3781 \text{m}$

$\rho_{\text{larutan } CaCl_2} = 1{,}0550 \text{ kg / lt} = 65{,}8784 \text{ lb / ft}^3 = 1054{,}9720 \text{ kg / m}^3$

Volume bahan masuk F – 223 = 325,9475 lt / jam = 11,5094 ft^3 / jam

μ bahan masuk F – 223 = 1,0598 cp

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk F} - 223}{3600 \text{ dt / jam}}$$

$$\text{Rate pemompaan (Q)} = \frac{325{,}9475 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 0{,}0032 \text{ ft}^3 \text{ / dt}$$

$\text{ID optimum} = 3{,}9 \,.\, Q^{0,36} \,.\, \rho^{0,18}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \,.\, (0{,}0032 \text{ ft}^3 / \text{dt})^{0,36} \,.\, (65{,}8784 \text{ lb / ft}^3)^{0,18}$

$= 0{,}5066 \text{ in}$

Maka dipilih pipa 1/2 in sch. 80 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,546 in = 0,0455 ft = 0,0139 m

OD = 0,84 in = 0,07 ft = 0,0213 m

Luas penampang (A) = 0,00163 ft^2

Kecepatan aliran mula-mula = v_1 = 0

$$v_2 = \frac{Q}{A} = \frac{0{,}0032\ ft^3/dt}{0{,}00163\ ft^2} = 1{,}9614\ ft/dt$$

$$N_{Re} = \frac{ID \cdot v_2 \cdot \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0455\ ft . 1{,}9614\ ft/dt . 65{,}8784\ lb/ft^3}{1{,}0598 cp .\ 6{,}72.10^{-4} lb/ft.dt.cp} = 8255{,}9525$$

N_{Re} > 2100 → aliran turbulen → dari Geankoplis, 1993, pp. 88, fig. 2.10-3 diperoleh :

Digunakan pipa commercial steel, e = 4,6 .10^{-5} , $\frac{e}{ID} = \frac{4{,}6.10^{-5}\ m}{0{,}0139 m} = 0{,}0033$

Sehingga : f = 0,009

<u>Elbow 90°</u> : 3 buah → $\frac{L_e}{ID} = 35$ → $L_e = 3.35.0{,}0455$ ft = 4,7775 ft

(Geankoplis, 1993, pp. 93, table 2.10-1)

<u>Gate valve</u> : 1 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 9 . 0,0455 ft = 0,4095 ft

Globe valve : 1 buah → $\frac{L_e}{ID} = 300$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 300 . 0,0455 ft = 13,65 ft

Panjang total = 25 ft + 4,7775 ft + 0,4095 ft + 13,65 ft = 43,8370 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0,009.(1,9614\ ft/dt)^2.43,8370\ ft}{32,1740\ lb.ft/lb_f.dt^2\ 0,0455\ ft}$$

$$f = 20,736\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar $\alpha = 1$ dan $K_C = 0,55$

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0,55.(1,9614\ ft/dt)^2}{2.32,1740\ lb.ft/lb_f.dt^2.1}$$

$$f_C = 0,0329\ ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 1{,}9614\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2.1}$$

$$f_e = 5{,}9785\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (20,736 + 0,0329 + 5,9785) lb_f / lb

= 20,829 lb_f / lb

<u>Asumsi</u> : ΔP = 1,5 atm = 22,04 lb / in^2 = 3174,4005 lb / ft^2

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$11{,}0827\ ft + \frac{0^2 - (1{,}9614\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2} - \frac{3174{,}4005\ lb/ft^2}{65{,}8784\ lb/ft^3} - 20{,}829\ ft.lb_f/lb = W_S$$

$$W_S = -57{,}9915\ ft.lb_f/lb$$

$$m_1 = \frac{343{,}8655\ kg/jam}{3600\ dt/jam} = 0{,}0955\ kg/dt = 0{,}2106\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_1}{\eta.550} = \frac{57{,}9915\ ft.lb_f/lb.0{,}2106\ lb/dt}{0{,}20.550} = 0{,}111\ ft.lb_f/dt$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%}0{,}111\ hp = 0{,}1306\ hp$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,1306 hp × 2 = 0,2613 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

31. Pompa (L – 311)

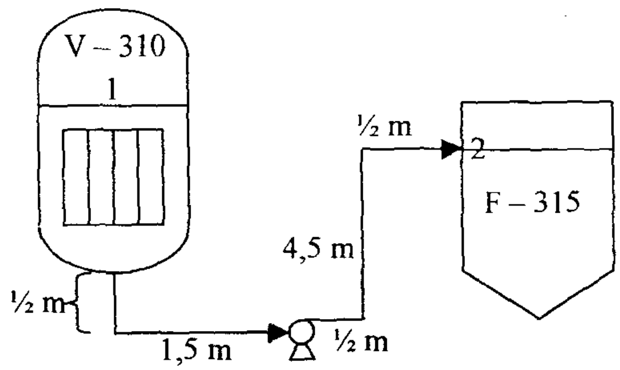
Fungsi : memompa larutan $CaCl_2$ pekat dari Evaporator V – 310 menuju ke Tangki Penampung Larutan Pekat $CaCl_2$ F – 315

Tipe : gear pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas tinggi (2,5 cp – 100.000 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1,5 m + ½ m + 4,5 m + ½ m

= 7,5 m = 24,606 ft ≈ 25 ft

Jumlah elbow = 3 buah

Jumlah valve = 2 (Gate Valve dan Globe Valve)

Tinggi feed masuk (Z_2) = 4,5 m = 14,7636 ft

Tinggi liquid pada Evaporator V – 310 = 5 ft

Z_1 = ½ m + 5 ft = 1,6404 ft + 5 ft = 6,6404 ft

$\Delta Z \quad = Z_2 - Z_1$

$= 14{,}7636 \text{ ft} - 6{,}6404 \text{ ft}$

$= 8{,}1232 \text{ ft} = 2{,}4760 \text{ m}$

$\rho_{\text{larutan CaCl}_2\text{pekat}} = 0{,}2125 \text{ kg / lt} = 13{,}2682 \text{ lb / ft}^3 = 212{,}4755 \text{ kg / m}^3$

Volume bahan masuk F – 315 = 42,5545 lt / jam = 1,5026 ft^3 / jam

μ bahan masuk F – 315 = 8,9863 cp

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk F} - 315}{3600 \text{ dt / jam}}$$

$$\text{Rate pemompaan (Q)} = \frac{1{,}5026 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 4{,}174.10^{-4} \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3{,}9 \cdot \dot{Q}^{0,36} \cdot \rho^{0,18}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3{,}9 \cdot (4{,}174.10^{-4} \text{ ft}^3 \text{ / dt})^{0,36} \cdot (13{,}2682 \text{ lb / ft}^3)^{0,18}$

$= 0{,}2143 \text{ in}$

Maka dipilih pipa 1/8 in sch. 40 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,269 in = 0,0224 ft = 0,0068 m

OD = 0,405 in = 0,0338 ft = 0,0103 m

Luas penampang (A) = 0,0004 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{4{,}174.10^{-4} \text{ ft}^3 \text{ / dt}}{0{,}0004 \text{ ft}^2} = 1{,}0435 \text{ ft / dt}$$

$$N_{Re} = \frac{ID \cdot v_2 \cdot \rho_{campuran}}{\mu_{campuran}} = \frac{0{,}0224\ ft \cdot 1{,}0435\ ft/dt \cdot 13{,}2682\ lb/ft^3}{8{,}9863\, cp \cdot 6{,}72 \cdot 10^{-4}\, lb/ft.dt.cp} = 392{,}8735$$

$N_{Re} < 2100$ → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : $f = 0{,}18$

Elbow 90° : 3 buah → $\frac{L_e}{ID} = 35 \rightarrow L_e = 3.35.0{,}0224\ ft = 2{,}3538\ ft$

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 1 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

$Le = 1 \,.\, 9 \,.\, 0{,}0224\ ft = 0{,}2018\ ft$

Globe valve : 1 buah → $\frac{L_e}{ID} = 300$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

$Le = 1 \,.\, 300 \,.\, 0{,}0224\ ft = 6{,}7250\ ft$

Panjang total = 25 ft + 2,3538 ft + 0,2018 ft + 6,7250 ft = 34,2805 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}18.(1{,}0435\ ft/dt)^2.34{,}2805\ ft}{32{,}1740\, lb.ft/lb_f.dt^2\ 0{,}0224\ ft}$$

$$f = 9{,}3158\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C . v^2}{2 . g_c . \alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55.(1{,}0435\ ft/dt)^2}{2.32{,}1740\,lb.ft/lb_f.dt^2.1/2}$$

$$f_C = 0{,}0093\,ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2 . g_c . \alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 1{,}0435\ ft/dt)^2}{2.32{,}1740\,lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0{,}0169\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (9,3158 + 0,0093 + 0,0169) ft . lb_f / lb

= 9,3421 ft . lb_f / lb

<u>Asumsi</u> : ΔP = 1,5 atm = 22,04 lb / in^2 = 3174,4005 lb / ft^2

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$8{,}1232\ ft + \frac{0^2 - (1{,}0435\ ft/dt)^2}{2.32{,}1740\ lb.ft/lb_f.dt^2} - \frac{3174{,}4005\ lb/ft^2}{13{,}2682\ lb/ft^3} - 9{,}3421\ ft.lb_f/lb = W_S$$

$$W_S = -32{,}5341\ ft.lb_f/lb$$

$$m_1 = \frac{69{,}1170\ kg/jam}{3600\ dt/jam} = 0{,}0192\ kg/dt = 0{,}0423\ lb/dt$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S . m_1}{\eta.550} = \frac{32{,}5341\,\text{ft.lb}_f/\text{lb}.0{,}0423\,\text{lb/dt}}{0{,}20.550} = 0{,}0125\,\text{ft.lb}_f/\text{dt}$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}0125\ \text{hp} = 0{,}0147\ \text{hp}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0147 hp × 2 = 0,0295 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

32. Pompa (L – 316)

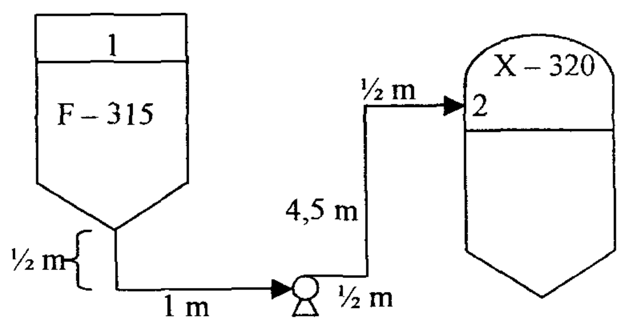
Fungsi : memompa larutan $CaCl_2$ pekat dari Tangki Penampung Larutan Pekat $CaCl_2$ F – 315 menuju ke Kristaliser X – 320

Tipe : gear pump

Dasar pemilihan : cocok digunakan untuk bahan berviskositas tinggi (2,5 cp – 100.000 cp)

Jumlah : 1 buah

Sketsa :



Perhitungan :

Perkiraan panjang pipa lurus = ½ m + 1 m + ½ m + 4,5 m + ½ m

= 7 m = 22,9656 ft ≈ 23 ft

Jumlah elbow = 3 buah

Jumlah valve = 2 (Gate Valve dan Globe Valve)

Tinggi feed masuk (Z_2) = 4,5 m = 14,7636 ft

Tinggi liquid pada Tangki Penampung Larutn Pekat $CaCl_2$ F – 315 = 1,4 ft

Z_1 = ½ m + 1,4 ft = 1,6404 ft + 1,4 ft = 3,5363 ft

$\Delta Z = Z_2 - Z_1$

$= 14,7636$ ft – 3,5363 ft

$= 11,2273$ ft = 3,4221 m

$\rho_{\text{larutan } CaCl_2 \text{ pekat}} = 0,2129 \text{ kg / lt} = 18,2267 \text{ lb / ft}^3 = 291,8819 \text{ kg / m}^3$

Volume bahan masuk X – 320 = 42,8620 lt / jam = 1,5135 ft^3 / jam

μ bahan masuk X – 320 = 6,2437 cp

$$\text{Rate pemompaan (Q)} = \frac{\text{volume bahan masuk X} - 320}{3600 \text{ dt / jam}}$$

$$\text{Rate pemompaan (Q)} = \frac{1,5135 \text{ ft}^3 \text{ / jam}}{3600 \text{ dt / jam}} = 4,2041.10^{-4} \text{ ft}^3 \text{ / dt}$$

ID optimum $= 3,9 \cdot Q^{0,36} \cdot \rho^{0,18}$ (Peter & Timmerhaus, 1985, pp. 496)

$= 3,9 \cdot (4,2041.10^{-4} \text{ ft}^3 \text{ / dt})^{0,36} \cdot (18,2267 \text{ lb / ft}^3)^{0,18}$

$= 0,2148$ in

Maka dipilih pipa 1/8 in sch. 40 (Geankoplis, 1993, pp. 892, A.5-1) dengan data-data sebagai berikut :

ID = 0,269 in = 0,0224 ft = 0,0068 m

OD = 0,405 in = 0,0338 ft = 0,0103 m

Luas penampang (A) = 0,0004 ft^2

Kecepatan aliran mula-mula = $v_1 = 0$

$$v_2 = \frac{Q}{A} = \frac{4,2041.10^{-4}\ ft^3/dt}{0,0004\ ft^2} = 1,0510\ ft/dt$$

$$N_{Re} = \frac{ID.v_2.\rho_{campuran}}{\mu_{campuran}} = \frac{0,0224\ ft.1,0510\ ft/dt.18,2267\ lb/ft^3}{6,2437 cp.\ 6,72.10^{-4} lb/ft.dt.cp} = 536,5947$$

$N_{Re} < 2100$ → aliran laminar → dari Geankoplis, 1993, pp. 88, fig. 2.10-3

diperoleh : f = 0,18

Elbow 90°: 3 buah → $\frac{L_e}{ID} = 35$ → $L_e = 3.35.0,0224$ ft = 2,3538 ft

(Geankoplis, 1993, pp. 93, table 2.10-1)

Gate valve : 1 buah → $\frac{L_e}{ID} = 9$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 9 . 0,0224 ft = 0,2018 ft

Globe valve : 1 buah → $\frac{L_e}{ID} = 300$ (pada keadaan wide open)

(Geankoplis, 1993, pp. 93, table 2.10-1)

Le = 1 . 300 . 0,0224 ft = 6,7250 ft

Panjang total = 23 ft + 2,3538 ft + 0,2018 ft + 6,7250 ft = 32,2805 ft

a. Friksi karena gesekan dalam pipa

$$f = \frac{2.f.v^2.L}{g_c.D}$$

$$f = \frac{2.0{,}18.(1{,}0510\ ft/dt)^2.32{,}2805\ ft}{32{,}1740\, lb.ft/lb_f.dt^2\ 0{,}0224\ ft}$$

$$f = 8{,}8996\ ft.lb_f/lb$$

b. Friksi karena kontraksi dari tangki ke pipa

$$f_C = \frac{K_C.v^2}{2.g_c.\alpha}$$ → untuk aliran laminar α = ½ dan K_C = 0,55

(Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_C = \frac{0{,}55.(1{,}0510\ ft/dt)^2}{2.32{,}1740\, lb.ft/lb_f.dt^2.1/2}$$

$$f_C = 0{,}0094\, ft.lb_f/lb$$

c. Friksi karena perluasan (enlargement)

$$f_e = \frac{(v_1 - v_2)^2}{2.g_c.\alpha}$$ (Geankoplis, 1993, pp. 93, eq. 2.10-16)

$$f_e = \frac{(0 - 1{,}0510\ ft/dt)^2}{2.32{,}1740\, lb.ft/lb_f.dt^2.1/2}$$

$$f_e = 0{,}0172\ ft.lb_f/lb$$

$\Sigma F = f + f_C + f_e$ = (8,8996 + 0,0094 + 0,0172) ft . lb_f / lb

= 8,9262 ft . lb_f / lb

<u>Asumsi</u> : ΔP = 1,5 atm = 22,04 lb / in^2 = 3174,4005 lb / ft^2

$$\Delta Z + \frac{\Delta v^2}{2.g_c} + \frac{\Delta P}{\rho} - \Sigma F = W_S$$

$$3{,}4221\ \text{ft} + \frac{0^2 - (1{,}0510\ \text{ft/dt})^2}{2.32{,}1740\ \text{lb.ft/lb}_f.\text{dt}^2} - \frac{3174{,}4005\ \text{lb/ft}^2}{6{,}2437\ \text{lb/ft}^3} - 8{,}9262\ \text{ft.lb}_f/\text{lb} = W_S$$

$$W_S = -29{,}2406\ \text{ft.lb}_f/\text{lb}$$

$$m_l = \frac{69{,}1170\ \text{kg/jam}}{3600\ \text{dt/jam}} = 0{,}0192\ \text{kg/dt} = 0{,}0423\ \text{lb/dt}$$

Efisiensi pompa = 20%

$$\text{Brake hp} = \frac{-W_S.m_l}{\eta.550} = \frac{29{,}2406\,\text{ft.lb}_f/\text{lb}.0{,}0423\,\text{lb/dt}}{0{,}20.550} = 0{,}0113\ \text{ft.lb}_f/\text{dt}$$

Efisiensi motor = 85% (Peter & Timmerhaus, 1985, pp. 521, Fig. 14-38)

$$\text{Power} = \frac{100\%}{85\%} 0{,}0113\,\text{hp} = 0{,}0133\ \text{hp}$$ → power < 2 hp

Menurut Badger, 1957, pp. 173, jika power < 2 hp maka power perlu dikalikan 2 sehingga menjadi :

Power = 0,0133 hp × 2 = 0,0265 hp → dipilih motor 0,5 hp

Bahan konstruksi : carbon steel

26. Condenser (E – 312)

Fungsi : mengembunkan uap air yang keluar dari Evaporator V – 310

Tipe : horizontal 1-2 condenser

Dasar pemilihan : desainnya sederhana, luas perpindahan panasnya besar, pressure drop-nya kecil

Jumlah : 1 buah

Perhitungan :

1. **Heat Balance**

Massa uap air = 274,7485 kg / jam = 605,8204 lb / jam

Dari App. B dapat diperoleh :

- Air pendingin, Q = 48021,6827 kJ / jam = 45515,5941 Btu / jam

Massa air pendingin yg dibutuhkan = 41438,4950 kg / jam

= 91173,4315 lb / jam

2. **ΔT_{LMTD}**

$\Delta T_1 = T_2 - t_1 = 40°C - 30°C = 10°C = 50°F$

$\Delta T_2 = T_1 - t_2 = 150°C - 35°C = 115°C = 239°F$

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = \frac{50° F - 239° F}{\ln \frac{50° F}{239° F}} = 202,77° F$$

3. **T_C dan t_C**

$F_C = 0,5$ (non minyak bumi)

$T_C = 40°C + (0,5\ (150 - 40)°C) = 95°C = 203°F$

$t_C = 30°C + (0,5\ (35 - 30)°C) = 32,5°C = 90,5°F$

Asumsi : L = 48 in = 4 ft (Badger, 1995, pp. 208)

$U_D = 2,0112$ Btu / ft^2. jam .°F

$$A = \frac{Q}{U_D . \Delta T_{LMTD}} = \frac{48021,6827\ \text{Btu / jam}}{2,0112\ \text{Btu / ft}^2.\text{jam}.°F . 202,77° F} = 117,7546\ \text{ft}^2$$

Dipilih tube dengan OD = 1¼ in, sehingga a" = 0,3271 ft^2 / lin ft

(Kern, 1965, pp. 843, table 10)

$$\text{Number of tubes, } N_t = \frac{A}{a''.4} = \frac{117{,}7546}{0{,}3271\,.4} = 91$$

$$\left.\begin{array}{l} N_t = 91 \\ OD = 1\frac{1}{4} \text{ in on } 1\frac{9}{16} \text{in triangular pitch} \end{array}\right\} \text{ID shell} = 19\frac{1}{4} \text{ in ; 2 passes}$$

(Kern, 1965, pp. 842, table 9)

$$A = 91\ .\ 4\ .\ 0{,}3271 = 117{,}7547\ ft^2$$

$$U_D = \frac{Q}{A\,.\,\Delta T_{LMTD}} = \frac{48021{,}6827\ \text{Btu / jam}}{117{,}7547\ ft^2\,.\,202{,}77°F} = 2{,}0112\ \text{Btu}/ft^2.\text{jam}.°F$$

Shell side (Uap air, fluida panas)	**Tube side (air pendingin, fluida dingin)**
4. Pt = 1,54 in C' = P_t – OD = (1,54 – 1,25) in = 0,29 in B = 5 in $a_s = \frac{ID.C'.B}{144.P_t} = \frac{19{,}25.0{,}29.5}{144.1{,}54} = 0{,}1259\ ft^2$ (Kern, 1965, pp. 138, eq. 7.1)	**4.** $a'_t = 0{,}985\ in^2$ (Kern, 1965, pp. 843, table 10) $a_t = \frac{N_t.a'_t}{144.n} = \frac{91.0{,}985}{144.2} = 0{,}3078$ (Kern, 1965, pp. 150, eq.7.48)
5. $G_S = \frac{W}{a_s} = \frac{605{,}8204\ lb}{0{,}1259\ ft^2} = 4813{,}1389\ lb/ft^2$	**5.** $G_t = \frac{W}{a_t} = \frac{91173{,}4315\ lb}{0{,}3078\ ft^2} = 296197{,}9502\ lb/ft^2$
6. $G'' = \frac{W}{L.N_t^{2/3}} = \frac{605{,}8204\ lb}{4\ ft.91^{2/3}} = 7{,}5415\ lb/hr.ft$ (Kern, 1965, pp. 266, eq. 12.43) <u>Asumsi</u> : h_o = 150 Btu/hr.ft^2.°F Dari (8) diperoleh h_{io}=1075 Btu/hr.ft^2.°F $t_w = tc + \frac{h_o}{h_o + h_{io}}(T_V - tc)$ $t_w = 90{,}5 + \frac{150}{150+1075}(788-90{,}5) = 175{,}9°F$ (Kern, 1965, pp. 98, eq. 5.31) $t_f = \frac{T_V + tw}{2} = \frac{788+175{,}9}{2} = 481{,}95°F$ (Kern, 1965, pp. 260, eq. 12.19)	**6.** $V = \frac{G_t}{3600.\rho} = \frac{296197{,}9502\ lb/ft^2}{3600\ s.62{,}5\ lb/ft^3} = 1{,}316\ fps$ Pada t_C =90,5°F, μ=0,7679cp =1,8576 lb/ft.h (Geankoplis, 1993, pp. 855, A.2–4) D = 0,62 / 12 = 0,0517 ft (Kern,1965,pp. 843, table 10) $Re_t = \frac{D.G_t}{\mu} = \frac{0{,}0517.14849{,}73}{1{,}8576} = 8238{,}32$ (Kern, 1965, pp. 138, eq. 7.3) **7.** h_i= 1300 Btu / hr . ft^2 . °F (Kern, 1965, pp. 834, fig. 25) **8.** $h_{io} = h_i.\frac{ID}{OD} = 1300.\frac{0{,}62}{0{,}75} = 1075\ Btu/hr.ft^2$

$k_f = 0,153$ Btu / hr. ft.°F $\mu_f = 1,241.10^{-5}$ lb / ft . s $\rho_f = 0,215$ lb / ft^3 (Geankoplis, 1993, pp. 863, A.2–12) $h\left(\frac{\mu_f^2}{k_f^3.\rho_f^2.g}\right)^{\frac{1}{3}} = 1,5\left(\frac{4.G'}{\mu_f}\right)^{-\frac{1}{3}}$ (Kern, 1965, pp. 266, eq. 12.42) $h\left(\frac{(1,241.10^{-5})^2}{(0,153)^3.0,215^2.32,174}\right)^{\frac{1}{3}} = 1,5\left(\frac{4.7,5415}{1,241.10^{-5}}\right)^{-\frac{1}{3}}$ $h_o = 19,7670$ Btu/hr.ft^2.°F Harga h_o baru digunakan untuk mencari harga t_W baru tetapi hal ini tidak diperlukan karena harga properties-nya tidak jauh berbeda.	

Pressure Drop

Shell side	Tube side
1. Pada $T_V = 788$°F, $\mu = 1,6826.10^{-5}$ lb/ft.s $= 0,0606$ lb/ft.hr (Geankoplis, 1993, pp. 863, A.2–12) $D_e = 0,73 / 12 = 0,0608$ ft (Kern, 1965, pp. 838, fig. 28) $Re_S = \frac{D_e.G_S}{\mu} = \frac{0,0608.8,7425}{0,0606} = 8,78$ (Kern, 1965, pp. 138, eq. 7.3) $f = 0,044$ (Kern, 1965, pp. 839, fig. 29) **2.** No. of crosses, $N + 1 = 3$ $\rho = 0,0198$ lb / ft^3 (Geankoplis, 1993, pp. 863, A.2–12) $Sg = 0,0198 / 62,5 = 3,168.10^{-4}$ $D_S = 19,25 / 12 = 1,6042$ ft **3.** $\Delta P_S = \frac{0,5.f.G_S^2.D_S.(N+1)}{5,22.10^{10}.D_e.S_g}$ (Kern, 1965, pp. 273, eq. 12.47) $\Delta P_S = \frac{0,5.0,044.8,7425^2.1,6042.3}{5,22.10^{10}.0,0608.3,168.10^{-4}}$ $\Delta P_S = 0,0255$	**1.** $Re_t = 8238,2317$ $f = 0,0012$ (Kern, 1965, pp. 836, fig. 26) **2.** $\Delta P_t = \frac{f.G_t^2.L.n}{5,22.10^{10}.D.S_g.\Phi_t}$ $\Delta P_t = \frac{0,0012.296197,9502^2.4.2}{5,22.10^{10}.0,0517.1.1}$ $\Delta P_t = 0,0703$ psi **3.** $\Delta P_\tau = \frac{4.n}{Sg}.\frac{2.V^2}{g'}$ $\Delta P_\tau = \frac{4.2}{1}.\frac{2.0,066^2}{32,174'} = 0,0022$ psi **4.** $\Delta P_T = \Delta P_t + \Delta P\tau$ $= 1,7661.10^{-4}$ psi $+ 0,0022$ psi $= 0,0023$ psi

$$U_C = \frac{h_{io}.h_o}{h_{io}+h_o} = \frac{1075.178,1689}{1075+178,1689}\ \frac{Btu}{hr.ft^2.°F} = 152,8378\ \frac{Btu}{hr.ft^2.°F}$$

$U_D = 0{,}3982$

$$R_d = \frac{U_C - U_D}{U_C . U_D} = \frac{152{,}8378 - 0{,}3982}{152{,}8378 . 0{,}3982} \frac{ft^2.hr.°F}{Btu} = 2{,}5047 \frac{ft^2.hr.°F}{Btu}$$

Bahan konstruksi : Cast iron

APPENDIX D

PERHITUNGAN ANALISA EKONOMI

APPENDIX D

PERHITUNGAN ANALISA EKONOMI

Harga alat akan berubah setiap saat tergantung pada kondisi ekonomi dan politik, untuk itu dibutuhkan suatu metode yang dapat dipakai untuk mengkonversi harga alat pada beberapa tahun yang lalu agar dapat diperoleh harga alat yang ekivalen untuk waktu sekarang.

Ekivalensi itu dapat dihitung dengan menggunakan persamaan :

$$\text{Harga alat saat ini} = \frac{\text{Indeks harga saat ini}}{\text{Indeks harga tahun X}} \times \text{Harga alat tahun X}$$

Harga alat yang digunakan dalam pra rencana Pabrik Gelatin ini didasarkan pada harga alat yang terdapat pada pustaka sebagai berikut :

a. Garret, D.E., 1989, "Chemichal Engineering Economics", Van Nostrand Reinhold, New York.

b. Peters,M.S., Timmerhouse, K.D., 1991, "Plant Design and Economics for Chemical Engineers", 4^{th} ed., Mc.Graw Hill Co., Singapore.

c. Ulrich, G.D., 1984, "A Guide To Chemical Engineering Process Design and Economic", John Willey and Sons, Singapore.

A. PERHITUNGAN HARGA PERALATAN

Dalam perhitungan ini digunakan indeks harga sebagai berikut:

- Marshall & Swift Installed Equipment Index

  Tahun X (Januari 1990) = 904 (Peters & Timmerhaus, tabel 3, p.163)

  Saat ini (Juni 2002) = 1073,5 (Chemical Engineering, Januari 2003)

- Chemical Engineering Plant Cost Index

  Tahun X (awal 1987) = 320 (Garret, p. 255)

  Saat ini (Juli 2003) = 392,7 (Chemical Engineering, Oktober 2003)

Contoh perhitungan :

Nama alat : Tangki Penampung Waste $Ca(OH)_2$ F – 110

Fungsi : menampung waste $Ca(OH)_2$ sebelum dimasukkan ke Reaktor R – 210

Tipe : Tangki silinder dengan bagian bawah berbentuk konis dan tutup atas berbentuk datar (flat head)

Kapasitas : 239,3939 kg / jam

Jumlah : 1 buah

Harga tahun 1990 : $US 250 (Peter & Timmerhaus, fig. 14-79, p.563)

Harga alat saat ini $= \dfrac{1073{,}5}{904} \times \$\ 250 = \$\ 350{,}85$

Dengan cara yang sama didapatkan harga alat yang lain seperti pada tabel D.1.

Tabel D.1 Harga Peralatan Proses

Nama alat	Kode	Jumlah	Harga tahun 2003, @ Rp	Total Rp
Tangki Penampung Waste $Ca(OH)_2$	F-110	1	406.134.000,-	406.134.000,-
Tangki Penampung Lar. HCl 32%	F-120	1	383.301.000,-	383.301.000,-
Reaktor	R-210	1	348.183.000,-	348.183.000,-
Tangki Penampung Hasil Reaksi	F-211	1	340,587.000,-	340,587.000,-
Centrifugal Separator	H-220	1	64.125.000,-	64.125.000,-
Tangki Penampung Limbah Padat	F-221	1	287.658.000,-	287.658.000,-
Screw Conveyor	J-222	1	16.193.160,-	16.193.160,-
Tangki Penampung Larutan $CaCl_2$	F-223	1	340.587.000,-	340.587.000,-
Evaporator	V-310	1	186.888.330,-	186.888.330,-
Tangki Penampung Lar.Pekat $CaCl_2$	F-315	1	287.658.000,-	287.658.000,-
Kristaliser	X-320	1	13.556.250,-	13.556.250,-
Tangki Penampung Kristal $CaCl_2.2H_2O$	F-323	1	287.658.000,-	287.658.000,-
Screw Conveyor	J-322	1	16.193.160,-	16.193.160,-
Tumbling Mill	C-330	1	213.750.000,-	213.750.000,-
Screw Conveyor	J-324	1	16.193.160,-	16.193.160,-
Screen	H-332	1	186.887.800,-	186.887.800,-
Screw Conveyor	J-331	1	16.193.160,-	16.193.160,-
Screw Conveyor	J-333	1	16.193.160,-	16.193.160,-
Tangki Penampung Produk	F-335	1	160.312.500,-	160.312.500,-
Screw Conveyor	J-334	1	16.193.160,-	16.193.160,-
Pompa	L-111	1	1.800.000,-	1.800.000,-

Nama alat	Kode	Jumlah	Harga tahun 2003, @ Rp	Total Rp
Pompa	L-121	1	1.800.000,-	1.800.000,-
Pompa	L-212	1	1.800.000,-	1.800.000,-
Pompa	L-224	1	1.800.000,-	1.800.000,-
Pompa	L-311	1	1.800.000,-	1.800.000,-
Pompa	L-316	1	1.800.000,-	1.800.000,-
Condenser	E-312	1	15.149.970,-	15.149.970,-
TOTAL				**3,630,394,710,-**

Tabel D.2 Harga Peralatan Utilitas

No	Nama alat	Kode	Jumlah	Total, Rp
1.	Settling Tank	F – 210	1	2.600.000
2.	River Pump	L – 211	1	1.000.000
3.	Clarifier	H – 212	1	5.250.000
4.	Sand Filter	H – 213	1	13.500.000
5.	Water Storage Tank	F – 214	1	2.600.000
6.	Process Water Pump	L – 215	1	3.000.000
7.	Softener Pump	L – 216	1	1.000.000
8.	Water Softener Tank	F – 220	1	12.500.000
9.	Boiler Feed Water Tank	F – 221	1	720.000
10.	Boiler Water Pump	L – 222	1	1.000.000
TOTAL				**43.170.000**

Total harga peralatan = Harga Peralatan Proses + Harga Peralatan Utilitas

= Rp. 3.630.394.710,- + Rp. 43.170.000,-

= Rp. 3.673.564.710,-

B. PERHITUNGAN HARGA TANAH DAN BANGUNAN

Luas tanah = 10.000 m^2

Luas bangunan = 3.191 m^2

Harga tanah = Rp. 500.000,- /m^2

Harga bangunan = Rp. 750.000,-/m^2

Jadi :

Harga tanah = 10.000 m^2 × Rp.500.000,-/m^2 = Rp. 5.000.000.000,-

Harga bangunan = 3.191 m^2 × Rp. 750.000,-/m^2 = Rp. 2.393.250.000,-

Total harga tanah dan bangunan = Rp. 5.000.000.000,- + Rp. 2.393.250.000,-

= Rp. 7.393.250.000,-

C. PERHITUNGAN HARGA BAHAN BAKU DAN HARGA JUAL PRODUK

- **Harga Bahan Baku**

1. Waste $Ca(OH)_2$

   Harga : Rp. 1.200,- / kg

   Kebutuhan : 239,3939 kg / jam

   Total : Rp. 2.275.200.000,- / tahun

2. HCl

   Harga : Rp. 2.500,- / lt

   Kebutuhan : 127,2070 lt / jam

   Total : Rp. 2.518.698.284,- / tahun

Total harga bahan baku per tahun

= Rp. 2.275.200.000,- + Rp. 2.518.698.284,-

= Rp. 4.793.898.284,-

- **Harga Jual Produk**

  Harga : Rp. 35.000,- / kg

  Produksi : 69,1170 kg / jam

  Total : Rp. 19.159.220.304,- / tahun

D. PERHITUNGAN GAJI KARYAWAN

Perincian gaji karyawan tiap bulan dapat dilihat pada tabel D.4 berikut ini.

Tabel D.4 Gaji Karyawan

No.	Jabatan	Jumlah	Gaji karyawan (Rp)	Total (Rp)
1	Direktur Utama	1	7,000,000.00	7,000,000.00
2	Direktur Teknik & Produksi	1	5,000,000.00	5,000,000.00
3	Direktur Administrasi & Keuangan	1	5,000,000.00	5,000,000.00
4	Sekretaris	2	1,000,000.00	2,000,000.00
5	Kabag Produksi	1	2,500,000.00	2,500,000.00
7	Kabag Keuangan	1	2,500,000.00	2,500,000.00
8	Kabag Pemasaran	1	2,500,000.00	2,500,000.00
9	Kabag Personalia & Umum	1	2,500,000.00	2,500,000.00
10	Kasie Proses	1	1,500,000.00	1,500,000.00
11	Kasie Penelitian & Pengembangan	1	1,500,000.00	1,500,000.00
12	Kasie Utilitas	1	1,500,000.00	1,500,000.00
13	Kasie Pemeliharaan & Perbaikan	1	1,500,000.00	1,500,000.00
14	Kasie Laboratorium & QC	1	1,500,000.00	1,500,000.00
15	Kasie Promosi & Penjualan	1	1,500,000.00	1,500,000.00
17	Kasie Pembelian	1	1,500,000.00	1,500,000.00
18	Kasie Gudang	1	1,500,000.00	1,500,000.00
20	Kasie Keamanan	1	1,500,000.00	1,500,000.00
21	Seksi Proses	12	1,000,000.00	12,000,000.00
22	Seksi Penelitian & Pengembangan	2	1,000,000.00	2,000,000.00
23	Seksi Utilitas	2	1,000,000.00	2,000,000.00
24	Seksi Pemeliharaan & Perbaikan	2	1,000,000.00	2,000,000.00
25	Seksi Laboratorium & QC	2	1,000,000.00	2,000,000.00
26	Seksi Promosi & Penjualan	2	1,000,000.00	2,000,000.00
27	Seksi Keuangan	2	1,000,000.00	2,000,000.00
28	Seksi Pembelian	2	1,000,000.00	2,000,000.00
29	Seksi Personalia	2	1,000,000.00	2,000,000.00
30	Seksi Gudang	6	800,000.00	4,800,000.00
31	Seksi Keamanan	2	800,000.00	1,600,000.00
32	Sopir & Pesuruh	6	600,000.00	3,600,000.00
		60		80,500,000.00

Total gaji karyawan per bulan = Rp. 80.500.000,-

Ditetapkan 1 tahun produksi adalah 12 bulan + 1 bulan tunjangan, jadi gaji karyawan

per tahun = Rp. 80.500.000,- × 13

= Rp. 1.046.500.000,-

E. PERHITUNGAN BIAYA UTILITAS

Kebutuhan Air

Air PDAM yang harus disuplai per hari = 16 m^3 / hari

Harga beli air PDAM per 10 m^3 pertama = Rp. 750,-

Harga beli air PDAM per 10 m^3 kedua = Rp. 1300,-

Biaya untuk air PDAM per tahun

= (10 × Rp. 750,- + 6 × Rp. 1300,-) × 330

= Rp. 5.049.000,-

Kebutuhan Listrik

Total kebutuhan listrik = 229,965 kWh

Beban listrik terpasang = 650 kVA

Biaya beban per bulan = Rp.25.000,- / kVA

Biaya listrik per tahun = Rp. 25.000,- × 650 × 12 = Rp. 195.000.000,-

Biaya penggunaan listrik :

- Waktu Beban Puncak = Rp. 425,- / kWh (pk. 18.00 – 22.00)
- Luar Waktu Beban Puncak = Rp. 350,- / kWh (pk. 22.00 – 18.00)

Biaya penggunaan listrik = (Rp. 425,- × 4 × 229,965 × 330) + (Rp. 350,- × 20 × 229,965 × 330) + (Rp. 425,- × 4 × 1,4914 × 35) + (Rp. 350,- × 20 × 1,4914 × 35)

= Rp. 665.852.007,-

Biaya listrik terpakai per tahun = biaya beban + biaya penggunaan listrik

= Rp. 195.000.000,- + Rp. 665.852.007,-

= Rp. 860.852.007,-

Kebutuhan bahan bakar

Densitas bahan bakar = 55 lb / ft^3 = 0,881 kg / lt

(Perry, 1999, 16-29)

Kebutuhan bahan bakar per bulan = 69,75 lt / bulan

Harga bahan bakar per liter = Rp.1440,- / lt

Biaya bahan bakar per tahun = 69,75 / bulan × 12 bln / th × Rp. 1440,-

= Rp. 100.436,-

Total biaya utilitas per tahun = Rp. 5.049.000,- + Rp. 860.852.007,- + Rp. 100.436,-

= Rp. 200.149.136,-

F. JADWAL SHIFT KARYAWAN

Jadwal shift karyawan : Shift I : 06.00 – 14.00

Shift II : 14.00 – 22.00

Shift III : 22.00 – 06.00