APPENDIX A
PERHITUNGAN NERACA MASSA

Kapasitas produksi = 50000 Ton/tahun
= 6313,13 kg/jam
Waktu operasi = 330 Hari
Basis perhitungan = 1 hari produksi 24 jam
Basis akrilonitril = 5086,11845 kg/jam

Komposisi akrilonitril

Komponen	% Berat
C_3H_3N	99,5
H_2O	0,5

Shandong kejian chemical, Cina

Komposisi asam sulfat monohidrat

Komposisi	% Berat
H_2SO_4	65
H_2O	35

Columbus, Amerika serikat

Komposisi	% Berat
NH_3	99,5
H_2O	0,5

PT Petrokimia Gresik

Data berat molekul bahan

No	Rumus molekul	BM
1	C_3H_3N	53
2	$H_2SO_4.H_2O$	116
3	$C_3H_5NO.H_2SO_4$	169
4	NH_3	17
5	$(NH_4)_2SO_4$	132
6	C_3H_5NO	71

H	=	1
N	=	14
O	=	16
S	=	32
C	=	12

Reaksi :

$C_3H_3N + H_2SO_4.H_2O \longrightarrow C_3H_5NO.H_2SO_4$

Kebutuhan C_3H_3N = % bahan baku x basis bahan baku
= 0,995 x 5086,12 kg/jam
= 5060,69 kg/jam
= $\frac{5060,69 \text{ kg/jam}}{53 \text{ kg/kmol}}$
= 95,484677 kmol/jam

Kebutuhan $H_2SO_4.H_2O$ berdasarkan mol reaksi

$$= \frac{\text{mol } C_3H_3N \text{ bereaksi} \times \text{koefisien } H_2SO_4.H_2O}{\text{koefisien } C_3H_3N}$$

$$= \frac{95{,}48467656 \text{ kmol/jam} \times 1}{1}$$

$$= 95{,}4847 \text{ kmol/jam}$$

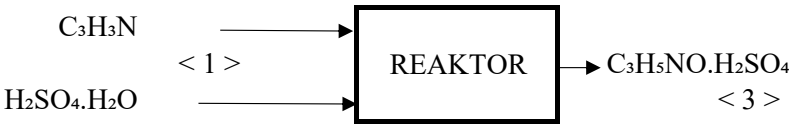
$$= 95{,}4847 \text{ kmol/jam} \times 116 \text{ kg/kmol}$$

$$= 11076{,}2225 \text{ kg/jam}$$

Feed larutan $H_2SO_4.H_2O$ 65% $= \frac{11076{,}2225}{0{,}65} = 17040{,}34228$ kg/jam

1. Reaktor (R-210)

Fungsi : Mereaksikan akrilonitril dan asam sulfat monohidrat menjadi akrilamida sulfat



Kondisi operasi :

Tekanan operasi : 1 atm

Suhu operasi : 90 °C ***Kirk Othmer, vol.1, hal 293***

Feed masuk

Komponen	Berat (kg/jam)
C_3H_3N	5060,687858
H_2O	25,43059225
Total	5086,11845

Komponen	Berat (kg/jam)
$H_2SO_4.H_2O$	11076,2225

Reaksi :

	C_3H_3N	+	$H_2SO_4.H_2O$	→	$C_3H_5NO.H_2SO_4$
M	95,4847		95,4847		-
R	90,7104		90,7104		90,71044
S	4,7742		4,7742		90,71044

Perhitungan :

Massa C_3H_3N = 5060,69 kg/jam

Massa H_2O = 25,4306 kg/jam

Mol C_3H_3N = $\frac{5060{,}69 \text{ kg/jam}}{53 \text{ kg/kmol}}$ = 95,48468 kmol/jam

Mol $H_2SO_4.H_2O$ = $\frac{11076{,}22 \text{ kg/jam}}{116 \text{ kg/kmol}}$ = 95,4847 kmol/jam

Konversi = 0,95
Mol yang bereaksi = 0,95 x 95,4847 kmol/jam
= 90,710443 kmol/jam
= 4807,6535 kg/jam
C_3H_3N sisa = 5060,69 - 4807,65 kg/jam
= 253,03439 kg/jam

$H_2SO_4.H_2O$ bereaksi = (1/1) x 90,7104 kmol/jam
= 90,7104 kmol/jam
= 90,7104 kmol/jam x 116 kg/kmol
= 10522,4 kg/jam
$H_2SO_4.H_2O$ sisa = 11076,2225 - 10522,4114 kg/jam
= 553,8111 kg/jam

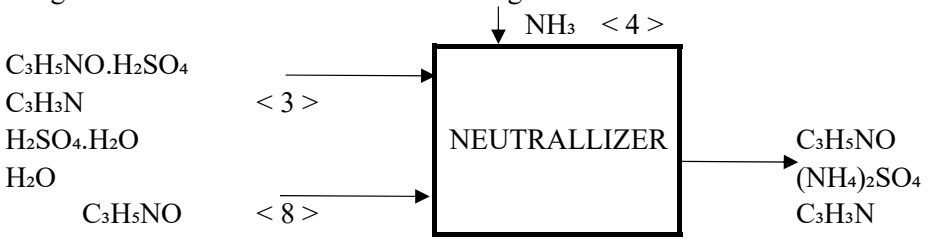
Produk $C_3H_5NO.H_2SO_4$ = (1/1) x 90,7104 kmol/jam
= 90,7104 kmol/jam
= 90,7104 kmol/jam x 169 kg/kmol
= 15330,1 kg/jam

Neraca Massa pada Reaktor (R-210) :

Komponen	Masuk (kg/jam)	Komponen	Keluar (kg/jam)
dari F-110 < 1 >		**dari R-210 < 3 >**	
C_3H_3N	5060,6879	$C_3H_5NO.H_2SO_4$	15330,0648
H_2O	25,4306	C_3H_3N	253,034393
	5086,11845	$H_2SO_4.H_2O$	553,8111
dari F-120 < 2 >		H_2O	25,4306
$H_2SO_4.H_2O$	11076,2225		
	16162,3409		16162,3409

2. NEUTRALLIZER (R-220)

Fungsi : Menetralkan akrilamida sulfat dengan menambahkan ammonia



Kondisi operasi
Tekanan operasi : 1 atm
Suhu operasi : 40 °C

Feed masuk :

Komponen	Berat (kg/jam)
$C_3H_5NO.H_2SO_4$	15330,0648
C_3H_3N	253,0344
$H_2SO_4.H_2O$	553,8111
NH_3	3084,1551
H_2O	25,4306

Recycle dari Filter Press

Komponen	Berat (kg/jam)
C_3H_5NO	6313,762653
H_2O	12444,50911

Reaksi :

	$C_3H_5NO.H_2SO_4$	+	$2\ NH_3$	⟶	C_3H_5NO	+	$(NH_4)_2SO_4$
M	90,7104		181,421		-		-
R	90,7104		181,421		90,71		90,7104
S	0,0000		0		90,71		90,7104

Perhitungan :

Berat $C_3H_5NO.H_2SO_4$ = 15330,0648 kg/jam

Mol $C_3H_5NO.H_2SO_4$ = $\frac{15330,065 \text{ kg/jam}}{169 \text{ kg/kmol}}$ = 90,7104 kmol/jam

Mol NH_3 umpan = (2/1) x 90,7104 kmol/jam

= 181 kmol/jam x 17 kg/kmol

Massa NH_3 umpan = 3084,1551 kg/jam

massa larutan NH_3 99,5% = $\frac{3084,1551}{0,995}$ = 3099,65332 kg/jam

H_2O dalam NH_3 = 3099,6533 - 3084,16 g/jam

= 15,498267 kg/jam

Produk C_3H_5NO = (1/1) x 90,7104 kmol/jam

= 90,710443 kmol/jam

= 90,710443 kmol/jam x 71 kg/kmol

= 6440,4414 kg/jam

Produk $(NH_4)_2SO_4$ = (1/1) x 90,7104 kmol/jam

= 90,710443 kmol/jam

= 90,710443 kmol/jam x 132 kg/kmol

= 11973,778 kg/jam

Akrilamida total = Produk akrilamida + recycle akrilamida

= 6440,441434 + 6313,76 kg/jam

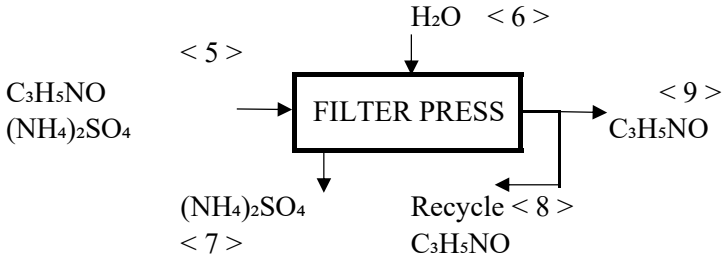
= 12754,20409

Neraca Massa pada Neutrallizer (R-220)

Komponen	Masuk (kg/jam)	Komponen	Keluar (kg/jam)
dari R-210 < 3 >		**dari R-220 < 5 >**	
$C_3H_5NO.H_2SO_4$	15330,0648	C_3H_5NO	12754,2041
C_3H_3N	253,0344	$(NH_4)_2SO_4$	11973,7784
$H_2SO_4.H_2O$	553,8111	C_3H_3N	501,0918
H_2O	25,4306	$H_2SO_4.H_2O$	553,8111
	16162,3409	H_2O	12485,4380
dari F-130 < 4 >			
NH_3	3084,155053		
H_2O	15,4983		
	3099,6533		
dari H-230 < 8 >			
C_3H_5NO	6313,762653		
C_3H_3N	248,0573911		
H_2O	12444,50911		
	19006,3292		
	38268,3234		38268,3234

3. Filter Press (H-230)

Fungsi : Memisahkan cake dan filtrat dari campuran



Kondisi operasi :
Tekanan operasi : 1 atm
Suhu operasi : 36 ℃

Feed masuk :

Berdasarkan perhitungan pada neutrallizer, maka :

Pemisahan berdasarkan perbedaan berat jenis, dimana berat jenis ammonium sulfat lebih besar dari pada akrilamida.

Komponen	Berat (kg/jam)
C_3H_5NO	12754
$(NH_4)_2SO_4$	11974
C_3H_3N	501
$H_2SO_4.H_2O$	554
H_2O	12485
Total	38268,3234

Diketahui:

Asumsi : 2% cake adalah filtrat yang terikut

98% cake merupakan padatan

Komponen yang terpisah :

Liquid	
Komponen	Berat (kg/jam)
C_3H_5NO	12754
C_3H_3N	501
H_2O	12485
Total	25741

Padatan	
Komponen	Berat (kg/jam)
$(NH_4)_2SO_4$	11974
$H_2SO_4.H_2O$	554
Total	12528

$$\text{Total cake} = \frac{\text{Jumlah padatan (cake)}}{98\%\ \text{cake}} = \frac{12528}{98\%} = 12783{,}3\ \text{kg/jam}$$

$$\text{Jumlah filtrat yang terikut} = \text{Total cake} - \text{Jumlah padatan cake} = 12783{,}3 - 12528 = 255{,}6651\ \text{kg/jam}$$

Meninjau jumlah komponen dalam filtrat yang terikut cake :

$$C_3H_5NO = \frac{C_3H_5NO\ \text{pada liqui}}{\text{Total liquid}} \times \text{Filtrat terikut cake} = \frac{12754}{25741} \times 255{,}6651 = 126{,}678781\ \text{kg/jam}$$

$$C_3H_3N = \frac{C_3H_3N\ \text{pada liquid}}{\text{Total liquid}} \times \text{Filtrat terikut cake} = \frac{501}{25741} \times 255{,}6651 = 4{,}97700176\ \text{kg/jam}$$

$$H_2O = \frac{H_2O\ \text{pada liquid}}{\text{Total liquid}} \times \text{Filtrat terikut cake}$$

$$= \frac{12485}{25741} \times 255{,}6651$$

= 124,009311 kg/jam

Maka, komponen liquid yang terikut cake adalah :

Komponen	Filtrat (kg/jam)	Terikut cake (kg/jam)	Filtrat (kg/jam)
C_3H_5NO	12754	126,6788	12627,5253
C_3H_3N	501	4,9770	496,1148
H_2O	12485	124,0093	12361,4287
Total	25741	255,6651	25485,0688

Proses pencucian :

cake terambil = 12528 kg/jam

Kebutuhan air pencuci = 100 % cake terambil

= 100 % x 12528 kg/jam

= 12527,6 kg/jam

Total air pada filtrat = Air pada filtrat + air pencuci

= 12361,43 + 12527,59

= 24889 kg/jam

Filtrat keluar = 50 % Recycle ke neutrallizer = 50 %

C_3H_5NO = 6313,76265 kg/jam C_3H_5NO = 6313,7627 kg/jam

C_3H_3N = 248,057391 kg/jam C_3H_3N = 248,05739 kg/jam

H_2O = 12444,5091 kg/jam H_2O = 12444,509 kg/jam

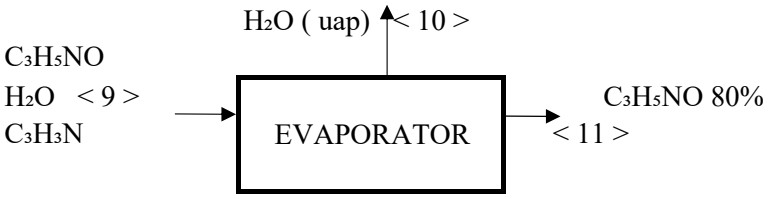
Neraca Massa pada Filter Press (H-230)

Komponen	**Masuk (kg/jam)**	**Komponen**	**Keluar (kg/jam)**
dari R-220 < 5 >		**Filtrat < 9 >**	
C_3H_5NO	12754,2041	C_3H_5NO	6313,7627
$(NH_4)_2SO_4$	11973,7784	C_3H_3N	248,057391
C_3H_3N	501,0918	H_2O	12444,5091
$H_2SO_4.H_2O$	553,8111		19006,3292
H_2O	12485,4380	**Recycle ke R-220 < 8 >**	
	38268,3234	C_3H_5NO	6313,7627
		C_3H_3N	248,0574
Air proses < 6 >		H_2O	12444,5091
H_2O	12527,58956		19006,3292
	12527,5896		
		Cake ke F-410 < 7 >	
		$(NH_4)_2SO_4$	11973,7784
		$H_2SO_4.H_2O$	553,8111
		C_3H_5NO	126,6788
		C_3H_3N	4,9770

	H_2O	124,0093
		12783,2547
50795,9130		50795,9130

4. Evaporator (V-240)

Fungsi : Memekatkan akrilamida sampai 80%



Kondisi operasi :

Tekanan operasi : 0,6136 atm ***Ludwig; 352***

Suhu operasi : 80 °C

Feed masuk

Komponen	Berat (kg/jam)	Fraksi
C_3H_5NO	6313,7627	0,3322
H_2O	12444,50911	0,6548
C_3H_3N	248,0573911	0,0131
Total	19006,3292	1,0000

Kadar pemekatan : 80 %

Neraca Massa : F = L + V

F.Xf = L.Xl + V.Xv

F = 19006,3292 kg/jam

Xf = 0,3322

Asumsi akrilamida tidak menguap, maka Xv = 0

Xl = 0,8 kadar pemekatan

F x Xf = L x Xl + V x Xv

19006,3292 kg/jam x 0,3322 = L x 0,800 + ~~V x 0~~

$$L = \frac{6313,76 \text{ kg/jam}}{0,800}$$

L = 7892,2 kg/jam

Komponen utama = 6313,7627 kg/jam

Berat H_2O akhir = Berat produk akhir - berat komponen utama

= 7892,2033 kg/jan - 6313,7627 kg/jam

= 1578,4407 kg/jam

Berat H_2O pada feed = 12444,5091

Penguapan H_2O = 12444,5091 kg/jan - 1578,4407 kg/jam

= 10866,0684

Karena titik didih akrilonitril lebih rendah daripada akrilamida, maka akrilonitril menguap bersama air

C_3H_3N menguap = 248,0573911 kg/jam

Neraca Massa pada Evaporator (V-240)

Komponen	Masuk (kg/jam)	Komponen	Keluar (kg/jam)
dari H-230 < 9 >		**ke S-310 < 11 >**	
C_3H_5NO	6313,7627	C_3H_5NO	6313,7627
H_2O	12444,50911	H_2O	1578,4407
C_3H_3N	248,0573911		7892,2033
	19006,3292	**ke E-241 < 10 >**	
		H_2O (uap air)	10866,0684
		C_3H_3N	248,0574
			11114,1258
	19006,3292		19006,3292

5. Crystallizer (S-310)

Fungsi : Mengkristalkan akrilamida dengan cara pendinginan

Kondisi operasi :

Tekanan operasi : 1 atm

Suhu operasi : 30 °C

Feed masuk :

Komponen	Berat (kg/jam)
C_3H_5NO	6313,7627
H_2O	1578,4407

Recycle dari Centrifug

Komponen	Berat (kg/jam)
C_3H_5NO	599,8075
H_2O	29990,3726
Total	30590,1801

Penentuan kristal yang terbentuk :

$$P = R \frac{100\ Wo - S\ (Ho - E)}{100 - S\ (R-1)}$$ ***Perry 7ed hal 18-37***

Dengan :
- P = Berat Kristal
- R = Ratio BM dari kristal larutan
- S = Kelarutan kristal pada mother liquor
- Wo = Berat bahan yang akan dikristalkan pada feed
- Ho = Total bahan liquid
- E = Evaporation

Perhitungan :

Penguapan H_2O : Tidak terjadi pennguapan H_2O

H_2O = 0 kg/jam

BM ratio (R) = $\frac{\text{BM } C_3H_5NO \text{ kristal}}{\text{BM } C_3H_5NO \text{ larutan}} = \frac{71 \text{ kg/kmol}}{71 \text{ kg/kmol}}$

= 1

Kelarutan kristal akrilamida dalam air (S) = $\frac{200}{100}$ g akrilamida / g air

= 2

Bahan yang akan dikristalkan (W_o) = 6313,7627 kg/jam + 599,8075 kg/jam

= 6913,5701 kg/jam

Total bahan liquid (H_o) = H_2O dari Evaporator + Centrifuge

= 1578,4407 kg/jam + 29990,3726 kg/jam

= 31568,8133 kg/jam

Evaporasi (E) = 0

maka kristal yang terbentuk :

$$P = R \frac{100\ Wo - S\ (Ho - E)}{100 - S\ (R-1)}$$

$$P = 1 \frac{100 \times 6913{,}5701 - 2 \times (31568{,}8133 - 0)}{100 - 2\ (1 - 1)}$$

P = 6282,19384 kg/jam

Berat kristal C_3H_5NO terbentuk = 6282,1938 kg/jam

Berat C_3H_5NO tidak mengkristal = Berat feed - Berat kristal

= 6913,5701 - 6282,1938 kg/jam

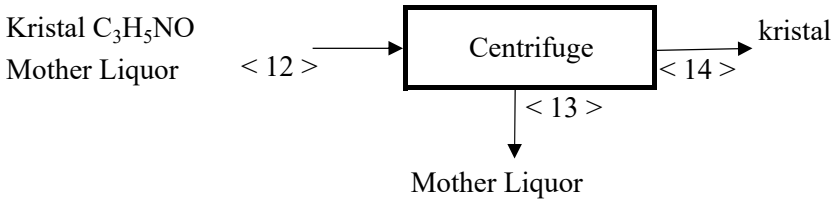
= 631,3763 kg/jam

Neraca Massa pada Cryztallizer

Komponen	Masuk (kg/jam)	Komponen	Keluar (kg/jam)
dari V-240 < 11 >		**Mother liquor <12>**	
C_3H_5NO	6313,7627	C_3H_5NO	631,3763
H_2O	1578,4407	H_2O	31568,8133
	7892,2033		32200,1895
Recycle dari H-320<13>			
C_3H_5NO	599,8075	**Kristal <12>**	
H_2O	29990,3726		6282,19384
	30590,1801		
	38482,3834		38482,3834

6. Centrifug (H-320)

Fungsi : Memisahkan kristal dan mother liquor secara sentrifugal



Kondisi Operasi :

Tekanan operasi : 1 atm

Suhu operasi : 30 ℃

Feed masuk

Komponen	Berat(kg/jam)
C_3H_5NO liquid	631,3763
H_2O	31568,8133
Kristal C_3H_5NO	6282,19384
Total	38482,38

Bahan bersifat solid :

C_3H_5NO = 6282,19384

Bahan bersifat liquid :

C_3H_5NO = 631,3763

H_2O = 31568,8133

Total = 32200,1895

Asumsi liquid terikut kedalam solid 5% ***Perry ed-8; 18-40***

Maka produk liquid = 95,00%

Terikut solid :

C_3H_5NO = 5% x 631,3763 = 31,5688 kg/jam

H_2O = 5% x 31568,8133 = 1578,441 kg/jam

Filtrat keluar :

C_3H_5NO = 631,3763 - 31,5688 = 599,8075 kg/jam

H_2O = 31568,8133 - 1578,44 = 29990,3726 kg/jam

Terdiri dari :

Komponen	Feed (kg/jam	Terikut solid (kg/jam)	Filtrat keluar (kg/jam)
C_3H_5NO	631,3763	31,56881327	599,8075
H_2O	31568,8133	1578,440663	29990,3726
Total	32200,1895	1610,009477	30590,1801

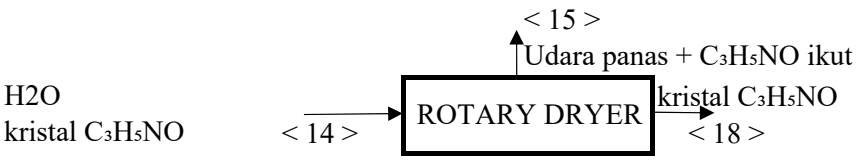
Total C_3H_5NO pada solid = 6282,1938 + 31,5688 = 6313,7627

Neraca Massa pada Centrifug :

Komponen	**Masuk (kg/jam)**	**Komponen**	**Keluar (kg/jam)**
dari S-310 <12>		**Cake ke B-330 <14>**	
C_3H_5NO kristal	6282,19384	C_3H_5NO	6313,7627
C_3H_5NO liquid	631,3763	H_2O	1578,4407
H_2O	31568,8133		7892,2033
	38482,38337	**Recycle ke V-240 <13>**	
		C_3H_5NO	599,8075
		H_2O	29990,3726
			30590,1801
	38482,3834		38482,3834

7. Rotary Dryer (B-320)

Fungsi : Untuk menurunkan kadar air dalam kristal akrilamida



Kondisi operasi :

Tekanan operasi : 1 atm

Suhu operasi : 75 °C

Feed masuk

Komponen	Berat (kg/jam)	Fraksi
H_2O	1578,4407	0,2008
kristal C_3H_5NO	6282,1938	0,7992
Total	7860,6345	1

Asumsi kehilangan padatan : 1 % ***Ludwig; 259***
maka, produk solid : 99 %
Kehilangan padatan :
C_3H_5NO = 1 % x 6313,7627 = 63,1376 kg/jam

Kompenen	Berat (kg/jam)	Kehilangan padatan (kg/jam)	Produk padatan (kg/jam)
C_3H_5NO	6313,7627	63,13762653	6250,6250

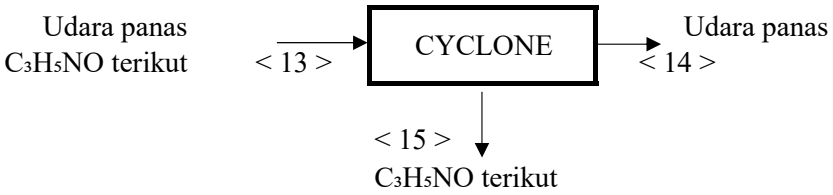
H_2O pada produk = 0,0020
Maka kadar produk solid = 1,00
Berat solid kering = 6250,6250
Berat akhir produk solid = Berat produk solid x $\frac{100}{\text{kadar akhir}}$
= 6250,6250 kg/jam x $\frac{1}{0,998}$
= 6263,202 kg/jam
Berat H_2O produk = Berat produk akhir - Berat solid kering
= 6263,20174 - 6250,6250 kg/jam
= 12,5767
Berat H_2O Feed = 1578,4407
H_2O yang menguap = Berat H_2O feed - Berat H_2O produk
= 1578,441 - 12,5767
= 1565,864

Neraca Massa pada Rotary Dryer :

Komponen	**Masuk (kg/jam)**	**Komponen**	**Keluar (kg/jam)**
dari S-310 < 12 >		**ke E-330 < 16 >**	
		C_3H_5NO	6250,6250
H_2O	1578,4407	H_2O	12,5767
kristal C_3H_5NO	6313,7627		6263,201737
	7892,2033		
		ke H 324 < 13 >	
		C_3H_5NO	63,13762653
		H_2O (udara panas	1565,8640
			1629,00158
	7892,2033		7892,2033

8. Cyclone (H-324)

Fungsi : Memisahkan padatan dan udara panas



Kondisi operasi :

Tekanan operasi : 1 atm

Suhu operasi : 53 °C

Feed masuk :

Komponen	Berat (kg/jam)
C_3H_5NO	63,1376
H_2O (g)	1565,8640

Asumsi Effisiensi Cyclone = 99 % ***Ludwig; 259***

Maka kehilangan padatan = 1 %

Padatan C_3H_5NO = 63,1376

Kehilangan padatan = 1% x 63,1376 kg/jam

= 0,6314 kg/jam

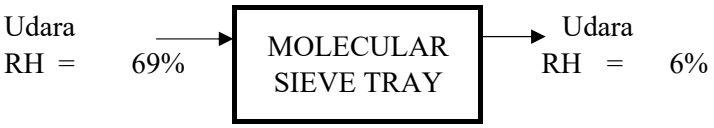
Produk C_3H_5NO = 63,1376 - 0,6314 kg/jam = 62,5063 kg/j

Neraca Massa pada Cyclone

Komponen	**Masuk (kg/jam)**	**Komponen**	**Keluar (kg/jam)**
dari B-320 < 13 >		**ke E-330 < 15 >**	
C_3H_5NO	63,1376	C_3H_5NO	62,5063
H_2O (udara panas)	1565,8640		
	1629,0016	**ke udara < 14 >**	
		C_3H_5NO	0,6314
		H_2O (udara panas)	1565,8640
			1566,4953
	1629,0016		1629,0016

9. Molecular Sieve Tray (D-322)

Fungsi : Untuk mengurangi kelembaban udara dari blower



Relative Humidity = 69%

Humidity = 0,018 $\frac{\text{kg } H_2O}{\text{kg udara keering}}$

Kebutuhan udara kering untuk Rotary dryer

H = 7892,2033 kg udara kering

Berat H_2O = 142,0597 kg H_2O menguap

Berat udara kering = 7892,2033 - 142,0597 = 7750,1437 kg

Berat H_2O tertahan = $\frac{H_2O \text{ yang lolos}}{1\text{-}20\%}$

$= \frac{142,0597}{1\text{-}20\%}$

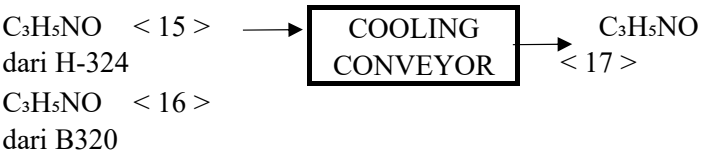
= 177,5745746 kg/jam

Neraca Massa pada Molecular Sieve Tray

Komponen	Masuk (kg/jam)	Komponen	Keluar (kg/jam)
Udara dari Blower G-321		**ke E-323**	
Udara	8069,7779	Udara kering	7750,1437
		H_2O	142,0597
			7892,2033
		H_2O tertahan	177,5745746
	8069,7779		8069,7779

10. Cooling Conveyor (E-330)

Fungsi : Mendinginkan kristal akrilamida hingga suhunya 30 ℃



Kondisi operasi :
Tekanan operasi : 1 atm
Suhu operasi : 30 ℃

Feed masuk = Produk Rotary Dryer + Produk Cyclone

Komponen	Rotary Dryer (kg/jam)	Cyclone (kg/jam)	Total (kg/jam)
C_3H_5NO	6250,6250	62,5063	6313,1313
H_2O	12,5767	-	12,5767

Neraca Massa pada Cooling Conveyor

Komponen	**Masuk (kg/jam)**	**Komponen**	**Keluar (kg/jam)**
dari B-320		**ke C-340**	
C_3H_5NO	6250,6250	C_3H_5NO	6313,1313
H_2O	12,5767	H_2O	12,5767
	6263,2017		6325,7080
dari H-324			
C_3H_5NO	62,5063		
	6325,7080		6325,7080

11. Ball Mill (C-340)

Fungsi : Menyeragamkan ukuran kristal sampai 45 mesh (0,355 mm)

Kondisi operasi :
Tekanan operasi : 1 atm
Suhu operasi : 30 ℃

Feed masuk

Komponen	Berat (kg/jam)
C_3H_5NO	6313,1313
H_2O	12,5767
Total	6325,7080

Komposisi produk keluar

Komponen	Berat (kg/jam)
C_3H_5NO	6313,1313
H_2O	12,5767
Total	6325,7080

Neraca Massa pada Ball Mill

Komponen	**Masuk (kg/jam)**	**Komponen**	**Keluar (kg/jam)**
dari E-330		**ke F-420**	
C_3H_5NO	6313,1313	C_3H_5NO	6313,1313
H_2O	12,5767	H_2O	12,5767
	6325,7080		6325,7080
	6325,7080		6325,7080

Spesifikasi Produk

Komponen	Berat (kg/jam)	% Berat
C_3H_5NO	6313,1313	0,99801
H_2O	12,5767	0,00199
Total	6325,7080	1

Kapasitas produksi = 50000 Ton/tahun
= 6313,1313 kg/jam

Berdasarkan hasil perhitungan pada basis 1000 kg/jam feed akrilonitril menghasilkan 1241,2474 kg/jam akrilamida, maka untuk menghasilkan 6313,1313 kg/jam akrilamida dibutuhkan bahan baku akrilonitril sebesar :

$$\frac{\text{Akrilonitril 1}}{\text{Akrilonitril 2}} = \frac{\text{Akrilamida 1}}{\text{Akrilamida 2}}$$

$$\frac{1000}{\text{Akrilonitril 2}} = \frac{1241,2474}{6313,131313}$$

$$6313131,313 = 1241,2474 \text{ Akrilonitril 2}$$

$$\text{Akrilonitril 2} = 5086,11846 \text{ kg/jam}$$

Jadi untuk menghasilkan kapasitas produksi 6313,1313 kg/jam akrilamida dibutuhkan feed akrilonitril sebesar 5086,11846 kg/jam

Cara -2

Untuk basis 5086,11845 kg/jam akrilonitril diperoleh produk sebesar :

Produk akrilamida = 6313,1313 kg/jam
= 151515,1507 kg/jam
= 50000000 kg/tahun (24 jam proses)
= 50000 ton/tahun (330 hari kerja)

Kapasitas terpasang = 50000 ton/tahun

Maka scale-up kapasitas = $\frac{50000}{50000}$
= 1

Jadi kebutuhan bahan baku akrilonitril adalah = scale up x basis
= 1 x 5086,1185
= 5086,1185 kg/jam

APPENDIX B
PERHITUNGAN NERACA PANAS

Kapasitas produksi = 50000 Ton/tahun
= 6313,13 kg/jam
Waktu operasi = 330 hari
Basis perhitungan = 1 hari produksi 24 jam
Satuan = Kilo Joule
Waktu operasi = 1 Jam proses
Suhu Reference = 25 °C = 298,15 K

$\Delta H = n.Cp.\Delta T$

$= \int_{Treff}^{T} Cp\ dT$ ***Himmelblau 8ed; 410***

Dengan :
- ΔH = Panas : Joule
- n = Mol bahan : mol
- Cp = Spesific Heat : J/K.mol
- Tref = Suhu Reference : Kelvin
- T = Suhu Bahan : Kelvin

$Cp = A + B.T + C.T^2$ ***Hiimmelblau 8ed; 411***

Dengan :
- Cp = Spesific Heat : J/K.mol
- A.B.C = Konstanta
- T = Suhu Bahan : Kelvin

Penyederhanaan Integrasi ΔH ***Himmelblau 8ed; 412***

$Cp = A + B.T + C.T^2$

$\Delta H = \int_{Treff}^{T} Cp\ dT = \int_{Treff}^{T} (A + B.T + C.T^2)\ dT$

$Cp = A(T-Treff) + B/2(T^2-Treff^2) + C/3(T^3-Treff^3)$
= J/mol.K x K
= J/mol

Data Konstanta Heat Capacity

Komponen	BM	A	B	C	D	E
C_3H_3N (lq)	53	33,362	0,5864	-0,0019	2,5E-06	-
C_3H_3N (g)	53	18,425	0,18336	-0,0001	1,9E-08	9,1E-13
H_2O (lq)	18	92,053	-0,04	-0,0002	5,3E-07	
H_2O (g)	18	33,933	-0,0084	3E-05	-2E-08	3,7E-12
C_3H_5NO (lq)	71	55,686	0,48631	-0,0011	1,1E-06	-
C_3H_5NO (c)	71	-25,136	0,47292	-	-	-
NH_3 (g)	17	33,573	-0,0126	8,9E-05	-7E-08	1,9E-11
NH_3 (lq)	17	-182,16	3,3618	-0,0144	2E-05	-

Yaws (J/mol.K)

Komponen	BM	A	B	C	D	E
$(NH_4)_2SO_4$	132	215,9	-	-	-	-

Himmelblau (J/mol.K)

Komponen	BM	A	B	C	D	E
$H_2SO_4.H_2O$	116	214,3	-	-	-	-

Lange's (J/mol.K)

Komponen	BM	A	B	C	D	E
$C_3H_5NO.H_2SO_4$	169	9,262	0,08216	-7E-05	2E-08	-

Cp Vaporization

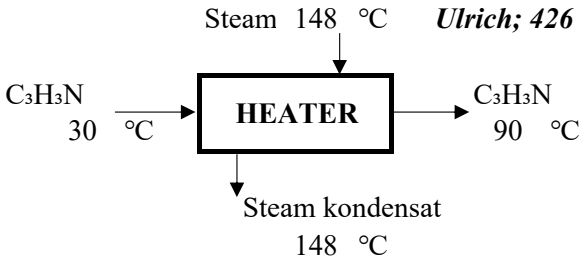
Komponen	ΔHvap J/mol	Literatur
C_3H_3N	32600	Lange's, T 6-2
H_2O	40660	Lange's, T 6-4

Enthalpi Pembentukan

Komponen	ΔHf kJ/mol	Literatur
C_3H_3N	180,6	Yaws; T 6.3
H_2O (lq)	-285,83	Lange's T 6.3
H_2O (g)	-241,826	Lange's T 6.3
C_3H_5NO (lq)	-170	Yaws; T 6.3
NH_3 (g)	-45,94	Lange's; T 6.3
NH_3 (lq)	-	
H_2SO_4	-814	Lange's; T 6.3
$H_2SO_4.H_2O$	-1127,6	Lange's; T 6.3
$(NH_4)_2SO_4$	-1180,9	Lange's; 6.84
$C_3H_5NO.H_2SO_4$	-984	

1. Heater Akrilonitril (E-112)

Fungsi : Menaikkan akrilonitril dari 30℃ menjadi 90℃



Kondisi operasi :

Tekanan : 1 atm

Suhu : 90 ℃

Bahan masuk

Komponen	Berat (kg/jam)	BM (kg/kmol)	kmol/jam
C_3H_3N	5060,6879	53	95,4847
H_2O	25,43059225	18	1,4128

T = 30 ℃ = 303,15 K

Treff = 25 ℃ = 298,15 K

Perhitungan kapasitas panas Akrilonitril

$$\int_{Treff}^{T} Cp\, dT = \int_{Treff}^{T} (A + B.T + C.T^2)\, dT$$

$$Cp = 33,4 \times (303 - 298) + \frac{0,59}{2} \times (303^2 - 298^2) + \frac{-0,0019}{3} \times (303^3 - 298^3) + \frac{2,5E\text{-}06}{4} \times (303^4 - 298^4)$$

$$= 545,66 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 95,4847 \text{ kmol/jam} \times 545,66 \text{ J/mol} = 52102,1 \text{ kJ/jam}$$

Perhitungan kapasitas panas Air

$$Cp = 92,05 \times (303 - 298) + \frac{-0,04}{2} \times (303^2 - 298^2) + \frac{-0,0002}{3} \times (303^3 - 298^3) + \frac{5,3E\text{-}07}{4} \times (303^4 - 298^4)$$

$$= 377,4864 \text{ J/mol}$$

ΔH = n x Cp
= 1,4128 kmol/jam x 377,486 J/mol = 533,317 kJ/jam
ΔH masuk total = ΔH akrilonitr + ΔH air
= 52102,1 kJ/jam + 533,317 kJ/jam
= 52635,5 kJ/jam

Bahan keluar

Komponen	Berat (kg/jam)	BM (kg/kmol)	kmol/jam
C_3H_3N	5060,6879	53	95,4847
H_2O	25,43059225	18	1,4128

T = 90 °C = 363,15 K
Treff = 25 °C = 298,15 K
Perhitungan kapasitas panas Akrilonitril

$$Cp = 18{,}43 \times (363 - 298) + \frac{0{,}18}{2} \times (363^2 - 298^2) + \frac{-0{,}0001}{3} \times (363^3 - 298^3) + \frac{1{,}9E\text{-}08}{4} \times (363^4 - 298^4) + \frac{9{,}E\text{-}13}{5} \times (363^5 - 298^5)$$

= 4466 J/mol
ΔH = n x Cp
= 95,48468 kmol/jam x 4466 J/mol = 426395 kJ/jam

Perhitungan kapasitas panas Air

$$Cp = 92{,}05 \times (363 - 298) + \frac{-0{,}04}{2} \times (363^2 - 298^2) + \frac{-0{,}0002}{3} \times (363^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (363^4 - 298^4)$$

= 4888,787 J/mol
ΔH = n x Cp
= 1,4128 kmol/jam x 4888,79 J/mol = 6906,93 kJ/jam

ΔH keluar total = ΔH akrilonitr + ΔH air
= 426395 kJ/jam + 6906,93 kJ/jam
= 433302

Neraca Energi Total

Q loss maksimum = 10% ***Ulrich; 432***
ΔH masuk total + Q supply = ΔH keluar total + Q loss
52635 kJ/jam + Q supply = 433302 kJ/jam + 10% Q supply
Q supply - 10% Q supply = 380666 kJ/jam

$$\text{Q supply} = \frac{380666 \text{ kJ/jam}}{90\%} = 422963 \text{ kJ/jam}$$

Q loss = 10% x 422963 kJ/jam
= 42296,3 kJ/jam

Kebutuhan steam pada tekanan 4,5 bar dan suhu 148°C ***Ulrich; 426***
Panas sensibel : panas yang dibutuhkan untuk merubah fasa liquid menjadi gas
T = 421,15 K
Cp steam = 9313,88612 J/mol

$$\text{n steam} = \frac{\text{Q steam}}{\text{Cp steam}} = \frac{422962,775 \text{ kJ/jam}}{9313,88612 \text{ J/mol}} = 45,4120622 \text{ kmol/jam}$$

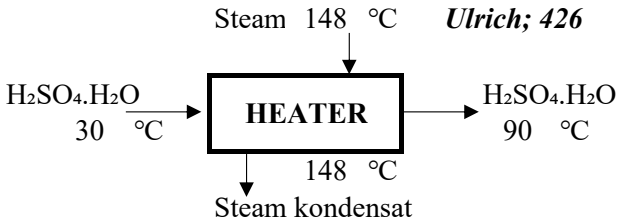
m steam = 45,4120622 kmol/jam x 18 kmol/jam
817,417 kg/jam

Jadi dibutuhkan steam sebesar 817,417 kg/jam

Neraca Panas pada Heater 1

Komponen Masuk, ΔH (kJ/jam)		Komponen Keluar, ΔH (kJ/jam)	
dari F-110		**ke R-210**	
C_3H_3N	52102,1374	C_3H_3N	426395,02
H_2O	533,316792	H_2O	6906,9311
Q supply	422962,775	Q loss	42296,278
	475598,2296		475598,2296

2. Heater Asam sulfat monohidrat (E122)
Fungsi : Menaikkan suhu asam sulfat monohidrat dari 30°C menjadi 90°C



Kondisi operasi :
Tekanan : 1 atm
Suhu : 90 °C

Bahan masuk

Komponen	Berat (kg/jam)	BM (kg/kmol)	kmol/jam
$H_2SO_4.H_2O$	11076,2225	116	95,4847

T = 30 °C = 303,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas Asam sulfat monohidrat

$$\int_{Treff}^{T} Cp\, dT = \int_{Treff}^{T} (A + B.T + C.T^2)\, dT$$

Cp = 216 x (303 - 298)
= 1079,5 J/mol
ΔH = n x Cp
= 95,4847 kmol/jam x 1079,5 J/mol = 103076 kJ/jam

ΔH masuk total = ΔH $H_2SO_4.H_2O$
= 103076 kJ/jam

Bahan keluar

Komponen	Berat (kg/jam)	BM (kg/kmol)	kmol/jam
$H_2SO_4.H_2O$	11076,2225	116	95,4847

T = 90 °C = 363,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas Asam sulfat monohidrat

$$\int_{Treff}^{T} Cp\, dT = \int_{Treff}^{T} (A + B.T + C.T^2)\, dT$$

Cp = 214 x (363 - 298)
= 13929,5 J/mol
ΔH = n x Cp
= 95,4847 kmol/jam x 13929,5 J/mol = 1330054 kJ/jam

ΔH keluar total = ΔH $H_2SO_4.H_2O$
= 1330054 kJ/jam

Neraca Energi Total

Q loss maksimum = 10% ***Ulrich; 432***
ΔH masuk total + Q supply = ΔH keluar total + Q loss
103076 kJ/jam + Q supply = 1330054 kJ/jam + 10% Q supply
Q supply - 10% Q supply = 1226978 kJ/jam

$$\text{Q supply} = \frac{1226978 \text{ kJ/jam}}{90\%}$$

= 1363309 kJ/jam

Q loss = 10% x 1363309 kJ/jam
= 136330,899 kJ/jam

Kebutuhan steam pada tekanan 4,5 bar dan suhu 148°C
Panas sensibel : panas yang dibutuhkan untuk menaikkan suhu tanpa merubah fasa

T = 148 °C = 421,15 K
T reff = 25 °C = 298,15 K

$$Cp = 33{,}93 \times (421 - 298) + \frac{-8{,}E\text{-}03}{2} \times (421^2 - 298^2) + \frac{3{,}E\text{-}05}{3} \times (421^3 - 298^3) + \frac{-2E\text{-}08}{4} \times (421^4 - 298^4) + \frac{3{,}7E\text{-}12}{5} \times (421^5 - 298^5)$$

= 4185 J/mol

$$n = \frac{Q}{Cp \times \Delta T}$$

$$= \frac{1363308{,}99 \text{ kJ/jam}}{4185 \text{ J/mol}} = 325{,}7723 \text{ kmol/jam}$$

m = 325,7723 kmol/jam x 18 kg/kmol
= 5863,901 kg/jam

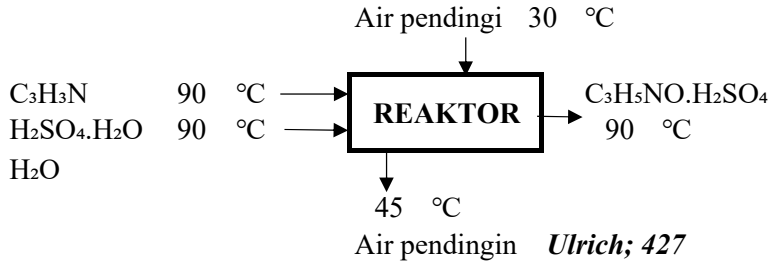
Jadi steam yang dibutuhkan sebesar 5863,9 kg/jam

Neraca Panas pada Heater 2

Komponen Masuk, ΔH (kJ/jam)		Komponen Keluar, ΔH (kJ/jam)	
dari F-110		**ke R-210**	
$H_2SO_4.H_2O$	103075,708	$H_2SO_4.H_2O$	1330053,8
Q supply	1363308,99	Q loss	136330,9
	1466384,701		1466384,701

3. Reaktor (R-210)

Fungsi : Mereaksikan akrilonitril dan asam sulfat monohidrat



Ulrich; 427

Kondisi operasi :

Tekanan : 1 atm
Suhu : 90 °C

Reaksi :

$C_3H_3N + H_2SO_4.H_2O \longrightarrow C_3H_5NO.H_2SO_4$

Bahan masuk

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_3N	5060,6879	53	95,4847
H_2O	25,4306	18	1,41281
$H_2SO_4.H_2O$	11076,2225	116	95,4847

T = 90 °C = 363,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilonitril

$$Cp = 18{,}43 \times (363 - 298) + \frac{0{,}18}{2} \times (363^2 - 298^2) + \frac{-0{,}0001}{3} \times (363^3 - 298^3) + \frac{1{,}9E\text{-}08}{4} \times (363^4 - 298^4) + \frac{9{,}1,E\text{-}13}{5} \times (363^5 - 298^5)$$

= 4466 J/mol

ΔH = n x Cp
= 95,48468 kmol/jam x 4466 J/mol = 426395 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (363 - 298) + \frac{-0{,}04}{2} \times (363^2 - 298^2) + \frac{-0{,}0002}{3} \times (363^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (363^4 - 298^4)$$

= 4888,787 J/mol

ΔH = n x Cp
= 1,4128 kmol/jam x 4888,79 J/mol = 6906,93 kJ/jam

Perhitungan kapasitas panas asam sulfat monohidrat

$Cp = 214{,}3 \times (363 - 298)$
= 13929,5 J/mol

ΔH = n x Cp
= 95,48468 kmol/jam x 13929,5 J/mol = 1330054 kJ/jam

ΔH masuk total = ΔH C_3H_3N + ΔH H_2O + ΔH $H_2SO_4.H_2O$
= 426395 + 6906,93 + 1330054 kJ/jam
= 1763356 kJ/jam

Bahan keluar

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_3N	253,0344	53	4,77423
$H_2SO_4.H_2O$	553,8111	116	4,77423
$C_3H_5NO.H_2SO_4$	15330,06482	169	90,7104
H_2O	25,43059225	18	1,41281

Perhitungan kapasitas panas akrilonitril

T = 90 °C = 363,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilonitril

$$Cp = 18,43 \times (363 - 298) + \frac{0,18}{2} \times (363^2 - 298^2) + \frac{-0,0001}{3} \times (363^3 - 298^3) + \frac{1,9E-08}{4} \times (363^4 - 298,2^4) + \frac{9,1,E-13}{5} \times (363^5 - 298^5)$$

$$= 4466 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 4,774234 \text{ kmol/jam} \times 4466 \text{ J/mol} = 21319,8 \text{ kJ/jam}$$

Perhitungan kapasitas panas asam sulfat monohidrat

$$Cp = 214,3 \times (363 - 298)$$

$$= 13929,5 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 4,774234 \text{ kmol/jam} \times 13929,5 \text{ J/mol} = 66502,7 \text{ kJ/jam}$$

Perhitungan kapasitas panas akrilamida sulfat

$$Cp = 9,262 \times (363 - 298) + \frac{0,08}{2} \times (363^2 - 298^2) + \frac{-0,0001}{3} \times (363^3 - 298^3) + \frac{2E-08}{4} \times (363^4 - 298^4)$$

$$= 1913,64 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 90,7104 \text{ kmol/jam} \times 1913,64 \text{ J/mol} = 173587 \text{ kJ/jam}$$

Perhitungan kapasitas panas air

$$Cp = 92,05 \times (363 - 298) + \frac{-0,04}{2} \times (363^2 - 298^2) + \frac{-0,0002}{3} \times (363^3 - 298^3) + \frac{5,3E-07}{4} \times (363^4 - 298^4)$$

$$= 4888,787 \text{ J/mol}$$

ΔH = n x Cp
= 1,4128 kmol/jam x 4888,79 J/mol = 6906,93 kJ/jam
ΔH keluar total = ΔH C_3H_3N + ΔH $H_2SO_4.H_2O$ + $C_3H_5NO.H_2SO_4$ + Δ H_2O
= 21319,8 + 66502,7 + 173587 + 6906,93 kJ/jam
= 268316,463 kJ/jam

Menghitung panas Reaksi (ΔHR 298) dan (ΔHR 363)
ΔHf 298 produk = (mol $C_3H_5NO.H_2SO_4$ x ΔHf $C_3H_5NO.H_2SO_4$)
= 90,7104 kmol/jam x -984 kJ/mol
= 90710,4 mol/jam x -984 kJ/mol
= -89259075,65 kJ/jam
ΔHf 298 reaktan = (mol $H_2SO_4.H_2O$ x ΔHf $H_2SO_4.H_2O$) +
(mol C_3H_3N x ΔHf C_3H_3N)
= 95484,7 mol/jam x -1127,6 kJ/mol +
95484,7 mol/jam x 180,6 kJ/mol
= -90423989 kJ/jam
ΔHR 298 = ΔHf 298 produk - ΔHf 298 reaktan
= -89259076 kJ/jam - -90423989 kJ/jam
= 1164913,05 kJ/jam
ΔHR 363 = (ΔH Produk - ΔH Reaktan) + ΔHR 25°C
= ((268316 - 1763356) + 1164913) kJ/jam
= -330126,24 kJ/jam

Panas reaksi bernilai negatif (-), hal ini menunjukkan reaksi berjalan secara eksotermis. Pada reaksi eksotermis reaktor memerlukan media pendingin untuk menjaga suhu

Neraca panas total :

ΔH masuk + ΔH Reaksi = ΔH keluar + Q serap + Q loss
Q loss = 10% ΔH masuk ***Ulrich; 432***
1763355,754 + 330126,237 = 268316,46 + 176335,58 + Q serap
Q serap = 1648830 kJ/jam

Kebutuhan air pendingin :

Suhu inlet air pendingin : 30 °C = 303,15 K
Suhu outlet air pendingin 45 °C = 318,15 K
Perhitungan kapasitas panas air pendingin :

$$\int_{Treff}^{T} Cp\, dT = \int_{Treff}^{T} (A + B.T + C.T^2)\, dT$$

$$Cp = 92{,}05 \times (318 - 303) + \frac{-0{,}04}{2} \times (318^2 - 303^2) + \frac{-0{,}0002}{3} \times (318^3 - 303^3) + \frac{5{,}3E\text{-}07}{4} \times (318^4 -$$

318 [4])

= 889,0879 J/mol

$$n = \frac{Q}{Cp \times \Delta T}$$

$$= \frac{1648829,95 \text{ kJ/jam}}{889,087897 \text{ J/mol}} = 1854,5185 \text{ kmol/jam}$$

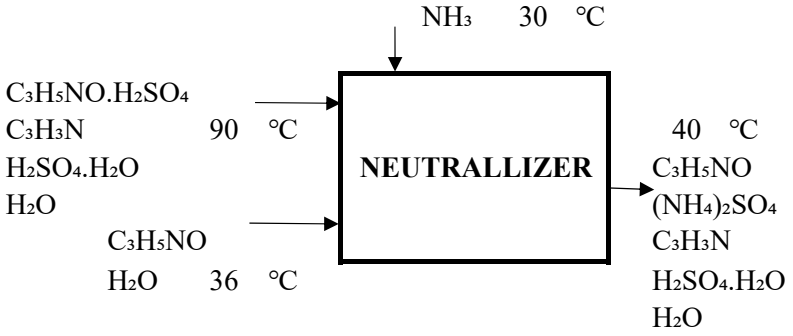
m = 1854,5185 kmol/jam x 18 kg/kmol = 33381,333 kg/jam

Neraca Panas pada Reaktor

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
dari feed			
C_3H_3N	426395,02	C_3H_3N	21319,751
H_2O	6906,9311	$H_2SO_4.H_2O$	66502,69
$H_2SO_4.H_2O$	1330053,8	$C_3H_5NO.H_2SO_4$	173587,09
	1763355,8	H_2O	6906,9311
		Q serap	1648830
Q reaksi	330126,24	**Q loss**	176335,58
	2093481,992		2093481,992

4. Neutrallizer (R-220)

Fungsi : Menetralkan akrilamida sulfat dengan menambahkan ammonia



Kondisi operasi :

Tekanan : 1 atm

Suhu : 40 °C

Reaksi :

$C_3H_5NO.H_2S^{(}+ \quad 2\ NH_3 \longrightarrow C_3H_5NO + (NH_4)_2SO_4$

Bahan masuk :

dari Reaktor

Komponen	Berat (kg/jam)	BM	kmol/jam
$C_3H_5NO.H_2SO_4$	15330,06482	169	90,7104
C_3H_3N	253,0343929	53	4,77423

$H_2SO_4.H_2O$	553,8111241	116	4,77423
H_2O	25,43059225	18	1,41281

T = 90 °C = 363,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida sulfat

$$Cp = 9{,}262 \times (363 - 298) + \frac{0{,}08}{2} \times (363^2 - 298^2) + \frac{-0{,}0001}{3} \times (363^3 - 298^3) + \frac{2E\text{-}08}{4} \times (363^4 - 298^4)$$

= 1913,64 J/mol

ΔH = n x Cp
= 90,7104 kmol/jam x 1913,64 J/mol = 173587 kJ/jam

Perhitungan kapasitas panas akrilonitril

$$Cp = 18{,}43 \times (363 - 298) + \frac{0{,}18}{2} \times (363^2 - 298^2) + \frac{-0{,}0001}{3} \times (363^3 - 298^3) + \frac{1{,}9E\text{-}08}{4} \times (363^4 - 298^4) + \frac{9{,}1E\text{-}13}{5} \times (363^5 - 298^5)$$

= 4465,586 J/mol

ΔH = n x Cp
= 4,7742 kmol/jam x 4465,59 J/mol = 21319,8 kJ/jam

Perhitungan kapasitas panas asam sulfat monohidrat

Cp = 214,3 x (363 - 298)
= 13929,5 J/mol

ΔH = n x Cp
= 4,774234 kmol/jam x 13929,5 J/mol = 66502,7 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (363 - 298) + \frac{-0{,}04}{2} \times (363^2 - 298^2) + \frac{-0{,}0002}{3} \times (363^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (363^4 - 298^4)$$

= 4888,787 J/mol

ΔH = n x Cp
= 4,7742 kmol/jam x 4888,79 J/mol = 23340,2 kJ/jam

ΔH total = $C_3H_5NO.H_2SO_4$ + ΔH C_3H_3N + ΔH $H_2SO_4.H_2O$ + Δ H_2O
dari reaktor = 173587 + 21319,8 + 66502,7 + 23340,2 kJ/jam
= 284749,746 kJ/jam

Ammonia

Komponen	Berat (kg/jam)	BM	kmol/jam
NH_3	3084,155053	17	181,421
H_2O	15,4982666	18	0,86101

T = 30 °C = 303,15 K
Treff = 25 °C = 298,15 K
Perhitungan kapasitas panas ammonia

$$Cp = 33{,}57 \times (303 - 298) + \frac{-1{,}E\text{-}02}{2} \times (303^2 - 298^2) + \frac{9{,}E\text{-}05}{3} \times (303^3 - 298^3) + \frac{-7E\text{-}08}{4} \times (303^4 - 298^4) + \frac{1{,}9E\text{-}11}{5} \times (303^5 - 298^5)$$

= 180,1390 J/mol
ΔH = n x Cp
= 181,4209 kmol/jam x 180,1390 J/mol
= 32680,9724 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (303 - 298) + \frac{-0{,}04}{2} \times (303^2 - 298^2) + \frac{-0{,}0002}{3} \times (303^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (303^4 - 298^4)$$

= 377,4864 J/mol
ΔH = n x Cp
= 0,8610 kmol/jam x 377,486 J/mol = 325,021 kJ/jam

ΔH total = ΔH NH_3 + ΔH H_2O
= 32680,9724 + 325,02137 kJ/jam
= 33005,9937 kJ/jam

dari Filter Press

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	6313,762653	71	88,9262
H_2O	12444,50911	18	691,362

T = 36 °C = 309,15 K
Treff = 25 °C = 298,15 K
Perhitungan kapasitas panas dari akrilamida

$$Cp = 55{,}69 \times (309 - 298) + \frac{0{,}49}{2} \times (309^2 - 298^2) + \frac{-0{,}0011}{3} \times (309^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (309^4 - 298^4)$$

= 1482,247 J/mol
ΔH = n x Cp
= 88,9262 kmol/jam x 1482,25 J/mol = 131811 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (309 - 298) + \frac{-0{,}04}{2} \times (309^2 - 298^2) + \frac{-0{,}0002}{3} \times (309^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (309^4 - 298^4)$$

= 829,8003 J/mol
ΔH = n x Cp
= 691,3616 kmol/jam x 829,8 J/mol = 573692 kJ/jam

ΔH total dari Filter Press = ΔH C_3H_5NO + ΔH H_2O
= (131811 + 573692) kJ/jam
= 705503 kJ/jam

Bahan keluar

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	12754,20409	71	179,637
$(NH_4)_2SO_4$	11973,77844	132	90,7104
C_3H_3N	501,091784	53	9,45456
$H_2SO_4.H_2O$	553,8111241	116	4,77423
H_2O	12485,43797	18	693,635

T = 40 °C = 313,15 K
Treff = 25 °C = 298,15 K
Perhitungan kapasitas panas akrilamida

$$Cp = 55{,}69 \times (313 - 298) + \frac{0{,}49}{2} \times (313^2 - 298^2) + \frac{-0{,}0011}{3} \times (313^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (313^4 - 298^4)$$

= 2025,253 J/mol

ΔH = n x Cp
= 179,6367 kmol/jam x 2025,25 J/mol = 363810 kJ/jam

Perhitungan kapasitas panas ammonium sulfat

Cp = 215,9 x (313 - 298)
= 3238,5 J/mol

ΔH = n x Cp
= 90,7104 kmol/jam x 3238,5 J/mol = 293766 kJ/jam

Perhitungan kapasitas panas akrilonitril

$Cp = 33{,}36 \times (313 - 298) + \frac{0{,}59}{2} \times (313^2 - 298^2) + \frac{-0{,}0019}{3} \times (313^3 - 298^3) + \frac{2{,}5E\text{-}06}{4} \times (313^4 - 298^4)$

= 1647,978 J/mol

ΔH = n x Cp
= 9,4546 kmol/jam x 1647,98 J/mol = 15580,9 kJ/jam

Perhitungan kapasitas panas asam sulfat monohidrat

Cp = 214,3 x (313 - 298)
= 3214,5 J/mol

ΔH = n x Cp
= 4,7742 kmol/jam x 3214,5 J/mol = 15346,8 kJ/jam

Perhitungan kapasitas panas air

$Cp = 92{,}05 \times (313 - 298) + \frac{-0{,}04}{2} \times (313^2 - 298^2) + \frac{-0{,}0002}{3} \times (313^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (313^4 - 298^4)$

= 1130,993 J/mol

ΔH = n x Cp
= 693,6354 kmol/jam x 1130,99 J/mol = 784497 kJ/jam

ΔH total keluar Neutrallizer = ΔH C_3H_5NO + ΔH $(NH_4)_2SO_4$ +
ΔH C_3H_3N + ΔH $H_2SO_4.H_2O$ + ΔH H_2O
= (363810 + 293766 + 15580,9 +
15346,8 + 784497) kJ/jam
= 1473000,1 kJ/jam

Reaksi :

	$C_3H_5NO.H_2SO_4$ +	2 NH_3 ⟶	C_3H_5NO +	$(NH_4)_2SO_4$
M	90,710443	181,420885	-	-
R	90,710443	181,420885	90,710443	90,710443
S	0	0	90,710443	90,710443

Menghitung panas Reaksi (ΔHR 298) dan (ΔHR 363)

ΔHf 298 produk = (mol C_3H_5NO x ΔHf C_3H_5NO) + (mol $(NH_4)_2SO_4$ x ΔHf $(NH_4)_2SO_4$)
= 90710,4 mol/jam x -170 kJ/mol + 90710,4 mol/jam x -1180,9 kJ/mol
= -122540737,1 kJ/jam

ΔHf 298 reaktan = (mol $C_3H_5NO.H_2SO_4$ x ΔHf $C_3H_5NO.H_2SO_4$) + (mol NH_3 x ΔHf NH_3)
= 90710,4 mol/jam x -984 kJ/mol + 181421 mol/jam x -45,94 kJ/mol
= -97593551 kJ/jam

ΔHR 298 = ΔHf 298 produk - ΔHf 298 reaktan
= -122540737 kJ/jam - -97593551 kJ/jam
= -24947186 kJ/jam

ΔHR 313 = (ΔH Produk - ΔH Reaktan) + ΔHR 25°C
= ((1473000 - 1023258,4280) + -2E+07) kJ/jam
= -24497444,3340 kJ/jam

Panas Reaksi bernilai negatif (-), maka reaksi ekotermis

Neraca panas total :

ΔH masuk + ΔH Reaksi = ΔH keluar + Q serap + Q loss

Q loss = 10% ΔH masuk ***Ulrich; 432***

1023258,4280 + 24497444,3 = 1473000,1 + 102325,84 + Q serap

Q serap = 23945376,8646 kJ/jam

Kebutuhan air pendingin :

Suhu inlet air pendingin : 30 °C = 303,15 K

Suhu outlet air pendingin 45 °C = 318,15 K

Perhitungan kapasitas panas air pendingin :

$$\int_{Treff}^{T} Cp\, dT = \int_{Treff}^{T} (A + B.T + C.T^2)\, dT$$

$$Cp = 92{,}05 \times (318 - 303) + \frac{-0{,}04}{2} \times (318^2 - 303^2) + \frac{-0{,}0002}{3} \times (318^3 - 303^3) + \frac{5{,}3E\text{-}07}{4} \times (318^4 - 318^4)$$

= 889,0879 J/mol

$$n = \frac{Q}{Cp \times \Delta T}$$

$$= \frac{23945376{,}9 \text{ kJ/jam}}{889{,}087897 \text{ J/mol}} = 26932{,}519 \text{ kmol/jam}$$

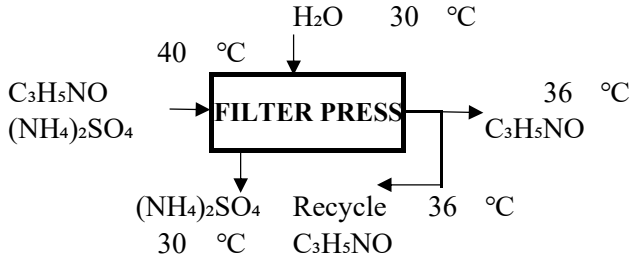
$$m = 26932{,}5192 \text{ kmol/jam} \times 18 \text{ kg/kmol} = 484785{,}35 \text{ kg/jam}$$

Neraca Panas pada Neutrallizer

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
dari R-210		**ke H-230**	
$C_3H_5NO.H_2SO_4$	173587,0906	C_3H_5NO	363809,7940
C_3H_3N	21319,7510	$(NH_4)_2SO_4$	293765,7688
$H_2SO_4.H_2O$	66502,6901	C_3H_3N	15580,9103
H_2O	23340,21447	$H_2SO_4.H_2O$	15346,7746
	284749,7462	H_2O	784496,8069
dari F-130			1473000,0545
NH_3	32680,97237		
H_2O	325,0213655	**Q loss**	102325,8428
	33005,99374		
dari H-230			
C_3H_5NO	131810,6028	**Q serap**	23945376,86
H_2O	573692,0853		
	705502,6880		
Q reaksi	24497444,3340		
	25520702,7619		25520702,7619

5. Filter Press (H-230)

Fungsi : Memisahkan cake dan filtrat dari campuran



Kondisi operasi :

Tekanan : 1 atm

Suhu : 36 °C

Bahan masuk

Slurry

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	12754,20409	71	179,637
$(NH_4)_2SO_4$	11973,77844	132	90,7104
C_3H_3N	501,091784	53	9,45456
$H_2SO_4.H_2O$	553,8111241	116	4,77423
H_2O	12485,43797	18	693,635

T = 40 °C = 313,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida

$$Cp = 55{,}69 \times (313 - 298) + \frac{0{,}49}{2} \times (313^2 - 298^2) + \frac{-0{,}0011}{3} \times (313^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (313^4 - 298^4)$$

= 2025,253 J/mol

ΔH = n x Cp

= 179,6367 kmol/jam x 2025,253 J/mol = 363810 kJ/jam

Perhitungan kapasitas panas ammonium sulfat

$$Cp = 215{,}9 \times (313 - 298)$$

= 3238,5 J/mol

ΔH = n x Cp

= 90,7104 kmol/jam x 3238,5 J/mol = 293766 kJ/jam

Perhitungan kapasitas panas akrilonitril

$$Cp = 33{,}36 \times (313 - 298) + \frac{0{,}59}{2} \times (313^2 - 298^2) + \frac{-0{,}0019}{3} \times (313^3 - 298^3) + \frac{2{,}5E\text{-}06}{4} \times (313^4 - 298^4)$$

= 1647,978 J/mol

ΔH = n x Cp

= 9,4546 kmol/jam x 1647,98 J/mol = 15580,9 kJ/jam

Perhitungan kapasitas panas asam sulfat monohidrat

$$Cp = 214{,}3 \times (313 - 298)$$

= 3214,5 J/mol

ΔH = n x Cp

= 4,7742 kmol/jam x 3214,5 J/mol = 15346,8 kJ/jam

Perhitungan kapasitas panas air

$Cp = 92,05 \times (313 - 298) + \frac{-0,04}{2} \times (313^2 - 298^2) + \frac{-0,0002}{3} \times (313^3 - 298^3) + \frac{5,3E-07}{4} \times (313^4 - 298^4)$

$= 1130,993$ J/mol

$\Delta H = n \times Cp$

$= 693,6354$ kmol/jam x $1130,99$ J/mol $= 784497$ kJ/jam

ΔH total masuk Filter Prees = $\Delta H\ C_3H_5NO + \Delta H\ (NH_4)_2SO_4 + \Delta H\ C_3H_3N + \Delta H\ H_2SO_4.H_2O + \Delta H\ H_2O$

$= (363810 + 293766 + 15580,9 + 15346,8 + 784497)$

$= 1473000,1$ kJ/jam

Air Proses

Komponen	Berat (kg/jam)	BM	kmol/jam
H_2O	12527,58956	18	695,977

T = 30 °C = 303,15

Treff = 25 °C = 298,15

Perhitungan kapasitas panas air proses

$Cp = 92,05 \times (303 - 298) + \frac{-0,04}{2} \times (303^2 - 298^2) + \frac{-0,0002}{3} \times (303^3 - 298^3) + \frac{5,3E-07}{4} \times (303^4 - 298^4)$

$= 377,4864$ J/mol

$\Delta H = n \times Cp$

$= 695,9772$ kmol/jam x $377,486$ J/mol $= 262722$ kJ/jam

ΔH total bahan masuk = ΔH masuk filter press + ΔH air proses

$= 1473000 + 262722$

$= 1735722$ kJ/jam

Bahan keluar

Filtrat

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	6313,762653	71	88,9262
C_3H_3N	248,0573911	53	4,68033
H_2O	12444,50911	18	691,362

T = 36 °C = 309,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida

$Cp = 55{,}69 \times (309 - 298) + \frac{0{,}49}{2} \times (309^2 - 298^2) + \frac{-0{,}0011}{3} \times (309^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (309^4 - 298^4)$

= 1482,247 J/mol

ΔH = n x Cp

= 88,9262 kmol/jam x 1482,25 J/mol = 131811 kJ/jam

Perhitungan kapasitas panas akrilonitril

$Cp = 33{,}36 \times (309 - 298) + \frac{0{,}59}{2} \times (309^2 - 298^2) + \frac{-0{,}0019}{3} \times (309^3 - 298^3) + \frac{2{,}5E\text{-}06}{4} \times (309^4 - 298^4)$

= 1205,253 J/mol

ΔH = n x Cp

= 4,6803 kmol/jam x 1205,25 J/mol = 5640,98 kJ/jam

Perhitungan kapasitas panas air

$Cp = 92{,}05 \times (309 - 298) + \frac{-0{,}04}{2} \times (309^2 - 298^2) + \frac{-0{,}0002}{3} \times (309^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (309^4 - 298^4)$

= 829,8003 J/mol

ΔH = n x Cp

= 691,3616 kmol/jam x ####### J/mol = 573692 kJ/jam

ΔH total filtrat keluar = (ΔH C_3H_5NO + ΔH H_2O + ΔH C_3H_3N)

= (131811 + 573692 + 5640,98) kJ/jam

= 711143,67 kJ/jam

Recycle ke Neutrallizer

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	6313,762653	71	88,9262
C_3H_3N	248,0573911	53	4,68033
H_2O	12444,50911	18	691,362

T = 36 °C = 309,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida

$$Cp = 55{,}69 \times (309 - 298) + \frac{0{,}49}{2} \times (309^2 - 298^2) + \frac{-0{,}0011}{3} \times (309^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (309^4 - 298^4)$$

= 1482,247 J/mol

ΔH = n x Cp
= 88,9262 kmol/jam x 1482,25 J/mol = 131811 kJ/jam

Perhitungan kapasitas panas akrilonitril

$$Cp = 33{,}36 \times (309 - 298) + \frac{0{,}59}{2} \times (309^2 - 298^2) + \frac{-0{,}0019}{3} \times (309^3 - 298^3) + \frac{2{,}5E\text{-}06}{4} \times (309^4 - 298^4)$$

= 1205,253 J/mol

ΔH = n x Cp
= 4,6803 kmol/jam x 1205,25 J/mol = 5640,98 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (309 - 298) + \frac{-0{,}04}{2} \times (309^2 - 298^2) + \frac{-0{,}0002}{3} \times (309^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (309^4 - 298^4)$$

= 829,8003 J/mol

ΔH = n x Cp
= 691,3616 kmol/jam x 829,8 J/mol = 573692 kJ/jam

ΔH total recycle = (ΔH C_3H_5NO + ΔH C_3H_3N + ΔH H_2O)
= (131811 + 5640,98 + 573692) kJ/jam
= 711143,67 kJ/jam

Cake

Komponen	Berat (kg/jam)	BM	kmol/jam
$(NH_4)_2SO_4$	11973,7784	132	90,7104
$H_2SO_4.H_2O$	553,8111	116	4,77423
C_3H_5NO	126,6788	18	7,03771
C_3H_3N	4,9770	19	0,26195
H_2O	124,0093	20	6,20047

T = 30 °C = 303,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas ammonium sulfat

Cp = 215,9 x (303 - 298)
= 1079,5 J/mol
ΔH = n x Cp
= 90,7104 kmol/jam x 1079,5 J/mol = 97921,9 kJ/jam

Perhitungan kapasitas panas asam sulfat monohidrat

Cp = 214,3 x (303 - 298)
= 1071,5 J/mol
ΔH = n x Cp
= 4,7742 kmol/jam x 1071,5 J/mol = 5115,59 kJ/jam

Perhitungan kapasitas panas akrilamida

$$Cp = 55{,}69 \times (303 - 298) + \frac{0{,}49}{2} \times (303^2 - 298^2) + \frac{-0{,}0011}{3} \times (303^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (303^4 - 298^4)$$

= 671,7363 J/mol
ΔH = n x Cp
= 7,0377 kmol/jam x 671,736 J/mol = 4727,49 kJ/jam

Perhitungan kapasitas panas akrilonitril

$$Cp = 33{,}36 \times (303 - 298) + \frac{0{,}59}{2} \times (303^2 - 298^2) + \frac{-0{,}0019}{3} \times (303^3 - 298^3) + \frac{2{,}5E\text{-}06}{4} \times (303^4 - 298^4)$$

= 545,6597 J/mol
ΔH = n x Cp
= 0,2619 kmol/jam x 545,66 J/mol = 142,934 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (303 - 298) + \frac{-0{,}04}{2} \times (303^2 - 298^2) + \frac{-0{,}0002}{3} \times (303^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (303^4 - 298^4)$$

= 377,4864 J/mol

ΔH = n x Cp
= 6,2005 kmol/jam x 377,486 J/mol = 2340,59 kJ/jam

ΔH total cake keluar = ΔH $(NH_4)_2SO_4$ + ΔH $H_2SO_4.H_2O$ + ΔH C_3H_5NO + ΔH C_3H_3N + ΔH H_2O
= 97921,9 + 5115,59 + 4727,49 + 142,934 + 2340,59
= 110248,525 kJ/jam

ΔH total bahan keluar = ΔH filtrat + ΔH recycle + ΔH cake
= 711144 + 711144 + 110249
= 1532535,86 kJ/jam

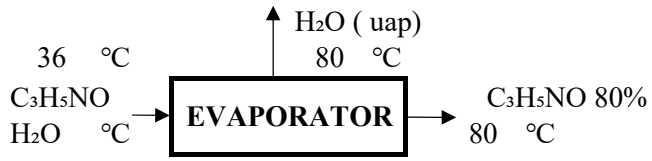
ΔH masuk = ΔH keluar
1735721,97 kJ/jam = 1532535,9 + Q loss
Q loss = 203186 kJ/jam
= 203186
1735721,969 = 1735721,969

Neraca Panas pada Filter Press (H-230)

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
dari R-210		**Filtrat**	
C_3H_5NO	363809,7940	C_3H_5NO	131810,6028
$(NH_4)_2SO_4$	293765,7688	C_3H_3N	5640,980463
C_3H_3N	15580,9103	H_2O	573692,0853
$H_2SO_4.H_2O$	15346,7746		711143,6685
H_2O	784496,8069	**Recycle ke R-220**	
	1473000,0545	C_3H_5NO	131810,6028
		C_3H_3N	5640,9805
Air proses		H_2O	573692,0853
H_2O	262721,9142		711143,6685
		Cake ke F-410	
		$(NH_4)_2SO_4$	97921,9229
		$H_2SO_4.H_2O$	5115,5915
		C_3H_5NO	4727,4854
		C_3H_3N	142,9342
		H_2O	2340,5913
			110248,5253
		Q loss	203186,1064
	1735721,9687		1735721,9687

6. Evaporator (V-240)

Fungsi : memekatkan akrilamida hingga kadar 80%



Kondisi operasi :

Tekanan : 0,6136 atm

Suhu : 80 ℃

Enthalpi Bahan Masuk = Enthalpi bahan Keluar

F. Hf + S . Hs = L . Hl + V. Hv + C . Hc

ΔHf + S. (Hs-Hc) = L . Hl + V. Hv

ΔHf + S x λ = ΔHl + V x Hv

Bahan masuk

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	6313,762653	71	88,9262
H_2O	12444,50911	18	691,362
C_3H_3N	248,0573911	53	4,68033

T = 36 ℃ = 309,15 K

Treff = 25 ℃ = 298,15 K

Perhitungan kapasitas panas akrilamida

$$Cp = 55{,}69 \times (309 - 298) + \frac{0{,}49}{2} \times (309^2 - 298^2) + \frac{-0{,}0011}{3} \times (309^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (309^4 - 298^4)$$

$$= 1482{,}247 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 88{,}9262 \text{ kmol/jam} \times 1482{,}25 \text{ J/mol} = 131811 \text{ kJ/jam}$$

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (309 - 298) + \frac{-0{,}04}{2} \times (309^2 - 298^2) + \frac{-0{,}0002}{3} \times (309^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (309^4 - 298^4)$$

$$= 829{,}8003 \text{ J/mol}$$

ΔH = n x Cp
= 691,3616 kmol/jam x 829,8 J/mol = 573692 kJ/jam

Perhitungan kapasitas panas akrilonitril

$$Cp = 33,36 \times (309 - 298) + \frac{0,59}{2} \times (309^2 - 298^2) + \frac{-0,0019}{3} \times (309^3 - 298^3) + \frac{2,5E\text{-}06}{4} \times (309^4 - 298^4)$$

= 1205,253 J/mol

ΔH = n x Cp
= 4,6803 kmol/jam x 1205,25 J/mol = 5640,98 kJ/jam

ΔH total masuk evaporator = $\Delta H\ C_3H_5NO$ + $\Delta H\ H_2O$ + $\Delta H\ C_3H_3N$
= 131811 + 573692 + 5640,98 kJ/jam
= 711143,67 kJ/jam

Bahan keluar

Produk bawah

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	6359,224648	71	89,5665
H_2O	2392,736535	18	132,93

T = 80 °C = 353,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida

$$Cp = 55,69 \times (353 - 298) + \frac{0,49}{2} \times (353^2 - 298^2) + \frac{-0,0011}{3} \times (353^3 - 298^3) + \frac{1,1E\text{-}06}{4} \times (353^4 - 298^4)$$

= 7571,607 J/mol

ΔH = n x Cp
= 89,5665 kmol/jam x 7571,61 J/mol = 678163 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 33,93 \times (353 - 298) + \frac{-0,01}{2} \times (353^2 - 298^2) + \frac{3,E\text{-}05}{3} \times (353^3 - 298^3) + \frac{-2E\text{-}08}{4} \times (353^4 - 298^4) + \frac{3,7E\text{-}12}{5} \times (353^5 - 298^5)$$

= 1858,596 J/mol

ΔH = n x Cp
= 132,9298 kmol/jam x 1858,6 J/mol = 247063 kJ/jam

ΔH total produk bawah = ΔH C_3H_5NO + ΔH H_2O
= (678162,63 + 247062,8) kJ/jam
= 925225,43 kJ/jam

Produk atas

T = 80 °C = 353,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilonitril

$$Cp = 33,36 \times (353 - 298) + \frac{0,59}{2} \times (353^2 - 298^2) + \frac{0,0000}{3} \times (353^3 - 298^3) + \frac{2,5E\text{-}06}{4} \times (353^4 - 298^4)$$

= 17111,71 J/mol
ΔH = n x Cp
= 4,6803 kmol/jam x 17111,7 J/mol = 80088,4 kJ/jam

Hv pada 176 °F = 1136,6 Btu/lb ***McCabe, 7ed; App 7; 1094***
= 2643,73 kJ/kg
λ Steam pada 176 °F = 992,6 Btu/lb = 2308,79 kJ/kg

ΔH = Berat x Hv
= 12324,87 kg/jam x 2643,73 kJ/kg
= 32583654,3 kJ/jam
ΔHf = 711143,668 kJ/jam
ΔHl = 925225,426 kJ/jam
ΔHv = 32663742,8 kJ/jam

ΔHf + S x λ Steam = ΔHl + ΔHv
711143,67 + S x 2308,79 = 925225,43 + 32663743

$$S = \frac{32877825 \text{ kJ/jam}}{2308,7876 \text{ kJ/kg}}$$

S = 14240,298 kg/jam
Q steam = S x λ Steam
= 14240,2985 kg/jam x 2308,7876 kJ/kg
= 32877824,5 kJ/jam

Steam Economy
V = Massa yang diuapkan Evaporator
S = Massa steam yang dibutuhkan Evaporator

Steam Economy $= \frac{V}{S} = \frac{12572,93 \text{ kg/jam}}{14240,298 \text{ kg/jam}} = 0,88291$

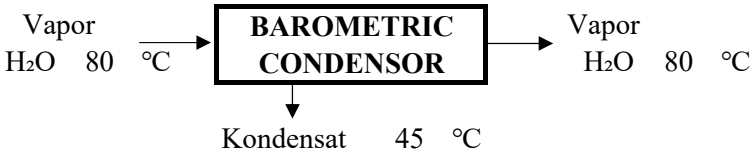
Karena steam economi (V/S) < 1, maka hanya dibutuhkan Single Effect Evaporator

Neraca Panas pada Evaporator

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
dari H-230 < 9 >		**Produk bawah**	
C_3H_5NO	131810,6028	C_3H_5NO	678162,6299
H_2O	573692,0853	H_2O	247062,7966
C_3H_3N	5640,980463		925225,4265
	711143,6685		
		Produk atas	
Q steam	32877824,52	H_2O (uap air)	32583654,3290
		C_3H_3N	80088,4362
			32663742,7651
	33588968,1916		33588968,1916

7. Barometric Condensor (E-241)

Fungsi : Mengkondensasi sebagian uap dan menjaga tekanan evaporator



Kondisi operasi :

Tekanan : 0,6136 atm = 9,01743 lb/in²

Suhu : 45 °C ***Ulrich; 427***

Enthalpi masuk

Enthalpi masuk = Enthalpi produk atas evaporator

= 32583654,3290 kJ/jam

Enthalpi keluar

Berat uap air = 12324,87229 kg/jam

Non-condensable tidak melebihi 1% dari total uap air yang terkondensasi ***Ludwig; 375***

Non-condensable = 1% x 12324,872 kg/jam

= 123,248723 kg/jam

Berat kondensat = 12324,8723 kg/jam - 123,24872 kg/jam

= 12201,6236 kg/jam

Enthalpi Uap menuju Jet Ejector

(Terjadi perubahan fase)

Komponen	Berat (kg/jam)	BM	kmol/jam
H_2O gas	123,2487229	18	6,84715
H_2O laten	123,2487229	18	6,84715

Panas laten (λH_2O) pada tekanan 9,0174 lb/in² dari McCabe 7ed; App 7

λH_2O = 985,187 Btu/lb = 2291,5438 kJ/kg

$\Delta H\ H_2O$ latent = m x λH_2O

= 123,248723 kg/jam x 2291,5438 kJ/kg

= 282429,847 kJ/jam

T = 80 °C = 353,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas H_2O gas

$$Cp = 33{,}93 \times (353 - 298) + \frac{-0{,}01}{2} \times (353^2 - 298^2) + \frac{3{,}E\text{-}05}{3} \times (353^3 - 298^3) + \frac{-2E\text{-}08}{4} \times (353^4 - 298^4) + \frac{3{,}7E\text{-}12}{5} \times (353^5 - 298^5)$$

= 1858,596 J/mol

ΔH = n x Cp

= 6,8472 kmol/jam x 1858,6 J/mol = 12726,1 kJ/jam

ΔH total = $\Delta H\ H_2O$ gas + $\Delta H\ H_2O$ laten

= 12726,0873 + 282429,85

= 295155,934 kJ/kg

Enthalpi kondensat menuju Hot Well

Komponen	Berat (kg/jam)	BM	Kmol/jam
H_2O	12201,6236	18	677,8680

T = 45 °C = 318,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas H_2O

$$Cp = 92{,}05 \times (318 - 298) + \frac{-0{,}04}{2} \times (318^2 - 298^2) + \frac{-2{,}E\text{-}04}{3} \times (318^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (318^4 - 298^4)$$

= 1507,155 J/mol

ΔH = n x Cp

= 677,8680 kmol/jam x 1507,15 J/mol = 1021652 kJ/jam

ΔH masuk = ΔH keluar + Q serap

32583654,3290 kJ/jam = 1316807,9 kJ/jam + Q serap

Q serap = 31266846,4210 kJ/jam

Kebutuhan air pendingin

Suhu inlet air pendingin = 30 °C = 303,15

Suhu outlet air pendingin = 45 °C = 318,15

Perhitungan kapasitas panas air pendingin

$$Cp = 92{,}05 \times (318 - 303) + \frac{-0{,}04}{2} \times (318^2 - 303^2) + \frac{-2{,}E\text{-}04}{3} \times (318^3 - 303^3) + \frac{5{,}3E\text{-}07}{4} \times (318^4 - 303^4)$$

= 1129,668 J/mol

$$n = \frac{Q}{Cp \times \Delta T}$$

$$= \frac{31266846{,}4210 \text{ kJ/jam}}{1129{,}668419 \text{ J/mol}}$$

= 27677,89724 kmol/jam

m = 27677,8972 kmol/jam x 18 kg/kmol

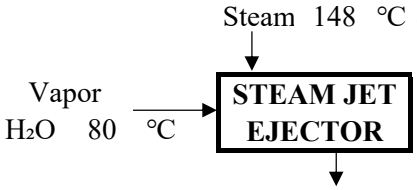
= 498202,15 kg/jam

Neraca panas pada Barometric Condensor

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
Uap air		**Ke Steam Jet Ejector (G-242**	
H_2O	32583654,3290	H_2O	295155,934
		Ke Hot Well F-243	
		H_2O	1021651,974
		Q serap	31266846,4210
	32583654,3290		32583654,3290

8. Steam Jet Ejector (G-242)

Fungsi : Menghisap uap air dengan steam, untuk memvacumkan evaporator



Kondisi operasi :
Tekanan : 0,6136 atm = 9,0174 lb/in²
Suhu : 80 °C

Enthalpi Masuk

Enthalpi Masuk = Enthalpi keluar barometric condensor
= ########## kJ/jam

Berat uap air masuk steam jet ejector = 123,24872 kg/jam

Diasumsikan digunakan 20% steam berlebih untuk proses pemvaccuman evaporator, maka :

Kebutuhan steam = 123,248723 kg/jam x 120%
= 147,898467 kg/jam

Enthalpi steam

(Terjadi perubahan fase)

Komponen	Berat (kg/jam)	BM	kmol/jam
H_2O gas	147,8984674	18	8,21658
H_2O laten	147,8984674	18	8,21658

Panas laten (λH_2O) pada tekanan 9,0174 lb/in² dari McCabe 7ed; App 7

λH_2O = 985,187 Btu/lb = 2291,5438 kJ/kg

$\Delta H H_2O$ latent = m x λH_2O
= 147,898467 kg/jam x 2291,5438 kJ/kg
= 338915,816 kJ/jam

T = 148 °C = 421,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas H_2O gas

$$Cp = 33{,}93 \times (421 - 298) + \frac{-0{,}01}{2} \times (421^2 - 298^2) + \frac{3{,}E\text{-}05}{3} \times (421^3 - 298^3) + \frac{-2E\text{-}08}{4} \times (421^4 - 298^4) + \frac{3{,}7E\text{-}12}{5} \times (421^5 - 298^5)$$

= 4184,852 J/mol

ΔH = n x Cp
= 8,2166 kmol/jam x 4184,85 J/mol = 34385,2 kJ/jam

ΔH total steam masuk = ΔH H_2O latent + ΔH H_2O gas
= (338915,82 + 34385,182) kJ/jam
= 373301 kJ/jam

Bahan keluar

Total air terkondensasi = uap air + steam
= ####### kg/jam + 147,898 kg/jam
= ####### kg/jam

Menuju Hot well

Komponen	Berat (kg/jam)	BM	Kmol/jam
H_2O	271,1472	18	15,0637

T = 80 °C = 353,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (353 - 298) + \frac{-0{,}04}{2} \times (353^2 - 298^2) + \frac{-2{,}E\text{-}04}{3} \times (353^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (353^4 - 298^4) +$$

= 4136,371 J/mol
ΔH = n x Cp
= 15,0637 kmol/jam x 4136,37 J/mol = 62309,2 kJ/jam

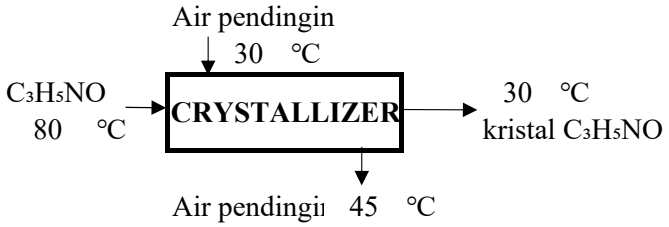
ΔH masuk = ΔH keluar + Q loss
373300,9975 kJ/jam = 62309,191 kJ/jam + Q loss
Q loss = 310991,81 kJ/jam

Neraca Panas pada Steam Jet Ejector

Komponen	**Masuk ΔH (kJ/jam)**	**Komponen Keluar**	**ΔH (kJ/jam)**
Uap air		**Menuju Hot well**	
H_2O	373300,9975	H_2O	62309,19118
		Q loss	310991,8063
	373300,9975		373300,9975

9. Crystallizer (S-310)

Fungsi : Mengkristalkan larutan akrilamida dengan cara pendinginan



Kondisi operasi :

Tekanan operasi : 1 atm

Suhu operasi : 30 ℃

Bahan masuk

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO	6359,224648	71	89,5665
H_2O	2392,736535	18	132,93

T = 80 ℃ = 353,15 K

Treff = 25 ℃ = 298,15 K

Perhitungan kapasitas panas akrilamida

$$Cp = 55{,}69 \times (353 - 298) + \frac{0{,}49}{2} \times (353^2 - 298^2) + \frac{-1{,}E\text{-}03}{3} \times (353^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (353^4 - 298^4) +$$

$$= 7571{,}607 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 89{,}5665 \text{ kmol/jam} \times 7571{,}61 \text{ J/mol} = 678163 \text{ kJ/jam}$$

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (353 - 298) + \frac{-0{,}04}{2} \times (353^2 - 298^2) + \frac{-2{,}E\text{-}04}{3} \times (353^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (353^4 - 298^4) +$$

$$= 4136{,}371 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 132{,}9298 \text{ kmol/jam} \times 4136{,}37 \text{ J/mol} = 549847 \text{ kJ/jam}$$

ΔH total masuk criztallize = ΔH C_3H_5NO + ΔH H_2O
= 678163 kJ/jam + 549847 kJ/jam
= 1228009,7 kJ/jam

Bahan keluar

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c)	6311,369917	71	88,8925
C_3H_5NO (l)	47,8547307	71	0,67401
H_2O	2392,736535	18	132,93

T = 30 °C = 303,15 K
Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida (c)

$$Cp = -25{,}1 \times (303 - 298) + \frac{0{,}47}{2} \times (303^2 - 298^2)$$

= 585,237 J/mol
ΔH = n x Cp
= 88,8925 kmol/jam x 585,237 J/mol = 52023,2 kJ/jam

Perhitungan kapasitas panas akrilamida (l)

$$Cp = 55{,}69 \times (303 - 298) + \frac{0{,}49}{2} \times (303^2 - 298^2) + \frac{-1{,}E\text{-}03}{3} \times (303^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (303^4 - 298^4)$$

= 671,7363 J/mol
ΔH = n x Cp
= 0,6740 kmol/jam x 671,736 J/mol = 452,757 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (303 - 298) + \frac{-0{,}04}{2} \times (303^2 - 298^2) + \frac{-2{,}E\text{-}04}{3} \times (303^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (303^4 - 298^4) +$$

= 377,4864 J/mol
ΔH = n x Cp
= 132,9298 kmol/jam x 377,486 J/mol = 50179,2 kJ/jam

ΔH total keluar criztallize = ΔH C_3H_5NO (c) + ΔH C_3H_5NO (l) + ΔH H_2O
= (52023,2 + 452,757 + 50179,2) kJ/jam
= 102655,15 kJ/jam

ΔH Kristalisasi

ΔHsolution C_3H_5NO (c) = -2,251 kkal/mol ***Perry 7ed; T 2-225***

= -9424,4868 J/mol

Komponen	Berat (kg/jam)	kmol/jam	Cp (J/mol)	ΔH (kJ/jam)
C_3H_5NO (c)	6311,369917	88,8925	-9424,4868	-837766,51
			Total	-837766,51

ΔH masuk + ΔH kristalisasi = ΔH keluar + Q serap + Q loss

Q loss = 10% ΔH masuk

= 122801 kJ/jam

1228009,7 + 837766,514 = 102655 + 122801 + Q serap

Q serap = 1840320 kJ/jam

Kebutuhan air pendingin

Suhu inlet air pendingin : 30 °C = 303,15

Suhu outlet air pendingin : 45 °C = 318,15

Perhitungan kapasitas panas air pendingin

$$Cp = 92,05 \times (318 - 303) + \frac{-0,04}{2} \times (318^2 - 303^2) + \frac{-2,E-04}{3} \times (318^3 - 303^3) + \frac{5,3E-07}{4} \times (318^4 - 303^4) +$$

= 1129,668 J/mol

$$n = \frac{Q}{Cp \times \Delta T} = \frac{1840320 \text{ kJ/jam}}{1129,67 \text{ J/mol}} = 1629,08 \text{ kmol/jam}$$

m = 1629,0799 kmol/jam x 18 kg/kmol

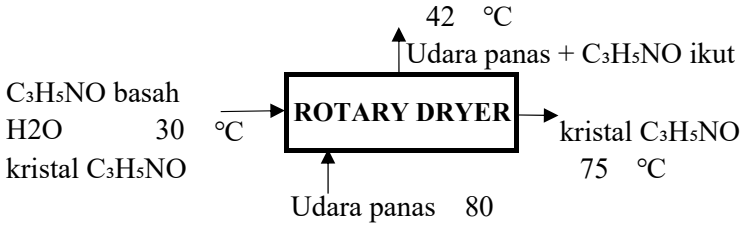
= 29323,44 kg/jam

Neraca Panas pada Criztallizer

Komponen	**Masuk ΔH (kJ/jam)**	**Komponen**	**Keluar ΔH (kJ/jam)**
dari V-240		**Mother liquor**	
C_3H_5NO	678162,6299	C_3H_5NO	452,7571846
H_2O	549847,0334	H_2O	50179,19204
	1228009,6634		50631,94922
Q Crystallization	837766,5137	**Kristal**	52023,19906
		Q loss	122801
		Q serap	1840320
	2065776,1771		2065776,1771

10. Rotary Dryer (B-320)

Fungsi : Mengeringkan kristal akrilamida dengan udara panas



Kondisi operasi :

Tekanan : 1 atm

Suhu : 75 °C

Udara masuk

TDB = 30 °C

TWB = 25 °C

Data diperoleh dari Psycrometric Chart, Himmelblau 8-ed; 493

Kelembaban = 0,018 lb H_2O/lb udara kering

Relative Humidity (RH) = 69%

Enthalpy = 76 kJ/kg Enthalpy = 130 kJ/kg

Deviasi Enthalpy = 0,15 kJ/kg Deviasi Enthalpy = -3 kJ/kg

V = 0,89 m^3 udara masuk

ΔH = Q + W , dimana W = 0

ΔH = ΔH2 - ΔH1

ΔH = (130 -3) kJ/kg - (76 + 0,15) kJ/kg

= 127 kJ/kg - 76,2 kJ/kg

= 51 kJ/kg

Suhu udara yang keluar Rotary Dryer = 42 °C ***(Psycrometric chart)***

Bahan masuk

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c)	6313,7627	71	88,9262
C_3H_5NO (l)	0,0000	71	0
H_2O	119,6368	18	6,64649

T = 30 °C = 303,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida (c)

$$Cp = -25{,}1 \times (303 - 298) + \frac{0{,}47}{2} \times (303^2 - 298^2)$$

= 585,237 J/mol

ΔH = n x Cp
= 88,9262 kmol/jam x 585,237 J/mol = 52042,9 kJ/jam

Perhitungan kapasitas panas akrilamida (l)

$Cp = 55{,}69 \times (303 - 298) + \frac{0{,}49}{2} \times (303^2 - 298^2) + \frac{-1{,}E\text{-}03}{3} \times (303^3 - 298^3) + \frac{1{,}1E\text{-}06}{4} \times (303^4 - 298^4) +$

= 671,7363 J/mol

ΔH = n x Cp
= 0,0000 kmol/jam x 671,736 J/mol = 0 kJ/jam

Perhitungan kapasitas panas air

$Cp = 92{,}05 \times (303 - 298) + \frac{-0{,}04}{2} \times (303^2 - 298^2) + \frac{-2{,}E\text{-}04}{3} \times (303^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (303^4 - 298^4) +$

= 377,4864 J/mol

ΔH = n x Cp
= 6,6465 kmol/jam x 377,486 J/mol = 2508,96 kJ/jam

ΔH total masuk dryer = ΔH C_3H_5NO (c) + ΔH C_3H_5NO (l) + ΔH H_2O
= (52042,9 + 0 + 2508,96) kJ/jam
= 54551,881 kJ/jam

Bahan keluar

Menuju Cyclone

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c	63,13762653	71	0,88926
H_2O	118,4737988	18	6,58188

T = 42 °C = 315,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida (c)

$Cp = -25{,}1 \times (315 - 298) + \frac{0{,}47}{2} \times (315^2 - 298^2)$

= 2038,044 J/mol

ΔH = n x Cp
= 0,8893 kmol/jam x 2038,04 J/mol = 1812,36 kJ/jam

Perhitungan kapasitas panas air

$Cp = 92,05 \times (315 - 298) + \frac{-0,04}{2} \times (315^2 - 298^2) + \frac{-0,0002}{3} \times (315^3 - 298^3) + \frac{5,3E-07}{4} \times (315^4 - 298^4)$

$= 1281,498$ J/mol

$\Delta H = n \times Cp$

$= 6,5819$ kmol/jam x $1281,5$ J/mol $= 8434,66$ kJ/jam

ΔH total $= \Delta H\, C_3H_5NO\,(c) + \Delta H\, H_2O$

$= 1812,35544$ kJ/jam $+ 8434,6635$ kJ/jam $= 10247$ kJ/jam

Menuju Cooling Conveyor

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c	6250,625027	71	88,037
H_2O	1,16302799	18	0,06461

T = 75 °C = 348,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida (c)

$Cp = -25,1 \times (348 - 298) + \frac{0,47}{2} \times (348^2 - 298^2)$

$= 6384,405$ J/mol

$\Delta H = n \times Cp$

$= 88,0370$ kmol/jam x $6384,4$ J/mol $= 562064$ kJ/jam

Perhitungan kapasitas panas air

$Cp = 92,05 \times (348 - 298) + \frac{-0,04}{2} \times (348^2 - 298^2) + \frac{-0,0002}{3} \times (348^3 - 298^3) + \frac{5,3E-07}{4} \times (348^4 - 298^4)$

$= 3760,623$ J/mol

$\Delta H = n \times Cp$

$= 0,0646$ kmol/jam x $3760,62$ J/mol $= 242,984$ kJ/jam

ΔH total $= \Delta H\, C_3H_5NO\,(c) + \Delta H\, H_2O$

$= 562063,677$ kJ/jam $+ 242,98385$ kJ/jam $= 562307$ kJ/jam

Enthalpi udara masuk

T = 80 °C = 353,15 K = 176 °F

Treff = 25 °C = 298,15 K = 77 °F
Perhitungan kapasitas panas udara masuk
BM udara = 28,9643 kg/kmol
Cp udara = 0,25 Btu/lb.°F ***Kern; 805***
= 0,5815 kJ/kg.°F
= 102,344 Kj/kg
= 2964,32 kJ/kmol
ΔH = n x Cp
= n x 2964,32 kJ/kmol

Enthalpi udara keluar
T = 42 °C = 315,15 K = 108 °F
Treff = 25 °C = 298,15 K = 77 °F
Perhitungan kapasitas panas udara keluar
BM udara = 28,9643 kg/kmol
Cp udara = 0,24 Btu/lb.°F ***Kern; 805***
= 0,55824 kJ/kg.°F
= 60,0666 kJ/kg
= 1739,79 kJ/kmol
ΔH = n x Cp
= n x 1739,79 kJ/kmol

ΔH masuk = ΔH keluar
54551,881 kJ/jam + 2964,32 n kJ/kmol = 572554 kJ/jam + 1739,79 n kJ/kmol
1224,5346 n kJ/kmol = 518002 kJ/jam
n = 423,019 kmol/jam
m = 423,019 kmol/jam x 29 kg/kmol
= 12252,5 kg/jam
Jadi, massa udara yang dibutuhkan untuk mengeringkan kristal akrilamida sebesar 11217,2 kg/jam

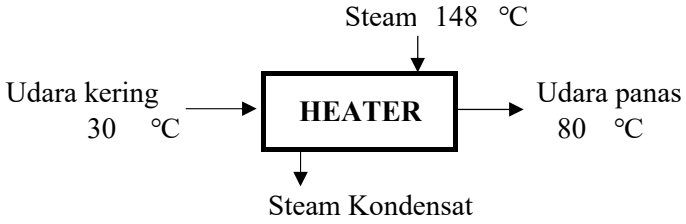
ΔH udara masuk
ΔH = 423,0193 kmol/jam x 2964,32 kJ/kmol
= 1253965,62 kJ/jam
ΔH udara keluar
ΔH = 423,0193 kmol/jam x 1739,79 kJ/kmol
= 735963,822 kJ/jam

Neraca Panas pada Rotary Dryer

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
dari S-310		**ke Cooling Conveyor E-330**	
C_3H_5NO (c)	52042,92184	C_3H_5NO (c)	562063,6768
C_3H_5NO (l)	0	H_2O	242,9838536
H_2O	2508,959602		562306,6606
	54551,88144	**ke Cyclone H-324**	
		C_3H_5NO (c)	1812,355437
Udara masuk	1253965,62	H_2O	8434,66348
			10247,01892
		Udara keluar	735963,8223
	1308517,5018		1308517,5018

11. Heater (E-323)

Fungsi : Memanaskan udara menjadi udara panas



Enthalpi udara masuk

T = 30 °C = 303,15 K = 86 °F
Treff = 25 °C = 298,15 K = 77 °F

Perhitungan panas udara masuk

BM udara = 28,9643 kg/kmol
Cp udara = 0,24 Btu/lb.°F ***Kern; 805***
= 0,55824 kJ/kg.°F
= 48,0086 kJ/kg =
= 1390,54 kJ/kmol
mol udara = 423,019 kmol/jam
ΔH = n x Cp
= n x 1390,54 kJ/kmol
= 423,0193 kmol/jam x 1390,54 kJ/kmol
= 588223,873 kJ/jam

Enthalpi udara keluar

T = 80 °C = 353,15 K = 176 °F
Treff = 25 °C = 298,15 K = 77 °F

Perhitungan panas udara masuk

BM udara = 28,9643 kg/kmol
Cp udara = 0,25 Btu/lb.°F ***Kern; 805***
= 0,5815 kJ/kg.°F
= 102,344 kJ/kg
= 2964,32 kJ/kmol
mol udara = 423,019 kmol/jam
ΔH = n x Cp
= n x 2964,32 kJ/kmol
= 423,0193 kmol/jam x 2964,32 kJ/kmol
= 1253965,62 kJ/jam

ΔH masuk = ΔH keluar
588223,87 kJ/jam + Q supply = 1253966 kJ/jam + Q loss
Maksimum Q loss = 10% Q supply ***Ulrich; 432***
diambil Q loss = 5% Q supply
Q loss = 35039 kJ/jam
Q supply = 700781 kJ/jam

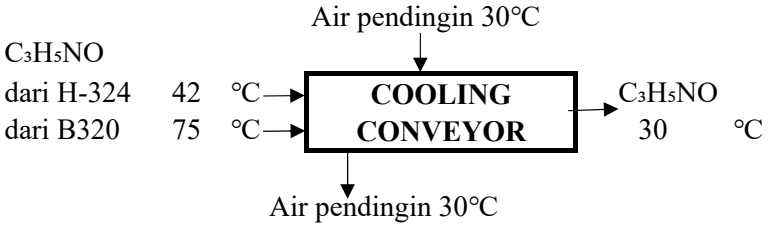
Kebutuhan steam
panas laten
dipakai steam pada tekanan 4,5 bar dan suhu 148 °C ***Ulrich;426***
λ Steam = 912 Btu/lb ***McCabe 7ed; App 7***
= 2120,34 kJ/kg
Q steam = m steam x λ Steam
m steam = 700781 kJ/jam
2120,34 kJ/kg
= 330,503 kg/jam

Neraca Panas pada Heater 3

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
Udara bebas	588223,8728	**Udara panas**	1253965,62
Q supply	700781	**Q loss**	35039
	1289005		1289005

12. Cooling Conveyor (E-330)

Fungsi : Mendinginkan akrilamida dari rotary dryer



Kondisi operasi :

Tekanan : 1 atm

Suhu : 30 °C

Bahan masuk

dari Rotary dryer

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c)	6250,625027	71	88,037
H_2O	1,16302799	18	0,06461

T = 75 °C = 348,15 K

Treff = 25 °C = 298,15 K

Perhitungan kapasitas panas akrilamida (c)

$Cp = -25{,}1 \times (348 - 298) + \frac{0{,}47}{2} \times (348^2 - 298^2)$

= 6384,405 J/mol

ΔH = n x Cp

= 88,0370 kmol/jam x 6384,4 J/mol = 562064 kJ/jam

Perhitungan kapasitas panas air

$Cp = 92{,}05 \times (348 - 298) + \frac{-0{,}04}{2} \times (348^2 - 298^2) + \frac{-0{,}0002}{3} \times (348^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (348^4 - 298^4)$

= 3760,623 J/mol

ΔH = n x Cp

= 0,0646 kmol/jam x 3760,62 J/mol = 242,984 kJ/jam

ΔH total = $\Delta H\, C_3H_5NO$ (c) + $\Delta H\ H_2O$

= 562063,677 kJ/jam + 242,98385 kJ/jam = 562307 kJ/jam

dari Cyclone

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c)	63,13762653	71	0,88926
H_2O	118,4737988	18	6,58188

T = 42 °C = 315,15 K
Treff = 25 °C = 298,15 K
Perhitungan kapasitas panas akrilamida (c)

$$Cp = -25{,}1 \times (315 - 298) + \frac{0{,}47}{2} \times (315^2 - 298^2)$$

= 2038,044 J/mol
ΔH = n x Cp
= 0,8893 kmol/jam x 2038,04 J/mol = 1812,36 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92{,}05 \times (315 - 298) + \frac{-0{,}04}{2} \times (315^2 - 298^2) + \frac{-0{,}0002}{3} \times (315^3 - 298^3) + \frac{5{,}3E\text{-}07}{4} \times (315^4 - 298^4)$$

= 1281,498 J/mol
ΔH = n x Cp
= 6,5819 kmol/jam x 1281,5 J/mol = 8434,66 kJ/jam

ΔH total = ΔH C_3H_5NO (c) + ΔH H_2O
= 1812,35544 kJ/jam + 8434,6635 kJ/jam = 10247 kJ/jam

Bahan keluar

Komponen	Berat (kg/jam)	BM	kmol/jam
C_3H_5NO (c)	6313,131277	71	88,9173
H_2O	1,16302799	18	0,06461

T = 30 °C = 303,15 K
Treff = 25 °C = 298,15 K
Perhitungan kapasitas panas akrilamida (c)

$$Cp = -25{,}1 \times (303 - 298) + \frac{0{,}47}{2} \times (303^2 - 298^2)$$

= 585,237 J/mol
ΔH = n x Cp
= 88,9173 kmol/jam x 585,237 J/mol = 52037,7 kJ/jam

Perhitungan kapasitas panas air

$$Cp = 92,05 \times (303 - 298) + \frac{-0,04}{2} \times (303^2 - 298^2) + \frac{-0,0002}{3} \times (303^3 - 298^3) + \frac{5,3E-07}{4} \times (303^4 - 298^4)$$

$$= 377,4864 \text{ J/mol}$$

$$\Delta H = n \times Cp$$

$$= 0,0646 \text{ kmol/jam} \times 377,486 \text{ J/mol} = 24,3904 \text{ kJ/jam}$$

$$\Delta H \text{ total} = \Delta H\, C_3H_5NO\,(c) + \Delta H\, H_2O$$

$$= 52037,7176 \text{ kJ/jam} + 24,390402 \text{ kJ/jam} = 52062,1 \text{ kJ/jam}$$

$$\Delta H \text{ masuk} = \Delta H \text{ keluar}$$

$$562306,66 + 10247 = 52062,1 + Q \text{ serap}$$

$$Q \text{ serap} = 520492 \text{ kJ/jam}$$

Kebutuhan air pendingin :

Suhu inlet air pendingin = 30 °C = 303,15 K

Suhu outlet air pendingin = 45 °C = 318,15 K

Perhitungan kapasitas panas air

$$Cp = 92,05 \times (318 - 303) + \frac{-0,04}{2} \times (318^2 - 303^2) + \frac{-0,0002}{3} \times (318^3 - 303^3) + \frac{5,3E-07}{4} \times (318^4 - 303^4)$$

$$= 1129,668 \text{ J/mol}$$

$$n = \frac{Q}{Cp \times \Delta T}$$

$$= \frac{520491,6 \text{ kJ/jam}}{1129,668 \text{ J/mol}}$$

$$= 460,7472 \text{ kmol/jam}$$

$$m = 460,7472 \text{ kmol/jam} \times 18 \text{ kg/kmol}$$

$$= 8293,45 \text{ kg/jam}$$

Jadi, kebutuhan air pendingin sebesar 8293,45 kg/jam

Neraca Panas pada Cooling Conveyor

Komponen	Masuk ΔH (kJ/jam)	Komponen	Keluar ΔH (kJ/jam)
dari Rotary Dryer		**Menuju unit produk**	
C_3H_5NO	562063,6768	C_3H_5NO	52037,71755
H_2O	242,9838536	H_2O	24,39040153
	562306,6606		52062,10795
dari Cyclone			
C_3H_5NO	1812,355437	**Q serap**	520491,5716
H_2O	8434,66348		
	10247,01892		
	572553,6795		572553,6795

APPENDIX C
PERHITUNGAN SPESIFIKASI ALAT

1. Tangki Penyimpanan Akrilonitril (F-110)

Fungsi : Menampung akrilonitril selama 6 hari dari supplier
Type : Silinder vertikal dengan tutup atas dan tutup bawah standard dishead
Dasar pemilihan : Sesuai untuk menyimpan bahan liquid pada tekanan 15-200 psig

Kondisi operasi :
Tekanan : 1 atm
Suhu : 30 °C
Waktu tinggal : 6 hari

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)	
C_3H_3N	5060,68786	0,995	0,806	***Kirk Othmer***
H_2O	25,4305923	0,005	1,027	***Yaws***
Total	5086,11845	1		

Menghitung Volume Tangki

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}995}{0{,}806} + \frac{0{,}005}{1{,}027}} \times 62{,}43$$

$$= 50{,}3728 \text{ lb/cuft}$$

Rate massa = 5086,118 kg/jam = 11212,97 lb/jam

$$\text{Rate volume} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{11212{,}97 \text{ lb/jam}}{50{,}3728 \text{ lb/cuft}} = 222{,}5998 \text{ cuft/jam}$$

Direncanakan 6 hari dengan 4 buah tangki
(mempermudah pengeluaran dan pengisian, sehingga)

$$\text{Volume bahan} = \frac{222{,}5998 \text{ cuft/jam} \times 6 \text{ hari} \times 24 \text{ jam/hari}}{4 \text{ tangki}}$$

$$= 8013{,}594 \text{ cuft}$$

Asumsi bahan mengisi 80% volume tangki, maka Vol Tangki :

$$V = \frac{8013{,}5938 \text{ cuft}}{80\%}$$

$$= 10016{,}992 \text{ cuft}$$

Menentukan dimensi tangki

Asumsi rasio dimensi : H/D = 2 ***Ulrich; T 4-27; 248***

Vo = 1/4 Π. D.²H

$$10017 = \frac{1}{4} \times \pi \times D^2 \times 2 \times D$$

$$D^3 = \frac{10016{,}99 \text{ cuft}}{1{,}57}$$

$D^3 = 6380{,}2$

D = 18,54724 ft = 222,5668 in = 5,7 m

H = 37,09447 ft = 445,1337 in = 11,3 m

Menentukan tekanan design

P operasi = 1 atm = 14,7 psig

P hidrostatis = $\rho \times \frac{g}{gc} \times$ H liq (H liq = 80% H tangki)

= 50,3728 lbm/ft³ x 0,9946 lbf/lbm x 29,676 ft

= 1486,757 lbf/ft²

= 10,32404 lbf/in²

= 10,32404 psig

P operasi = 14,7 Psig + 10,324 psig

= 25,024 psig

P design diambil 10% lebih besar dari P operasi untuk faktor keamanan

P design = 1,1 x 25,024 psig

= 27,526 psig

Direncanakan :

1. Bahan konstruksi = Carbon steel SA-285 grade C
   f = 13750 psi ***T 13.1 B&Y; 251***
2. Pengelasan double welded butt joint
   E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Menentukan tebal shell minimum :

Tebal shell berdasarkan ASME code untuk tangki silinder :

$$ts = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$ ***eq. 13.1 B&Y; 254***

Dimana :

ts = tebal shell (in) C = faktor korosi

P = tekanan design (Psi) f = alllowable stress

ri = jari-jari dalam (in) E = faktor pengelasan

Mencari tebal shell (ts) menggunakan f yang diijinkan

$$ts = \frac{27{,}526 \text{ psig} \times 111{,}28 \text{ in}}{13750 \text{ psi} \times 0{,}8 - 0{,}6 \times 27{,}526 \text{ psig}} + 1/8$$

= 0,4039 in

ts yang diperoleh di standarkan dengan tebal shell yang dijual dipasaran
dengan melihat ***T 5.7 B&Y; 90***

ts = 7/16 in

Menghitung tebal tutup atas standard dishead (th)

OD = ID + 2 ts
= 222,57 in + 7/8 in
= 223,44 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 216
icr = 13,00
rc = 170
6%rc = 10,2

Karena icr > 6% rc, maka digunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/icr)^{0.5} \right)$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$$W = 1/4 \times \left(3 + \frac{170}{13}^{0.5} \right)$$

= 1,65405

maka tebal tutup (th) dapat dihitung

asumsi th = 8/16 in

$$8/16 = \frac{27,526 \text{ psig} \times 170 \times 1,6541}{2 \times f \times 0,8 - 0,2 \times 27,526 \text{ psig}} + 1/8$$

$$3/8 = \frac{27,526 \text{ psi} \times 170 \times 1,6541}{2 \times f \times 0,8 - 0,2 \times 27,526 \text{ psi}}$$

f = 12903,65 psi

f actual < f allowable, maka th 1/2 in dapat digunakan

Menentukan tinggi tutup atas

ha = 0,169 d
= 0,169 x 18,547 ft = 3,1345 ft = 37,614 in = 0,9554 m

Menghitung tebal tutup bawah standard dishead

OD = ID + 2 ts
= 222,567 in + 7/8 in
= 223,442 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 216
icr = 13

rc = 170
6%rc = 10,2
Karena icr > 6% rc, maka digunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/icr)^{0.5} \right)$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$$W = 1/4 \times \left(3 + \frac{170}{13}^{0.5} \right)$$

= 1,65405
maka tebal tutup (th) dapat dihitung
asumsi th = 8/16 in

$$1/2 = \frac{27,526 \text{ psig} \times 170 \times 1,6541}{2 \times f \times 0,8 - 0,2 \times 0 \text{ psig}} + 1/8$$

$$3/8 = \frac{27,526 \text{ psi} \times 170 \times 1,6541}{2 \times f \times 0,8 - 0,2 \times 27,526 \text{ psi}}$$

f = 12903,65 psi
f actual < f allowable, maka t 1/2 in dapat digunakan

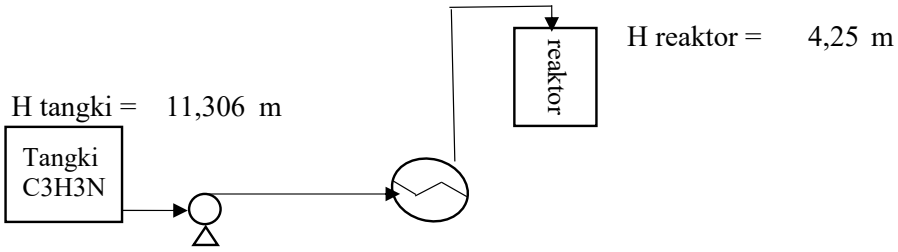
Menentukan tinggi tutup bawah
hb = 0,169 d
= 0,169 x 18,547 ft = 3,1345 ft = 37,614 in = 0,9554 m

Spesifikasi

Fungsi	:	Menyimpan akrilonitril selama 6 hari
Type	:	Silinder vertikal dengan tutup atas bawah standard dishead
Volume	:	8013,594 cuft = 226,92 m^3
Diameter	:	18,547 ft = 5,6532 m
Tinggi	:	37,094 ft = 11,306 m
Tebal shell	:	7/16 in = 0,0111 m
Tebal tutup atas	:	1/2 in = 0,0127 m
Tebal tutup bawah	:	1/2 in = 0,0127 m
Bahan konstruksi	:	Carbon steel SA-285 grade C
Jumlah	:	4 buah

2. Pompa-1 (L-111)

Fungsi : Mengalirkan akrilonitril melewati heater menuju reaktor
Type : Centrifugal pump
Dasar pemilihan : Sesuai untuk viskositas < 10 cp dan bahan liquid



Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_3N	5060,68786	0,995	0,806
H_2O	25,4305923	0,005	1,027
Total	5086,11845	1	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62,43$$

$$= \frac{1}{\frac{0,995}{0,806} + \frac{0,005}{1,027}} \times 62,43$$

= 50,3728 lb/cuft

Rate massa = 5086,118 kg/jam = 11212,97 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{11212,97 \text{ lb/jam}}{50,3728 \text{ lb/cuft}}$$

= 222,5998 cuft/jam = 3,709997 cuft/menit
= 27,75449 gpm = 0,061833 cuft/s

Menghitung diameter optimum dengan persamaan :

Asumsi aliran turbulen

$$\text{Diameter optimum} = 3.9 \times q_f^{0.45} \times \rho^{0.13}$$

eq. 15; Peters 4-ed; 496

Dengan :

q_f = Fluid flow rate; (cuft/detik)
ρ = Fluid Density; (lb/cuft)
Di = Diameter pipa optimum, (in)

Di = 3,9 x 0,0618 0,45 cuft/s x 50,3728 0,13 lb/cuft
= 1,8552 in

Dari diameter optimum, dipilih pipa 1 1/2 in, sch 40 berdasarkan McCabe

OD = 1,9 in = 0,1583 ft = 0,0483 m ***McCabe: App 3; 1090***
ID = 1,61 in = 0,1342 ft = 0,0409 m
A = 0,01414 ft²
Kecepatan linier, $v = \frac{qf}{A}$

$= \frac{0,0618 \text{ cuft/s}}{0,0141 \text{ ft}^2}$

$= 4,3729$ ft/s

ρ reference = 62,43 lb/cuft
sg reference = 1
μ reference = 1 cps

$\text{sg bahan} = \frac{\rho \text{ bahan}}{\rho \text{ reference}} \times \text{sg reference}$

$= \frac{50,3728 \text{ lb/cuft}}{62,43 \text{ lb/cuft}} \times 1$

$= 0,8069$

μ berdasarkan sg bahan :

$\mu \text{ bahan} = \frac{\text{sg bahan}}{\text{sg reference}} \times \mu \text{ reference}$

$= \frac{0,8069}{1} \times 1 \text{ cps}$

$= 0,8069$ cps
$= 0,0005$ lb/ft.s

$NRe = \frac{D \, v \, \rho}{\mu}$

$= \frac{0,1342 \text{ ft} \times 4,3729 \text{ ft/s} \times 50,3728 \text{ lb/cuft}}{0,000542 \text{ lb/ft.s}}$

Nre = 54508,175
Nre > 2100 (asumsi aliran turbulen benar)

Dipilih pipa commercial steel, dengan :
ε = 0,000046 m ***Geankoplis; 88***

$\varepsilon/D = \frac{0,000046 \text{ m}}{0,040894 \text{ m}}$

$= 0,0011249$

f = 0,006 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***
Panjang pipa lurus = 17,5 m = 57,415 ft
- 1 gate valve = n x Le/D x ID
  (wide open) = 1 x 9 x 0,1342 ft
  = 1,2075 ft

Panjang total pipa = 1,2075 ft + 57,415 ft = 58,622 ft

Friksi yang terjadi

karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ ***Geankoplis 3ed, eq 2.10-6; 89***

$$= \frac{2 \times 0,006 \times (4,3729 \text{ ft/s})^2 \times 58,622 \text{ ft}}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 0,1342 \text{ ft}}$$

$$= 3,1163016 \text{ ft.lbf/lbm}$$

karena kontraksi dalam pipa

$$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :

$\alpha = 1$

$Kc = 0,5$, maka :

$$F2 = \frac{0,5 \times (4,3729 \text{ ft/s})^2}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

$$= 0,148587 \text{ ft.lbf/lbm}$$

karena gate valve , Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$$

$$= \frac{1 \times 0,17 \times (4,3729 \text{ ft/s})^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$$

$$= 0,0505 \text{ ft.lbf/lbm}$$

karena ekspansi pipa ke heater

$$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ ($A1 < A_2$, maka V1 dianggap = 0)

$$= \frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$$

$$= \frac{(4,3729 \text{ ft/s})^2 - 0}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

$$= 0,2972 \text{ ft.lbf/lbm}$$

karena elbow 90° , Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2}$$ n = jumlah elbow

$$= \frac{1 \times 0,75 \times (4,3729 \text{ ft/s})^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$$

$$= 0,2229 \text{ ft.lbf/lbm}$$

Sehingga :

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$

$= 3,83546 \text{ ft.lbf/lbm}$

Energi Tekanan

$EP = \frac{\Delta P}{\rho}$

P1 = 1 atm + P h
= 2116,8 lbf/ft² + ρ g/gc h
= 2116,8 lbf/ft² + 50,3728 lbm/ft³ x 1 lbf/lbm x 29,676 ft
= 3603,5572 lbf/ft²

P_2 = 2116,8 lbf/ft²

ΔP = 2116,8 lbf/ft² - 3603,6 lbf/ft²
= -1486,757 lbf/ft²

$EP = \frac{-1486,757 \text{ lbf/ft}^2}{50,3728 \text{ lbm/ft}^3}$
= -29,51509 ft.lbf/lbm

Energi Kinetik

$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$
$= \frac{(4,3729 \text{ ft/s})^2}{2 \times 1 \times 32,174 \text{ lbm.ft/s}^2.\text{lbf}}$
= 0,2972 ft.lbf/lbm

Energi Potensial

ΔZ = 15,556 m Z1 = 0 m Z2 = 15,556 m
51,038 ft

$EP = \Delta Z \frac{g}{gc}$
= 51,038 ft x 1 lbf/lbm = 50,762 ft.lbf/lbm

Persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$
= (-29,52 + 50,76181 + 0,2972 + 3,8355) ft.lbf/lbm
= 25,379355 ft.lbf/lbm

Power Pompa

$Hp = \frac{-Wf \times \text{flowrate(gpm)} \times sg}{3960}$
$= \frac{25,379 \text{ ft.lbf/lbm} \times 27,754 \text{ gpm} \times 0,8069}{3960}$
= 0,1435 Hp

Effisiensi Pompa

E = 30% ***Peters 4ed ; Figure 14 - 37; 520***

$BHP = \frac{0,1435}{30\%}$
= 0,4784 Hp

Effisiensi Motor

E = 80% ***Peters 4ed ; Figure 14 - 38; 521***

$$BHP = \frac{0{,}4784}{80\%}$$

= 0,598 Hp

Spesifikasi :

Fungsi	:	Mengalirkan akrilonitril melewati heater menuju reaktor		
Type	:	*Centrifugal pump*		
Power	:	1 Hp	=	745,7 watt
Rate volume	:	27,75449 gpm	=	0,1051 m^3/menit
Effisiensi pompa	:	30%		
Effisiensi motor	:	80%		
Bahan konstruksi	:	*Commercial Steel*		
Jumlah	:	1 buah		

3. Tangki Penyimpanan Asam sulfat monohidrat (F-120)

Fungsi : Menampung asam sulfat monohidrat selama 6 hari
Type : Silinder vertikal, tutup atas dan bawah standard dishead
Dasar pemilihar : Sesuai untuk menyimpan bahan liquid

Kondisi operasi :
Tekanan : 1 atm
Suhu : 30 ℃
Waktu tinggal : 6 hari

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$H_2SO_4.H_2O$	11076,2225	1	1,7512
Total	11076,2225	1	

Kirk Othmer

Menghitung Volume Tangki

ρ = 1,7512 g/cc x 62,43
= 109,3274 lb/cuft

Rate massa = 11076,22 kg/jam = 24418,89 lb/jam

$$\text{Rate volume} = \frac{\text{Rate massa}}{\rho}$$

$$= \frac{24418{,}89 \text{ lb/jam}}{109{,}3274 \text{ lb/cuft}} = 223{,}3556 \text{ cuft/jam}$$

Direncanakan 6 hari dengan 4 buah tangki
(mempermudah pengeluaran dan pengisian, sehingga)

Volume bahan = $\frac{223,3556 \text{ cuft/jam} \times 6 \text{ hari} \times 24 \text{ jam/hari}}{4 \text{ tangki}}$

= 8040,802 cuft

Asumsi bahan mengis 80% volume tangki, maka :

V = $\frac{8040,8016 \text{ cuft}}{80\%}$

= 10051,002 cuft

Menentukan dimensi tangki

Asumsi rasio dimensi : H/D = 2 ***Ulrich; T 4-27; 248***

Vo = 1/4 Π. D.²H

10051 = $\frac{1}{4}$ x π x D ² x 2 x D

D ³ = $\frac{10051}{1,57}$ cuft

D ³ = 6401,9

D = 18,5682 ft = 222,8184 in = 5,7 m

H = 37,13641 ft = 445,6369 in = 11,3 m

Menentukan tekanan design

P operasi = 1 atm = 14,7 Psig

P hidrostatis = ρ x $\frac{g}{gc}$ x H liq (H liq = 80% H tangki)

= 109,3274 lbm/ft³ x 0,9946 lbf/lbm x 29,709 ft

= 3230,456 lbf/ft²

= 22,43229 lbf/in²

= 22,43229 psi

P operasi = 14,7 psig + 22,432 psig

= 37,132 psig

P design diambil 10% lebih besar dari P operasi untuk faktor keamanan

P design = 1,1 x 37,132 psig

= 40,846 psig

Direncanakan :

1. Bahan konstruksi = *Low-Alloy Steels SA-202 grade A*
   f = 18750 psi ***T 13.1 B&Y; 251***
2. Pengelasan *double welded butt joint*
   E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Menentukan tebal shell minimum :

Tebal shell berdasarkan ASME code untuk tangki silinder :

ts = $\frac{P \times ri}{f\ E - 0,6\ P}$ + C ***eq. 13.1 B&Y; 254***

Dimana :

ts = tebal shell (in) C = faktor korosi
P = tekanan design (Psi) f = alllowable stress
ri = jari-jari dalam (in)
E = faktor pengelasan

Mencari tebal shell (ts) menggunakan f yang diijinkan

$$ts = \frac{40{,}846 \text{ psi} \times 111{,}41 \text{ in}}{18750 \text{ psi} \times 0{,}8 - 0{,}6 \times 40{,}846 \text{ psi}} + 1/8$$

$$= 0{,}4289 \text{ in}$$

ts yang diperoleh di standarkan dengan tebal shell yang dijual dipasaran dengan melihat T 5.7 B&Y; 90

ts = 7/16 in

Menghitung tebal tutup atas standard dishead (th)

OD = ID + 2 ts
= 222,818 in + 7/8 in
= 223,693 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 216
icr = 13
rc = 170
6%rc = 10,2

Karena icr > 6% rc, maka digunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/icr)^{0.5} \right)$$

Dimana :

P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$$W = 1/4 \times \left(3 + \frac{170}{13}^{0.5} \right)$$

= 1,65405

maka tebal tutup (th) dapat dihitung

Asumsi tl = 8/16

$$8/16 = \frac{40{,}846 \text{ psig} \times 170 \times 1{,}6541}{2 \times f \times 0{,}8 - 0{,}2 \times 40{,}846 \text{ psig}} + 1/8$$

$$6/16 = \frac{40{,}846 \text{ psi} \times 170 \times 1{,}6541}{2 \times f \times 0{,}8 - 0{,}2 \times 40{,}846 \text{ psi}}$$

f = 19147,26407 psi

f actual < f allowable, maka th = 8/16 in dapat digunakan

Menentukan tinggi tutup atas

ha = 0,169 d

= 0,169 x 18,568 ft = 3,138 ft = 37,656 in = 0,9565 m

Menghitung tebal tutup bawah standard dishead

OD = ID + 2 ts
= 222,818 in + 7/8 in
= 223,693 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 216
icr = 13
rc = 170
6%rc = 10,2

Karena icr > 6% rc, maka digunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/icr)^{0.5} \right)$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$$W = 1/4 \times \left(3 + \frac{170}{13}^{0.5} \right)$$

= 1,65405

maka tebal tutup (th) dapat dihitung

Asumsi tl = 8/16

$$8/16 = \frac{40,846 \text{ psi} \times 170 \times 1,6541}{2 \times f \times 0,8 - 0,2 \times 0 \text{ psi}} + 1/8$$

$$3/8 = \frac{40,846 \text{ psi} \times 170 \times 1,6541}{2 \times f \times 0,8 - 0,2 \times 40,846 \text{ psi}}$$

f = 19147 1/4 psi

f actual < f allowable, maka t 8/16 in dapat digunakan

Menentukan tinggi tutup bawah

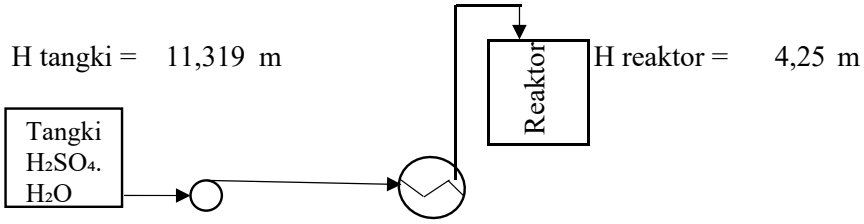
hb = 0,169 d
= 0,169 x 18,568 ft = 3,138 ft = 37,656 in = 0,9565 m

Spesifikasi

Fungsi	:	Menyimpan asam sulfat monohidrat selama 6 hari	
Type	:	Silinder vertikal dengan tutup atas standard dishead	
Volume	:	8040,802 cuft	= 227,69 m^3
Diameter	:	18,568 ft	= 5,6596 m
Tinggi	:	37,136 ft	= 11,319 m
Tebal shell	:	7/16 in	= 0,4375 m
Tebal tutup atas	:	8/16 in	= 0,0127 m

Tebal tutup bawah : 8/16 in = 0,0127 m
Bahan konstruksi : *Low-Alloy Steels SA-202 grade A*
Jumlah : 4 buah

4. Pompa-2 (L-121)
Fungsi : Mengalirkan $H_2SO_4.H_2O$ melewati heater menuju reaktor
Type : *Centrifugal pump*
Dasar pemilihan : Sesuai untuk liquid dengan viskositas < 10 cp



Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$H_2SO_4.H_2O$	11076,2225	1	1,7518
Total	11076,2225	1	

ρ = 1,7518 g/cc x 62,43
= 109,3649 lb/cuft

Rate massa = 11076,22 kg/jam = 24418,89 lb/jam
Rate volumetrik = $\frac{\text{Rate massa}}{\rho \text{ campuran}}$
= $\frac{24418,89 \text{ lb/jam}}{109,3649 \text{ lb/cuft}}$
= 223,2791 cuft/jam = 3,721318 cuft/menit
= 27,83918 gpm = 0,062022 cuft/s

Menghitung diameter optimum dengan persamaan :
Asumsi aliran turbulen

$$\text{Diameter optimum} = 3.9 \times q_f^{0.45} \times \rho^{0.13}$$ ***eq. 15; Peters 4-ed; 496***

Dengan :
q_f = Fluid flow rate; (cuft/detik)
ρ = Fluid Density; (lb/cuft)
Di = Diameter pipa optimum, (in)

Di = 3,9 x 0,062 0,45 cuft/s x 109,3649 0,13 lb/cuft
= 2,0548 in
Dari diameter optimum, dipilih pipa 2,00 in, sch 80 berdasarkan ***McCabe***
OD = 2,38 in = 0,0603 m ***McCabe: App 3; 1090***
ID = 1,94 in = 0,0493 m

A = 0,0205 ft²

Kecepatan linier, $v = \frac{qf}{A}$

$= \frac{0,062 \text{ cuft/s}}{0,0205 \text{ ft}^2}$

$= 3,0255$ ft/s

ρ reference = 62,43 lb/cuft

sg reference = 1

μ reference = 1 cps

$\text{sg bahan} = \frac{\rho \text{ bahan}}{\rho \text{ reference}} \times \text{sg reference}$

$= \frac{109,3649 \text{ lb/cuft}}{62,43 \text{ lb/cuft}} \times 1$

$= 1,7518$

μ berdasarkan sg bahan :

$\mu \text{ bahan} = \frac{\text{sg bahan}}{\text{sg reference}} \times \mu \text{ reference}$

$= \frac{1,7518}{1} \times 1 \text{ cps}$

$= 1,7518$ cps

$= 0,0012$ lb/ft.s

$NRe = \frac{D \, v \, \rho}{\mu}$

$= \frac{0,0493 \text{ ft} \times 3,0255 \text{ ft/s} \times 109,3649 \text{ lb/cuft}}{0,001177 \text{ lb/ft.s}}$

Nre = 13843,546

Nre > 2100 (asumsi aliran turbulen benar)

Dipilih pipa *commercial steel* , dengan :

ε = 0,000046 m ***Geankoplis: F 2.10-3; 88***

$\varepsilon/D = \frac{0,000046 \text{ m}}{0,0492506 \text{ m}}$

$= 0,000934$

f = 0,007 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***

Panjang pipa lurus = 14 m = 45,932 ft

- 1 *gate valve* = n x Le/D x ID

(wide open) = 1 x 9 x 0,0493 ft

= 0,4433 ft

Panjang total pipa = 0,4433 ft + 45,932 ft = 46,375 ft

Friksi yang terjadi

karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ ***Geankoplis 3ed, eq 2.10-6; 89***

$$= \frac{2 \times 0,007 \times (3,0255 \text{ ft/s})^2 \times 46,375 \text{ ft}}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 0,0493 \text{ ft}}$$

$$= 3,7504116 \text{ ft.lbf/lbm}$$

karena kontraksi dalam pipa

$$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :

$\alpha = 1$

$Kc = 0,5$, maka :

$$F2 = \frac{0,5 \times (3,0255 \text{ ft/s})^2}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

$$= 0,071124 \text{ ft.lbf/lbm}$$

karena *gate valve*

$$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$$, Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$$= \frac{1 \times 0,17 \times 3,0255 \text{ ft/s}^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$$

$$= 0,0242 \text{ ft.lbf/lbm}$$

karena ekspansi pipa ke heater

$$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 < A2, maka V1 dianggap = 0)

$$\frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$$

$$= \frac{(3,0255 \text{ ft/s})^2 - 0}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

$$= 0,1422 \text{ ft.lbf/lbm}$$

karena elbow 90°

Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2}$$ n = jumlah elbow

$$= \frac{1 \times 0,75 \times (3,0255 \text{ ft/s})^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$$

$$= 0,1067 \text{ ft.lbf/lbm}$$

Sehingga :

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$

= 4,09465 ft.lbf/lbm

Energi Tekanan

$EP = \frac{\Delta P}{\rho}$

P1 = 1 atm + P h
= 2116,8 lbf/ft² + ρ g/gc h
= 2116,8 lbf/ft² + 109,3649 lbm/ft³ x 1 lbf/lbm x 29,709 ft
= 5348,3633 lbf/ft²

P_2 = 2116,8 lbf/ft²

ΔP = 2116,8 lbf/ft² - 5348,4 lbf/ft²
= -3231,563 lbf/ft²

$EP = \frac{-3231,563 \text{ lbf/ft}^2}{109,3649 \text{ lbm/ft}^3}$
= -29,54846 ft.lbf/lbm

Energi Kinetik

$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$
$= \frac{(3,0255 \text{ ft/s})^2}{2 \times 1 \times 32,174 \text{ lbm.ft/s}^2.\text{lbf}}$
= 0,1422 ft.lbf/lbm

Energi Potensial

ΔZ = 15,569 Z1= 0 m Z2 = 15,569 m
51,08 ft

$EP = \Delta Z \frac{g}{gc}$
= 51,08 ft x 1 lbf/lbm = 50,804 ft.lbf/lbm

Persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$

= (-29,55 + 50,80352 + 0,1422 + 4,0947) ft.lbf/lbm
= 25,491962 ft.lbf/lbm

Power Pompa

$Hp = \frac{-Wf \times \text{flowrate(gpm)} \times sg}{3960}$
$= \frac{25,492 \text{ ft.lbf/lbm} \times 27,839 \text{ gpm} \times 1,7518}{3960}$
= 0,3139 Hp

Effisiensi Pompa

E = 30% ***Peters 4ed ; Figure 14 - 37; 520***

BHP = $\frac{0,3139}{30\%}$

= 1,0465 Hp

Effisiensi Motor

E = 80% ***Peters 4ed ; Figure 14 - 38; 521***

BHP = $\frac{1,0465}{80\%}$

= 1,3081 Hp

Spesifikasi

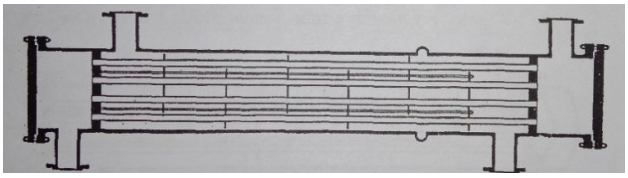
Fungsi	:	Mengalirkan asam sulfat monohidrat melewati heater menuju reaktor
Type	:	*Centrifugal pump*
Power	:	1 Hp = 745,7 watt
Rate volume	:	27,83918 gpm = 0,1054 m^3/menit
Effisiensi pompa	:	30%
Effisiensi motor	:	80%
Bahan konstruksi	:	*Commercial Steel*
Jumlah	:	1 buah

5. Heater Akrilonitril (E-112)

Fungsi : Memanaskan akrilonitril dari suhu 30°C menjadi 90 °C

Type : 1-2 Shell and Tube Heat Exchanger (Fixed Tube) (counter flow)

Dasar pemilihan : Sesuai untuk kapasitas besar



1) Neraca Panas

m C_3H_3N = 5060,688 kg/jam = 11156,91 lb/jam

Q supply = 422962,8 kJ/jam = 400891,4 Btu/jam

m steam = 817,4171 kg/jam = 1802,096 lb/jam

2) Log Mean Temperatur Difference (LMTD)

Fluida dingin

Suhu Akrilonitril				
t1 =	30	°C	=	86 °F
t2 =	90	°C	=	194 °F

Fluida panas

Suhu steam				
T1 =	148	°C	=	298,4 °F
T2 =	148	°C	=	298,4 °F

Δt_1 = T2 - t1
= 298,4 - 86
= 212,4 °F

Δt_2 = T_1 - t_2
= 298,4 - 194
= 104,4 °F

Kern; 90

$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{298,4 - 298,4}{194 - 86} = 0$

$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{194 - 86}{298,4 - 86} = 0,5085$

Kern: eq. 5.14; 149

$\Delta t\ LMTD = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$

Kern: eq. 5.14; 89

$= \frac{104,4\ °F - 212,4\ °F}{\ln \frac{104,4\ °F}{212,4\ °F}}$

= 152,0609 °F

FT = 1 ***Kern: Fg. 18; 828***

Δt = Δt LMTD x FT ***Kern : Pers.7.42, Hal. 149***
= 152,06 °F x 1
= 152,06 °F

3) Temperatur rata-rata

tc = tav akrilonitril
= $\frac{86 + 194}{2}$ °F
= 140 °F

Tc = tav steam
= $\frac{298 + 298,4}{2}$ °F
= 298,4 °F

μ bahan = 0,8069 cp
Range UD = 200-700 ***Kern: T 8; 840***
Trial UD = 220 Btu/jam.ft².°F
Luas penampang Heater :
Q = A. UD.ΔT

$A = \frac{400891,4\ BTU/jam}{220\ Btu/jam.ft^2.°F \times 152\ °F} = 11,984\ ft^2 = 1,1133\ m^2$

Dari Kern T 10; 843
Pipa (Tube)
OD = 1 1/4 in
BWG = 10
ID = 0,982 in
Flow Area (a't) = 0,757 in^2
Surface Per Lin ft (a") = 0,3271 ft²/ft panjang
Disusun Triangular
Pitch = 1 9/16 in
Panjang Tube = 2,5 ft = 0,762 m
Jumlah Tube :

Nt = A' / a" x L

$$= \frac{11{,}984 \text{ ft}^2}{0{,}3271 \text{ ft}^2/\text{ft panjang} \times 2{,}5 \text{ ft}}$$

= 14,65433

Nt distandardkan dengan ketetapan pada ***Kern T 9***

Nt = 14
IDs = 12 in
n = 2 passes

$$\text{UD koreksi} = \frac{\text{Nt}}{\text{Nt standard}} \times \text{UD Trial}$$

$$= \frac{14{,}7}{14} \times 220 \text{ Btu/jam.ft}^2.^\circ\text{F}$$

= 230,2823 Btu/jam.ft².°F

Perancangan HE

Type HE = 1 - 2 Artinya : 1 lewatan pada shell
2 lewatan maks pada bagian tube

Fluida panas (steam) didalam tube
Fluida dingin (akrilonitril) didalam shell
Fluida yang memiliki suhu lebih tinggi lebih baik diletakkan didalam tube, agar transfer panas lebih maksimal.

Bagian shell

IDs = 12 in
n = 2
Baffle space (B) = 3 in = 0,25 ft

Bagian tube

OD = 1 1/4 in
BWG = 10
ID = 0,982 in
Flow area per tube (a't) = 0,757 in²
surface per lin ft (a") = 0,3271 ft²
Disusun = Triangular
Pitch (Pt) = 1,5625
Panjang (l) = 2 ft = 0,6096 m
Nt = 14 buah
De = 0,91 ***Kern F 28; 838***

Viscocity of Liquid (cp)

$\log 10\ \mu = A + B/T + CT + DT^2$ ***Yaws***

Bahan	A	B	C	D	T (K)
C_3H_3N	-6,347	815,02	0,0157	-2E-05	333

$\log 10\ \mu$ = -0,587 cp , maka μ = 0,0259 cp

$\log 10\ \mu$ pada tw :
$\log 10\ \mu$ = -0,692
μ = 0,0153 cp

Thermal Conductivity of Liquid

$k\ (W/m.K) = A + BT + CT^2$ ***Yaws***

Bahan	A	B	C	T (K)
C_3H_3N	0,3726	-7E-04	1E-07	333,15

k = 0,1477 W/m.K

Heat capasity of Liquid

$Cp = A+BT+CT^2+DT^3$ (J/mol.K)

Bahan	A	B	C	D	T (K)
C_3H_3N	33,362	0,5864	-0,002	2E-06	333

Cp = 114,295 J/mol.K

Bagian Tube (Steam)	**Bagian Shell (Akrilonitril)**
Menghitung Nre Tube	**Menghitung Nre Shell**
$at = \frac{Nt \times a't}{n \times 144}$	$as = \frac{IDs \times C' \times B}{144 \times Pt}$; C' = Pt - 1 = 2 - 1 = 1/3
$= \frac{14 \times 0,757}{2 \times 144}$	$as = \frac{12 \times 1/3 \times 3}{144 \times 1,56}$
$= 0,0368\ ft^2$	$= 0,05\ ft^2$
$Gt = \frac{W\ Steam}{at}$	$Gs = \frac{W\ Bahan}{as}$
$= \frac{1802,096272\ lb/jam}{0,0368\ ft^2}$	$= \frac{11156,9069\ lb/jam}{0,05\ ft^2}$
$= 48971,8557\ lb/jam\ ft^2$	$= 223138,1387\ lb/jam\ ft^2$
μ Steam Pada Tc = 298,4 F	μ Bahan Pada tc = 140 F
μ Steam = 0,013 Cp ***Kern; 825***	μ = 0,02588 Cp
= 0,0315 lb/ft jam	= 0,0626 lb/ft jam
ID = 0,98 in = 0,0818 ft	
$Nre\ t = \frac{Gt \times ID}{\mu\ Steam}$	$De = \frac{4 \times as}{Watted\ Perimeter}$ ***Kern; 105***
$= \frac{48971,8557 \times 0,0818}{0,031454}$	$= \frac{4 \times 0,05}{Nt \cdot \pi \cdot (OD/12)}$
$= 127357,7$	$= \frac{4 \times 0,05}{14 \times \pi \times 0,10}$
	$= 0,0437\ ft$
Koefisien Perpindahan Panas	$Nre = \frac{Gs \times De}{\mu\ Bahan}$
hio = 1500 Btu/jam.ft² F ***Kern;***	$= \frac{223138,14 \times 0,04368}{0,0626}$
$tw = tc + \frac{hio}{hio + ho} \times (Tc - tc)$ ***164***	$= 155639,02$
$= 140 + \frac{1500}{1500 + 2370} \times 158$	**Koefisien Perpindahan panas**
$= 201,388\ F$	jH = 320 ***Kern: F 28; 838***
$= 367,254\ K$	

	Pada Tc = 140 F ***Dari Yaws*** k = 0,1477 W/ mK = 1,0247 Btu/ ft F Cp = 114,29 J/mol.K = 2,1565 kJ/kg K = 0,5151 BTU/lb. F $\frac{\lceil Cp\ \mu \rceil^{1/3}}{k} = \frac{0,52 \times 0,0626\ \text{^0.3}}{1,0247}$ = 0,3157 $ho = Jh \times \frac{k}{de} \times \lceil Cp\ \mu \rceil^{1/3} \times \varphi s$ $\frac{ho}{\varphi s} = 320 \times \frac{1,0247}{0,0437} \times 0,32$ = 2370,4576 Btu/jam.ft².°F **Pada Tw** = 201,39 F μ = 0,0153 cp ***Yaws*** = 0,037 lb/ft jam
	$\varphi w = \frac{\lceil \mu \rceil^{0.14}}{\mu}$ $= \frac{0,0626\ \text{^0.14}}{0,037}$ = 1,0764 $ho = \frac{ho}{\varphi w} \varphi s$ = 2370,458 x 1,0764 = 2551,47 Btu/jam.ft².°F

Clean Overall Coefficient, Uc

$$Uc = \frac{hio \times ho}{hio + ho}$$

$$= \frac{1500\ \text{Btu/jam.ft}^2\text{.°F} \times 2551,47\ \text{Btu/jam.ft}^2\text{.°F}}{1500\ \text{Btu/jam.ft}^2\text{.°F} + 2551,47\ \text{Btu/jam.ft}^2\text{.°F}}$$

= 944,646 Btu/jam.ft².°F

Design Overall Coefficient, UD

A = Nt x l x a"

= 14 x 2 ft x 0,3271 ft²/ft panjang

= 9,1588 ft²

$$Ud = \frac{Q}{A \times \Delta T\ LMTD}$$

$$= \frac{400891,3598\ \text{Btu/jam}}{9,1588\ \text{ft}^2 \times 152,06\ \text{°F}}$$

= 287,85 Btu/Jam.ft². °F

Dirt Factor Rd

$$Rd = \frac{Uc - Ud}{Uc \times Ud}$$

$$= \frac{944{,}65 \text{ Btu/jam.ft}^2.°F - 287{,}85 \text{ Btu/jam.ft}^2.°F}{944{,}65 \text{ Btu/jam.ft}^2.°F \times 287{,}85 \text{ Btu/jam.ft}^2.°F}$$

$$= 0{,}002415 \text{ ft}^2.°F.\text{jam/BTU}$$

Rd ketentuan = 0,002 ***Kern: T 12; 845***

Rd Hitung > Rd Ketentuan, Maka Alat dapat digunakan

PRESSURE DROP

Bagian Tube (Steam)	**Bagian Shell (Akrilonitril)**
Suhu Steam = 148 C	Nre = 155639,02
= 298,4 F ***Kern T7***	f = 0,0013 ***F 29; 839***
Didapat Spesifik Volume = 6,66	IDs = 12 in = 1 ft
$s = \frac{1 / 6{,}655}{62{,}43}$	N+1 = 12 L / B
= 0,0024	= 96
Nre = 127357,67	$\Delta Ps = \frac{f.Gs^2.Ds.(N+1)}{5.22 \times 10\text{^}10 \times De \times s \times \phi s}$
f = 0,0002 ***Kern: F 26; 836***	= 4,9799 < 10 psia
$\Delta Pt = \frac{f.Gt^2.L.n}{5{,}22 \times 10\text{^}10 \times Di \times s \times \phi t}$	Memenuhi untuk aquous solution
= 3E-05 psia < 2 psia	
Memenuhi untuk steam	

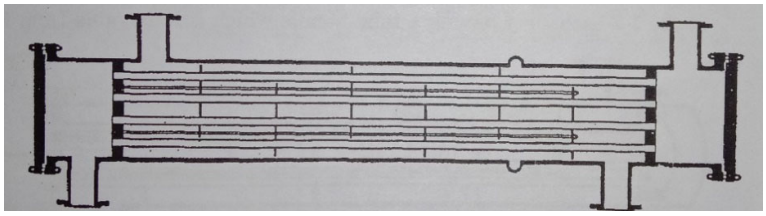
Spesifikasi

Fungsi	:	Memanaskan akrilonitril hingga 90°C			
Type	:	1-2 Shell and Tube Heat Exchanger (Fixed Tube) (counter flow)			
Tube					
OD	:	1 1/4	in	= 0,0318	m
BWG	:	10			
ID	:	0,9820	in	= 0,0249	m
Flow area per tube (a't)	:	0,7570	in^2	= 0,0005	m
Surface per lin ft (a")	:	0,3271	ft^2	= 0,0002	m
Disusun	:	Triangular			
Pitch	:	1,5625			
Panjang Tube	:	2	ft	= 0,6096	m
Jumlah Tube	:	14	Buah		
Diameter Shell	:	12	in	= 0,3048	m
Faktor Pengotor					
Rd ketentuan	:	0,002	m^2 C/ W		
Rd hitung	:	0,0024	m^2 C/ W		
Preasure Drop					
Shell	:	4,9799	psi		

Tube : 0,0000348 psi
Jumlah : 1 Buah

6. Heater Asam sulfat monohidrat (E-122)

Fungsi : Memanaskan asam sulfat monohidratl hingga 90 °C
Type : 1-2 Shell and Tube Heat Exchanger (Fixed Tube) (counter flow)
Dasar pemilihar : Sesuai untuk kapasitas besar



1) Neraca Panas

m $H_2SO_4.H_2O$ = 11076,22 kg/jam = 24418,89 lb/jam
Q supply = 1363309 kJ/jam = 1292168 Btu/jam
m steam = 5863,901 kg/jam = 12927,69 lb/jam

2) Log Mean Temperatur Difference (LMTD)

Fluida dingin

Suhu $H_2SO_4.H_2O$				
t1 =	30	°C	=	86 °F
t2 =	90	°C	=	194 °F

Fluida panas

Suhu steam				
T1 =	148	°C	=	298,4 °F
T2 =	148	°C	=	298,4 °F

$\Delta t_1 = T_2 - t_1$
$= 298,4 - 86$
$= 212,4$ °F

$\Delta t_2 = T_1 - t_2$
$= 298,4 - 194$
$= 104,4$ °F

Kern; 90

$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{298,4 - 298,4}{194 - 86} = 0$

$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{194 - 86}{298,4 - 86} = 0,5085$

Kern: eq. 5.14; 149

$\Delta t\ LMTD = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$

Kern: eq. 5.14; 89

$= \frac{104,4\ °F - 212,4\ °F}{\ln \frac{104,4\ °F}{212,4\ °F}}$

$= 152,0609$ °F

FT = 1 ***Kern: Fg. 18; 828***

$\Delta t = \Delta t\ LMTD \times FT$ ***Kern : Pers.7.42, Hal. 149***
$= 152,06\ °F \times 1$
$= 152,06\ °F$

3) Temperatur rata-rata

$tc = tav\ H_2SO_4.H_2O$ $= \frac{86 + 194}{2}\ °F = 140\ °F$

$Tc = tav\ steam$ $= \frac{298 + 298,4}{2}\ °F = 298,4\ °F$

μ bahan = 1,7518 cp
Range UD = 200-700 ***Kern: T 8; 840***
Trial UD = 220 Btu/jam.ft².°F
Luas penampang Heater :
$Q = A.\ UD.\Delta T$
$A = \frac{1292168\ BTU/jam}{220\ Btu/jam.ft^2.°F \times 152\ °F} = 38,626\ ft^2$

Dari Kern T 10; 843
Pipa (Tube)
OD = 1 in
BWG = 14
ID = 0,834 in
Flow Area (a't) = 0,546 in^2
Surface Per Lin ft (a") = 0,2618 ft²/ft panjang
Disusun Triangular
Pitch = 1,25 in
Panjang Tube = 6 ft
Jumlah Tube :

$Nt = A' / a'' \times L$
$= \frac{38,626\ ft^2}{0,2618\ ft^2/ft\ panjang \times 6\ ft} = 24,58995$

Nt distandardkan dengan ketetapan pada ***Kern T 9***
Nt = 24
IDs = 8 in
n = 1 passes
$UD\ koreksi = \frac{Nt}{Nt\ standard} \times UD\ Trial$
$= \frac{24,6}{24} \times 220\ Btu/jam.ft^2.°F$
$= 225,4079\ Btu/jam.ft^2.°F$

Perancangan HE
Type HE = 1 - 2 Artinya : 1 lewatan pada shell
2 lewatan maks pada bagian tube
Fluida panas (steam) dilewatkan tube
Fluida dingin (asam sulfat monohidrat) dilewatkan shell

Fluida yang memiliki suhu lebih tinggi dilewatkan tube, agar transfer panas lebih maksimal

Bagian shell

IDs = 8 in
n = 1
B = 1 x IDs
= 8 in

Bagian tube

OD	=	1	in
BWG	=	14	
ID	=	0,834	in = 0,0695 ft
Flow area per tube (a't)	=	0,546	in²
surface per lin ft (a")	=	0,2618	ft²
Disusun	=	Triangular	
Pitch (Pt)	=	1,25	
Panjang (l)	=	6	ft
Nt	=	24	buah
De	=	0,72	***Kern F 28; 838***

Heat capasity of Liquid

$Cp = A+BT+CT^2+DT^3$ (J/mol.K)

Bahan	A	B	C	D	T (K)
$H_2SO_4.H_2O$	214,3	-	-	-	333

Cp = 71394 J/mol.K

Bagian Tube (Steam)	**Bagian Shell ($H_2SO_4.H_2O$)**
Menghitung Nre Tube	**Menghitung Nre Shell**
$at = \frac{Nt \times a't}{n \times 144}$	$as = \frac{IDs \times C' \times B}{144 \times Pt}$
$= \frac{24 \times 0,546}{1 \times 144}$	C' = Pt - OD = 1 - 1 = 0,25
$= 0,091\ ft^2$	$as = \frac{8 \times 1/4 \times 8}{144 \times 1,25}$
	$= 0,0889\ ft^2$
Gt = W Steam / at	Gs = W Bahan / as
$= \frac{12927,68946}{0,091}$ lb/jam / ft^2	$= \frac{24418,8906}{0,0889}$ lb/jam / ft^2
$= 142062,5216$ lb/ jam ft^2	$= 274712,5198$ lb/ jam ft^2
μ Steam Pada Tc = 298,4 F	μ Bahan Pada tc = 140 F
μ Steam = 0,013 Cp ***Kern; 825***	μ = 3 Cp ***F.14; 823***
= 0,0315 lb/ft jam	= 7,2586 lb/ft jam
ID = 0,83 in = 0,0695 ft	

Nre t = $\frac{Gt \times ID}{\mu \text{ Steam}}$

= $\frac{142062,5216 \times 0,0695}{0,031454}$

= 313770,9

Koefisien Perpindahan Panas

hio = 1500 Btu/jam.ft² F ***Kern;***

tw = $tc + \frac{hio}{hio + ho} \times (Tc - tc)$ ***164***

= $140 + \frac{1500}{1500 + 2325} \times 158$

= 202,119 F

= 367,661 K

De = $\frac{4 \times as}{\text{Watted Perimeter}}$ ***Kern; 105***

= $\frac{4 \times 0,0889}{Nt \cdot \pi \cdot (OD/12)}$

= $\frac{4 \times 0,0889}{24 \times \pi \times 0,08}$

= 0,0566 ft

Nre = $\frac{Gs \times De}{\mu \text{ Bahan}}$

= $\frac{274712,52 \times 0,05662}{7,2586}$

= 2142,7447

Koefisien Perpindahan panas

jH = 25 ***Kern: F 28; 838***

Pada Tc = 140 F

Kern: T 4; 800

k = 0,25 Btu/jam.ft². °F

Cp = 71394 J/mol.K

= 1347,1 kJ/kg K

= 321,74 BTU/lb. F

$\frac{[Cp\ \mu]^{1/3}}{k} = \frac{322 \times 7,2586}{0,2500}$ ^0.3

= 21,061

ho = $Jh \times \frac{k}{de} \times [Cp\ \mu]^{1/3} \times \varphi s$

$\frac{ho}{\varphi s}$ = $25 \times \frac{0,2500}{0,0566} \times 21,061$

= 2324,9195 Btu/jam.ft².°F

Pada Tw = 202,12 F

μ = 1,1 cp ***Yaws***

= 2,6615 lb/ft jam

φw = $\frac{[\mu]^{0.14}}{\mu}$

= $\frac{7,2586}{2,6615}$ ^0.14

= 1,1508

ho = $\frac{ho}{\varphi w} \varphi s$

= 2324,9195 x 1,1508

= 2675,53 Btu/jam.ft².°F

Clean Overall Coefficient, Uc

$$Uc = \frac{hio \times ho}{hio + ho}$$

$$= \frac{1500 \text{ Btu/jam.ft}^2.\text{°F} \times 2675{,}53 \text{ Btu/jam.ft}^2.\text{°F}}{1500 \text{ Btu/jam.ft}^2.\text{°F} + 2675{,}53 \text{ Btu/jam.ft}^2.\text{°F}}$$

$$= 961{,}1463 \text{ Btu/jam.ft}^2.\text{°F}$$

Design Overall Coefficient, UD

$$A = Nt \times l \times a''$$

$$= 24 \times 6 \text{ ft} \times 0{,}2618 \text{ ft}^2/\text{ft panjang}$$

$$= 37{,}699 \text{ ft}^2$$

$$Ud = \frac{Q}{A \times \Delta T \text{ LMTD}}$$

$$= \frac{1292167{,}6040 \text{ Btu/jam}}{37{,}699 \text{ ft}^2 \times 152{,}06 \text{ °F}}$$

$$= 225{,}41 \text{ Btu/Jam.ft}^2.\text{ °F}$$

Dirt Factor Rd

$$Rd = \frac{Uc - Ud}{Uc \times Ud}$$

$$= \frac{961{,}15 \text{ Btu/jam.ft}^2.\text{°F} - 225{,}41 \text{ Btu/jam.ft}^2.\text{°F}}{961{,}15 \text{ Btu/jam.ft}^2.\text{°F} \times 225{,}41 \text{ Btu/jam.ft}^2.\text{°F}}$$

$$= 0{,}003396 \text{ ft}^2.\text{°F.jam/BTU}$$

Rd ketentuan = 0,002 ***Kern: T 12; 845***

Rd Hitung > Rd Ketentuan, Maka Alat dapat digunakan

PRESSURE DROP

Bagian Tube (Steam)	**Bagian Shell ($H_2SO_4.H_2O$)**
Suhu Steam = 148 C = 298,4 F ***Kern T7***	Nre = 2142,7447 f = 0,003 ***F 29; 839***
Didapat Spesifik Volume = 6,66	IDs = 8 in = 0,6667 ft
s = 1 / 6,655 / 62,43 = 0,0024	N+1 = 12 L / B = 108
Nre = 313770,87	$\Delta Ps = \frac{f.Gs^2.Ds.(N+1)}{5.22 \times 10\text{^}10 \times De \times s \times \phi s}$
f = 0,0001 ***Kern: F 26; 836***	= 4,7928 < 10 psia
$\Delta Pt = \frac{f.Gt^2.L.n}{5{,}22 \times 10\text{^}10 \times Di \times s \times \phi t}$	Memenuhi untuk aquous solution
= 0,1004 psia < 2 psia Memenuhi untuk steam	

Spesifikasi

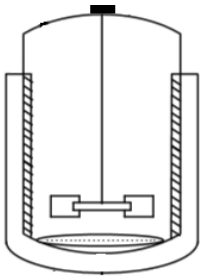
Fungsi	:	Memanaskan asam sulfat monohidrat hingga 90°C			
Type	:	1 - 2 Shell and tube Heat Exchanger			
Tube					
OD	:	1	in	=	0,0254 m
BWG	:	14			
ID	:	5/6	in	=	0,0212 m
Flow area per tube (a't)	:	0,5460	in^2	=	0,0004 m^2
Surface per lin ft (a")	:	0,2618	ft^2	=	0,0243 m^2
Pitch	:	1	in^2	=	0,0008 m^2
Panjang Tube	:	6	ft	=	1,8288 m
Disusun	:	Triangular			
Jumlah Tube	:	24	Buah		
Diameter Shell	:	8	in	=	0,2032 m
Faktor Pengotor					
Rd ketentuan	:	0,002	m^2 C/ W		
Rd hitung	:	0,0034	m^2 C/ W		
Preasure Drop					
Shell	:	4,7928	psi		
Tube	:	0,1004	psi		
Jumlah	:	1 Buah			

7. Reaktor (R-210)

Fungsi : Mereaksikan akrilonitril dan asam sulfat monohidrat membentuk akrilamida sulfat

Type : Mixed Flow Reaktor, Silinder tegak dengan tutup atas dan bawah standard dishead dilengkapi dengan pengaduk, baffle dan jaket pendingin

Dasar pemilihan : Dapat meningkatkan konversi hingga 95%



Kondisi operasi :
Tekanan operasi : 1 atm
Suhu operasi : 90 °C
Waktu tinggal : 1 jam

Kirk Othmer Vol. 1; 278

Komponen	A	B	n	Tc	T (K)
C_3H_3N	0,2503	0,2293	0,28939	535	363,15
H_2O	0,3471	0,274	0,28571	647,13	

$$\rho = A \times B^{-(1 - T / Tc)^n}$$

Yaws T8-2

Feed akrilonitril dari Heater-1

Komponen	Berat (kg)	Fraksi	ρ (gr/cc)
C_3H_3N	5060,688	0,995	0,7226
H_2O	25,431	0,005	0,9656
Total	5086,118	1	

Yaws

Rate massa akrilonitril = 5086,118 kg/jam = 11212,972 lb/jam

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62,43 = \text{lb/cuft}$$

$$= \frac{1}{\frac{0,995}{0,7226} + \frac{0,005}{0,9656}} \times 62,43$$

$$= 45,1695 \text{ lb/cuft}$$

Feed asam sulfat monohidrat dari Heater-2

Komponen	Berat (kg)	ρ (gr/cc)
$H_2SO_4.H_2O$	11076,22	1,7518

Rate massa as sulfat monohidrat = 11076,22 kg/jam = 24419 lb/jam

ρ = 1,7518 x 62,43 = 109,3649 lb/cuft

Tahap-tahap perancangan

1. Perancangan dimensi reaktor
2. Perancangan sistem pengaduk
3. Perancangan sistem pendingin
4. Perancangan penyangga

1. PERANCANGAN DIMENSI REAKTOR

Komponen	Berat (kg)	Fraksi	ρ (gr/ml)
C_3H_3N	5060,688	0,313	0,7226
H_2O	25,431	0,002	0,9656
$H_2SO_4.H_2O$	11076,22	0,685	1,7518
Total	16162,34	1,00	

Rate massa = 16162,34 kg/jam = 35631,86 lb/jam

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62,43 = \text{lb/cuft}$$

$$= \frac{1}{\frac{0,313}{0,7226} + \frac{0,002}{0,9656} + \frac{0,685}{1,7518}} \times 62,43$$

$$= 75,56791 \text{ lb/cuft}$$

$$\text{Rate volum} = \frac{\text{Rate massa}}{\text{densitas}}$$

$$= \frac{35631,86 \text{ lb/jam}}{75,56791 \text{ lb/cuft}}$$

= 471,5211 cuft/jam
Volume bahan = 471,5211 cuft/jam x 1 jam
= 471,5211 cuft
Asumsi bahan mengisi 80% dari volume tangki
Volume tangki = $\frac{471,5211 \text{ cuft}}{80\%}$
= 589,4013 cuft

Menentukan dimensi tangki
Asumsi rasio dimensi : H/D =2 , maka H = 2 D ***Ulrich: T 4-27; 248***
Volume tangki = Vol. silinder + Vol. tutup atas + Vol tutup bawah
589,401 cuft = $\pi/4\ D^2\ (2D)$ + 0,0847 D^3 + 0,0847 D^3
589,401 cuft = 1,57 D^3 + 0,1694 D^3
D^3 = 338,8532 cuft
D = 6,97 ft = 83,66 in H = 13,9434 ft = 167,3202 in

Menentukan tekanan design
P hidrostatis = (ρ.(g / gc). H)
= 75,568 lb/ft^3 x 1 lbf/lbm x 11,2 ft
= 838,38 lbf/ft^2
= 5,8221 lbf/in^2 = 5,8221 psig
P operasi = 14,7 psig
Faktor keamanan 10% :
P design = 1,1 x (5,8221 + 14,7)
= 22,574 Psig
Direncanakan :
1. Bahan konstruksi : Carbon steels SA-285 Grade C
f = 13750 psi ***B&Y : T 13.1; 251***
2. Pengelasan double welded butt joint
E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Menentukan tebal shell
Tebal shell berdasarkan ASME Code untuk tangki silinder :

$$t_s = \frac{P.\ ri}{f.\ E - 0.6\ P} + C \qquad \textit{B\&Y: eq 13.1; 254}$$

$$ts = \frac{22,57427 \text{ psig} \times 41,83 \text{ in}}{13750 \text{ psi} \times 0,8 - 0,6 \times 22,574 \text{ psig}} + 1/8$$

= 0,21095 in
ts distandardkan pada ***B&Y T 5.7; 90***
ts = 1/4 in

Menentukan tebal tutup atas standard dishead
OD = ID + 2 ts
= 83,66 in + 2 x 1/4 in
= 84,16 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 81
icr = 5,125
rc = 84
6%rc = 5,04

Karena ıcr > 6% rc, maka dıgunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/ıcr)^{0.5} \right)$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$$W = 1/4 \times \left(3 + \frac{84}{5,13}^{0.5} \right)$$

$$= 1,76212$$

maka tebal tutup (th) dapat dihitung

Asumsi th = 5/16

$$5/16 = \frac{22,574 \text{ psig} \times 84 \times 1,7621}{2 \times f \times 0,8 - 0,2 \times 22,574 \text{ psig}} + 1/8$$

$$1/5 = \frac{22,574 \text{ psi} \times 84 \times 1,7621}{2 \times f \times 0,8 - 0,2 \times 22,574 \text{ psig}}$$

$$f = 11140,83 \text{ psig}$$

f actual < f allowable, maka th = 5/16 in dapat digunakan

Menentukan tebal tutup bawah standard dishead

OD = ID + 2 ts
= 83,66 in + 2 x 1/4 in
= 84,16 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 81
icr = 5,125
rc = 84
6%rc = 5,04

Karena icr > 6% rc, maka digunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/ıcr)^{0.5} \right)$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$W = 1/4 \times (3 + \frac{84}{5,13} 0.5)$

$= 1,76212$

maka tebal tutup (th) dapat dihitung

asumsi th = 5/16

$5/16 = \frac{22,574 \text{ psig} \times 84 \times 1,7621}{2 \times f \times 0,8 - 0,2 \times 22,574 \text{ psig}} + 1/8$

$1/5 = \frac{22,574 \text{ psi} \times 84 \times 1,7621}{2 \times f \times 0,8 - 0,2 \times 22,574 \text{ psi}}$

$f = 11140,83 \text{ psi}$

f actual < f allowable, maka t 5/16 in dapat digunakan

Menentukan tinggi tutup atas (ha) dan tutup bawah (hb)

ha = 0,169 d

= 0,169 x 6,9717 ft = 1,1782 ft = 14,139 in = 0,3591 m

hb = 0,169 d

= 0,169 x 6,9717 ft = 1,1782 ft = 14,139 in = 0,3591 m

tinggi silinde = 13,9434 ft = 167,3202 in = 4,2499339 m

Tinggi total bejana = 16,2998 ft = 4,97 m

2. PERANCANGAN SISTEM PENGADUK

Penentuan Dimensi pengaduk

Tinggi bahan total (Hl) = 11,15468 ft = 133,8562 in

Diameter tangki (Dt) = 6,971676 ft = 83,66012 in

Ukuran pengaduk diambil dari ***McCabe ed 5; 243***

$\frac{Da}{Dt} = 1/3$	$\frac{E}{Da} = 1$	$\frac{L}{Da} = 1/4$	$\frac{J}{Dt} = \frac{1}{12}$
$\frac{W}{Da} = 1/5$			

Keterangan :

Da = Diameter Impeller

Dt = Diameter Tangki

L = Panjang Blade

W = Lebar Blade

E = Jarak Impeller dr Dasar tangki

J = Lebar baffle

Diameter impeller Da = 1/3 Dt = 1/3 x 6,9717

= 2,3 ft

Lebar Balde W = 1/5 Da = 1/5 x 2,3

= 0,46 ft

Jarak impeller dari dasar E = 1 Da = 1 x 2,3

= 2,32 ft

Lebar Baffle J = 0,08 Dt = 0,0833 x 6,9717

= 0,581 ft

Tebal Pengaduk = 0,1 J = 0,1 x 0,581
= 0,0581 ft
Panjang Balde L = 1/4 Da = 1/4 x 2,3
= 0,58 ft
Tinggi Pengaduk H = 1 Dt = 1 x 6,9717
= 6,9717 ft

Penentuan jumlah pengaduk

Tinggi bahan total (Hl) = 11,15468 ft = 133,8562 in
Diameter tangki (Dt) = 6,971676 ft = 83,66012 in

$$Sg = \frac{\rho \text{ Bahan}}{\rho \text{ reference } (H_2O)}$$

$$= \frac{75,5679 \text{ lb/cuft}}{62,43 \text{ lb/cuft}} = 1,2104$$

$$\text{Jumlah Impeler} = \frac{\text{Tinggi Bahan}}{\text{Diameter Bejana}} \times Sg$$

$$= \frac{11,155}{6,9717} \times 1,2104$$

= 1,9367 Jadi jumlah impeler = 2 buah

Penentuan power motor

Sg Reference = 1 ***Kern: T.6; 808***
μ Reference = 0,95 Cps ***Kern: F. 14; 822-823***

$$\mu \text{ Bahan} = \frac{Sg \text{ Bahan} \times \mu \text{ Reference}}{Sg \text{ Reference}}$$

$$= \frac{1,210 \times 0,95}{1}$$

= 1,1499 cps
= 0,0008 lb/ft.s

Penentuan putaran pengaduk :

V = π x Da x N
Dimana :
V = pheripheral speed (m/menit)
Da = diameter pengaduk (m)
N = putaran pengaduk (rpm)
V = 200 - 250 m/menit ***Joshi; 415***
dipilih putaran pengaduk = 100 rpm = 1,67 rps
Da = 2,3 ft = 0,7083 m
V = π x Da x N
= 3,14 x 0,7083 m x 100 rpm
= 222,413 m/menit
(memenuhi range 200-250 m/menit)

$$\text{Bilangan Reynold} = \frac{\rho \times Da^2 \times N}{\mu}$$

$$= \frac{75{,}568 \text{ lb/cuft} \times 5{,}4 \text{ ft}^2 \times 1{,}67 \text{ rps}}{0{,}000773 \text{ lb/ft.s}}$$

= 880240,1

Untuk Nre > 2100, diperlukan 4 buah baffle

Untuk Nre > 10000, perhitungan power pompa menggunakan pers:

$P = \frac{K\ \rho\ N^3\ D^5}{g}$ Dengan :

g : konstanta grafitasi 32 ft.lbm/s².lbf

Ludwig: eq. 5-5; 299

H : tingi liquid, ft

P : Power, ft lbf/s

W : lebar impeller, ft

μ : viskositas liquid, lb/ft.s

ρ : densitas liquid, lb/cuft

N : kecepatan putar pengaduk, rps

K = 4,5 ***Ludwig: T 5.1; 301***

$$P = \frac{4{,}5 \times 75{,}568 \text{ lb/cuft} \times 4{,}6296 \text{ (rps)}^3 \times 68 \text{ ft}^5}{32{,}2 \text{ ft.lbm/s}^2\text{.lbf}}$$

= 3316,43 ft.lbf/s

= 6,02987 Hp

Power losses pada gland 10 % Hp = 10% x 6,0299

= 0,603 Hp

Power input dengan gland losses = 6,0299 hp + 0,603 hp

= 6,633 HP

Transsmision sistem losses 20% = 20% x 6,633 HP

= 1,3266 HP

Power total = 6,633 + 1,3266

= 7,9594 HP

Effisiensi motor = 80%

Sehingga power motor $= \frac{7{,}9594}{80\%}$

= 9,9493 HP

3. PERANCANGAN SISITEM PENDINGIN

Sebagai media pendingin digunakan air pendingin suhu = 30 °C

Untuk menjaga suhu dalam reaktor tetap = 90 °C

Q serap = 1648830 kJ/jam = 1562789 BTU/jam

T bahan masuk = 90 °C = 194 °F

T bahan keluar = 90 °C = 194 °F

T pendingin masuk = 30 °C = 86 °F

T pendingin keluar = 45 °C = 113 °F

ΔT_1 = 81 °F

ΔT_2 = 108 °F

ΔT LMTD = 93,854 °F

Kebutuhan air pendingin = 33381,33 kg/jam = 73593 lb/jam

Volume pendingin = $\frac{\text{massa air}}{\text{densitas air}}$

$= \frac{33381{,}33 \text{ kg/jam}}{1000 \text{ kg/m}^3}$

$= 33{,}38133 \text{ m}^3\text{/jam}$

$= 1178{,}851 \text{ ft}^3\text{/jam}$

$= 0{,}327459 \text{ ft}^3\text{/s}$

Koefisien perpindahan panas bagian luar jaket : ***Kern: Eq. 20.4; 722***

$$hc = 0{,}87 \times \frac{k}{Di} \times \frac{L^2.N.\rho}{\mu}^{2/3} \times \frac{C.\mu}{k}^{1/3} \times \frac{\mu}{\mu w}^{0{,}14}$$

Keterangan:

L = diameter impeller = 2,3 ft

N = putaran pengaduk = 100 rpm = 6000 rph

ρ = densitas bahan = 75,56791 lb/cuft

μ = viskositas bahan = 0,000773 lb/ft.s = 0,0464 lb/ft.jam

= 1,1499 cps

C = kapasitas panas campuran (Btu/lb.°F)

Komposisi	% Berat	Cp (J/mol)	BM (kg/kmol)	Cp (kkal/kg)
C_3H_3N	0,313	4466	53	0,02022
H_2O	0,002	889,087897	18	0,01185
$H_2SO_4.H_2O$	0,685	13929,5	116	0,02882
$C_3H_5NO.H_2SO$	1,000	1913,63955	169	0,00272
Total	1,000	21198	356	0,06361

1 Joule = 0,00024 kkal

1 kkal/kg °C = 0,053254 Btu/lb°F

C = 0,001535 Btu/lb°F

K = konduktifitas larutan ***Perry ed 5: eq 3-89; 3-243***

$$K \text{ mix} = \frac{0{,}0677}{sg\ [\ 1 - 0{,}0003\ (t - 32)\ ]}$$

$$= \frac{0{,}0677}{1{,}2104\ [\ 1 - 0{,}0003\ (93{,}854 - 32)\ ]}$$

$= 0{,}056987 \text{ Btu/jam.ft}^2\text{.°F}$

$$Re\ p = \frac{[\ L^2\ N\ \rho\ ]^{2/3}}{\mu}$$

$$= \frac{(\ 5{,}4 \text{ ft}^2 \times 6000 \text{ rph} \times 75{,}568 \text{ lb/cuft}\ )^{2/3}}{0{,}0464 \text{ lb/ft.jam}}$$

$= 391843{,}1$

$$\frac{[\ C\ \mu\ ]^{1/3}}{k} = \left(\frac{0{,}0015 \text{ Btu/lb°F} \times 0{,}0464 \text{ lb/ft.jam}}{0{,}056987 \text{ Btu/jam.ft.°F}}\right)^{1/3}$$

$= 0{,}727139$

$$\frac{\mu}{\mu w}^{0{,}14} = \frac{0{,}046363}{1}^{0{,}14}$$

$= 0{,}6505$

Maka, koefisien perpindahan panas diluar jaket dapat dihitung :

$$hc = 0{,}87 \times \frac{k}{Di} \times \frac{L^2.N.\rho}{\mu}^{2/3} \times \frac{C.\mu}{k}^{1/3} \times \frac{\mu}{\mu w}^{0{,}14}$$

$$= 0{,}87 \times \frac{0{,}057 \text{ Btu/jam.ft.°F}}{6{,}9717 \text{ ft}} \times 391843 \times 0{,}7271 \times 0{,}6505$$

$$= 1318{,}12 \text{ Btu/jam.ft.°F}$$

Koefisien perpindahan panas bagian dalam jaket (hi)

Dari Kern: T 10, dipilih pipa 1 1/2 in 16 BWG dengan ukuran :

OD = 1,5 in = 0,125 ft
ID = 1,37 in = 0,1142 ft
flow area = 1,47 in² = 0,0102 ft²
surface per lin ft (a) = 0,3925 ft²
kecepatan aliran (v) = $\frac{W}{\rho \times A}$

$$= \frac{73593{,}24 \text{ lb/jam}}{62{,}43 \text{ lb/cuft} \times 0{,}0102 \text{ ft}^2}$$

$$= 115475{,}5 \text{ ft/jam}$$

$$= 32{,}07652 \text{ ft/s}$$

hi = 2000 Btu/jam.ft².°F ***Kern: F. 25; 835***

$$hio = hi \times \frac{ID}{OD}$$

$$= 2000 \text{ Btu/jam.ft}^2.°F \times \frac{0{,}11 \text{ ft}}{0{,}13 \text{ ft}}$$

$$= 1826{,}667 \text{ Btu/jam.ft}^2.°F$$

$$Uc = \frac{hi \times hio}{hi + hio}$$

$$= \frac{2000 \text{ Btu/jam.ft}^2.°F \times 1826{,}7 \text{ Btu/jam.ft}^2.°F}{2000 \text{ Btu/jam.ft}^2.°F + 1826{,}7 \text{ Btu/jam.ft}^2.°F}$$

$$= 954{,}7038 \text{ Btu/jam.ft}^2.°F$$

Rd = 0,0005 ***Kern: T.12; 845***

$$\frac{1}{Ud} = \frac{1}{Uc} + Rd = \frac{1}{954{,}7 \text{ Btu/jam.ft}^2.°F} + 0{,}0005$$

$$= 0{,}001547 \text{ jam.ft}^2.°F/Btu$$

maka nilai dari Ud = 646,2264 Btu/jam.ft².°F

$$A = \frac{Q}{UD \times LMTD}$$

$$= \frac{1562789{,}26 \text{ BTU/jam}}{646{,}23 \text{ Btu/jam.ft}^2.°F \times 93{,}854 \text{ °F}}$$

$$= 25{,}76705 \text{ ft}^2$$

Menentukan tinggi jaket

Tinggi jaket = Tinggi shell + Tinggi tutup bawah
= 13,9434 ft + 1,1782 ft
= 15,1216 ft

Asumsi :
Tebal air pendingin = 2 in
Tebal jaket (tj) = 6/16 in
Do shell = di + 2 ts
= 83,66 in + 2 x 6/16 in
= 84,41012 in
Di jaket = Do shell + 2 s
= 84,41 in + 2 x 2 in
= 88,41 in
Do jaket = Di jaket + 2 tebal jaket
= 88,41 in + 2 x 6/16
= 89,16012 in

Menghitung tebal jaket
Tebal jaket berdasarkan ASME Code :

$$ts = \frac{P \times Di}{f.E - 0{,}6.P} + C$$

P operasi jaket = 14,7 psig
P hidrostatis = 62,43 lb/cuft x 0,99 lbf/lbm x 15,1216 ft
= 938,9339 lbf/ft²
= 6,5204 Psig
P desain jaket = 21,22037 Psig

Direncanakan :
1. Bahan konstruksi : Carbon steels SA-285 Grade C
f = 13750 psi ***B&Y : T 13.1; 251***
2. Pengelasan double welded butt joint
E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8
Menentukan tebal shell jaket
Asumsi ts = 5/16 in

$$5/16 = \frac{21{,}22037 \times 88{,}41}{f \quad 0{,}8 - \quad 0{,}6 \quad 21{,}22} + 1/8$$

$$3/16 = \frac{21{,}22037 \times 88{,}41}{f \quad 0{,}8 - \quad 0{,}6 \quad 21{,}22}$$

f = 12523,2202 psi
f actual < f allowable, sehingga ts = 5/16 in dapat digunakan

4. PERANCANGAN PENYANGGA BEJANA

Jumlah penyangga = 4

Menentukan Berat total

Vol. tangki = 589,4013 cuft
Vol. bahan 471,5211 cuft
ρ material = 490 lb/cuft
W bejana kosong = (Vol. tangki - Vol bahan) x ρ material
= 57761,33 lb
W isi = 16162,34 kg/jam = 35631,86 lb/jam
= 35631,86 lb/jam x 1 jam
= 35631,86 lb
W pendingin = 33381,33 kg/jam
= 73593,24 lb

$$A = \frac{V}{ha} = \frac{28{,}701 \text{ ft}^3}{1{,}1782 \text{ ft}}$$

= 24,36 ft²
W tutup = luas tutup x th x (ρ /1728)
= 24,36 ft² x 0,026 ft x 0,2836 lb/ft³
= 0,179884 lb
W aksesoris = 8349,331 lb
Σ W = 175335,94 lb

Menentukan tinggi penyangga (L)

tinggi total bejana (H) = 16,2998 ft
tinggi tutup bawah ke permukaan tanah (l) = 5 ft
L = l + 0,5 H
= 5 ft + 0,5 x 16,2998 ft
= 13,1499 ft
= 157,799 in

Menentukan beban tiap penyangga

$$P = \frac{\Sigma W}{n}$$

$$= \frac{175336 \text{ lb}}{4} = 43833{,}99 \text{ lb} = 19882{,}76 \text{ kg}$$

Menentukan fc allowable

$$fc = \frac{P}{A} = \frac{43834 \text{ lbm} \times 1 \text{ lbf/lbm}}{9{,}3 \text{ in}^2} = 4687{,}8 \text{ lbf/in}^2$$

Direncanakan :
Jenis penyangga = Channels
dari B&Y: App G; 354

Axis 1-1	Axis 2-2
A = 9,3 in²	A = 9,3 in²
$r_{1\,1}$ = 5,05 in	$r_{2\,2}$ = 1,11 in

$\frac{L}{r_{1\,1}}$ = 31,2473 $\frac{L}{r_{2\,2}}$ = 142,16

untuk L/r x x > 120 menggunakan persamaan berikut:

$$fc = \frac{18000}{1 + \frac{1}{18000} \times (L/r_{1\,1})^2} \qquad fc = \frac{18000}{1 + \frac{1}{18000} \times (L/r_{2\,2})^2}$$

= 17073,847 psi = 8479,513 psi

untuk L/r x x < 120 menggunakan persamaan berikut:

fc = 17000 - 0,485 x $(L/r_{1\,1})$

= 16984,8 Psi

fc actual > fc allowable, maka penyangga dengan luas permukaan penyangga 9,3 in² dapat digunakan

Spesifikasi:

Fungsi : Mereaksikan akrilonitril dan asam sulfat monohidrat membentuk akrilamida sulfat

Type : Silinder tegak dengan tutup atas dan tutup bawah standard dishead, dilengkapi dengan pengaduk dan penyangga bejana

Operasi : Continous Strirred - Tank Reactor (CSTR)

Kapasitas : 589,4013 ft³

Dimensi shell :

Diameter shell	:	7,0	ft	=	2,125 m
Tinggi shell	:	14	ft	=	4,2499 m
Tebal shell	:	1/4	in	=	0,0064 m
Tebal tutup atas	:	5/16	in	=	0,0079 m
Tebal tutup bawah	:	5/16	in	=	0,0079 m

Sistem pengaduk

Dipakai impeller jenis turbin dengan 4 buah flat blade dengan 2 impeller

Diameter impeller	:	2,3	ft	=	0,7083 m
Jarak impeller dari dasar	:	2,3	ft	=	0,7083 m
Panjang blade	:	0,58	ft	=	0,1771 m
Tinggi pengaduk	:	7,0	ft	=	2,125 m
Power motor	:	9,9493	HP	=	7419,2 W

Sistem pendingin

Diameter jaket	:	88,41	in	=	2,2456 m
Tinggi jaket	:	15,12	ft	=	4,6091 m
Jaket spacing	:	2,38	in	=	0,7239 m
Tebal jaket	:	5/16	in	=	0,0079 m

Penyangga

Luas permukaan penyangga	:	9,3	in²	=	0,006 m²
Tinggi penyangga	:	13	ft	=	4,0081
Jenis penyangga	:	Channels			
Jumlah penyangga	:	4 buah			

8. Tangki penyimpanan Ammonia (F-130)

Fungsi : Menampung bahan baku Ammonia dari supplier
Type : *Horizontal pressure tank (bullet),* Elliptical Head
Dasar pemilihan : Sesuai untuk menyimpan gas yang ditekan pada tekanan 16-18 bar pada suhu ambient

Kondisi operasi
Tekanan : 17 atm
Suhu : 30 °C
Waktu tinggal : 7 hari

Komposisi Ammonia

Komposisi	Berat (kg)	Fraksi berat	ρ (g/cc)
NH_3	3068,73428	0,995	0,602
H_2O	15,4207753	0,005	1,027
Total	3084,15505	1	

Yaws

Menghitung Volume Tangki

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}995}{0{,}602} + \frac{0{,}005}{1{,}027}} \times 62{,}43$$

$$= 37{,}6608 \text{ lb/cuft}$$

Rate massa = 3084,155 kg/jam = 6799,398 lb/jam

$$\text{Rate volume} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{6799{,}398 \text{ lb/jam}}{37{,}6608 \text{ lb/cuft}} = 180{,}5432 \text{ cuft/jam}$$

Direncanakan 7 hari dengan 3 buah tangki
(mempermudah pengeluaran dan pengisian, sehingga)

$$\text{Volume bahan} = \frac{180{,}5432 \text{ cuft/jam} \times 7 \text{ hari} \times 24 \text{ jam/hari}}{3 \text{ tangki}}$$

$$= 10110{,}42 \text{ cuft}$$

Asumsi bahan mengisi 80% volume tangki, maka Vol Tangki :

$$V = \frac{10110{,}418 \text{ cuft}}{80\%}$$

$$= 12638{,}023 \text{ cuft}$$

Menentukan dimensi tangki

Asumsi rasio dimensi : H/D = 2 ***Ulrich; T 4-27; 248***

Volume = 1/4 Π. D.²H (gas holder)

$$12638 = \frac{1}{4} \times \pi \times D^2 \times 2 \times D$$

$D^3 = \frac{12638,02}{1,57}$ cuft

$D^3 = 8049,7$ ft

D = 20,04133 ft = 240,4959 in = 6,1 m

H = 40,08266 ft = 480,9919 in = 12,2 m

Vol Elliptical dishead = 0,000076 D^3 ***B&Y; 95***

= 0,000076 x 8049,7 ft^3

= 0,611777 ft^3

Mencari tinggi bahan untuk elliptical dishead

H bahan = Diameter tangki

Vol bahan = 1/4 Π. $D.^2H$

$10110,4\ ft^3 = \frac{1}{4} \times \pi \times D^2 \times 20,041$ ft

$D^2 = 642,6477\ ft^2$

H bahan = 25,35 ft

Menentukan tekanan design

Bejana Tekanan Dalam

P in = 17 atm = 249,83 psi

P out = 1 atm = 14,7 psi

P operasi = P in - P out + Ph

P hidrostatis = $\rho \times \frac{g}{gc} \times$ H liq (H liq = 80% H tangki)

= 37,6608 lbm/ft^3 x 0,9946 lbf/lbm x 642,65 ft

= 24071,73 lbf/ft^2

= 167,1541 lbf/in^2

= 167,1541 psi

P operasi = 249,8311 Psi - 14,7 psi + 167,15 psi

= 402,285 psig

P design diambi 10% lebih besar dari P operasi untuk faktor keamanan

P design = 1,1 x 402,285 psig

= 442,51 psig

Direncanakan :

1. Bahan konstruksi = *Low-alloy steels SA-203 Grade D*

   f = 16250 psi ***T 13.1 B&Y; 251***

2. Pengelasan double welded butt joint

   E = 0,8 ***T 13.2 B&Y; 254***

3. Faktor korosi (C) = 1/8

Menentukan tebal shell

Tebal shell berdasarkan ASME Code untuk tangki silinder :

$t_s = \frac{P.\ ri}{f.\ E - 0.6\ P} + C$ ***B&Y: eq 13.1; 254***

$ts = \frac{442,5137\ psig \times 10,021\ in}{16250\ Ps \times 0,8 - 0,6 \times 442,51\ psig} + 1/8$

= 0,47321 in
ts distandardkan pada ***B&Y T 5.7; 90***
ts = 7/16 in

Menentukan tebal tutup Elliptical Dishead

$$th = \frac{P \times d}{2 \times f \times E - 0,2\ P} + C$$

Asumsi th = 8/16 in

$$8/16\ in = \frac{442,51\ psig \times 240,5\ in}{2 \times f \times 0,8 - 0,2 \times 442,51\ psig}$$

$$6/16\ in = \frac{442,51\ psig \times 240,5\ in}{2 \times f \times 0,8 - 0,2 \times 442,51\ psig}$$

f = 177426,6
f actual < f allowable, sehingga th = 8/16 in dapat digunakan
th = 1/2 in
Menentukan sf elliptical dishead berdasarkan ***B&Y : T 5.11; 94***
sf = 3 in

Perancangan Penyangga
Jumlah penyangga = 4
Menentukan Berat total
Vol. tangki = 12638,02 cuft
Vol. bahan 10110,42 cuft
ρ material = 490 lb/cuft
W bejana kosong = (Vol. tangki - Vol bahan) x ρ material
= 1238526 lb
W isi = 3084,16 kg/jam = 6799,398 lb/jam
= 6799,398 lb/jam x 1 jam
= 6799,398 lb
Vol tutup = 0,000076 D^3
= 0,611777 ft^3
W tutup = Vol. tutup x ρ material
= 0,6118 ft^3 x 490 lb/cuft
= 299,7707 lb
W aksesoris = 62281,27 lb
Σ W = 1307906,7 lb

Menentukan tinggi penyangga (L)
Karena tangki berbentuk silinder horizontal, maka H bejana = D tangki
tinggi total bejana (H) = 20,0413 ft
tinggi dari permukaan tanah (l) = 5 ft
L = l + 0,5 H
= 5 ft + 0,5 x 20,0413 ft

= 15,0207 ft
= 180,248 in

Menentukan beban tiap penyangga

$P = \frac{\Sigma W}{n}$

$= \frac{1E+06 \text{ lb}}{4} = 326976,7 \text{ lb} = 148314,1 \text{ kg}$

Menentukan fc allowable

$fc = \frac{P}{A} = \frac{326977 \text{ lbm} \times 0,99 \text{ lbf/lbm}}{26,4 \text{ in}^2} = 12318 \text{ lbf/in}^2$

Direncanakan :
Jenis penyangga = Equal Angles
dari B&Y: App G; 354

Axis 1-1		Axis 2-2	
A	= 26,4 in²	A	= 26,4 in²
$r_{1\,1}$	= 2,51 in	$r_{2\,2}$	= 2,51 in
$\frac{L}{r_{1\,1}}$	= 71,8119	$\frac{L}{r_{2\,2}}$	= 71,812

untuk L/r x x < 120 menggunakan persamaan berikut:
fc = 17000 - 0,485 x $(L/r_{1\,1})$
= 16965,2 Psi
fc actual > fc allowable, maka jenis penyangga equal angles dengan luas permukaan penyangga 26,4 in² dapat digunakan

Spesifikasi:

Fungsi	:	Menampung bahan baku ammonia dari supplier		
Type	:	Horizontal pressure tank (bullet) dengan tutup Elliptical Head		
Bahan	:	*Low-alloy steels SA-203 Grade D*		
Diameter tangki	:	20,041 ft	=	6,1086 m
Tinggi tangki	:	40,083 ft	=	12,217 m
Tebal shell	:	7/16 in	=	0,0111 m
Tebal tutup	:	4/8 in	=	0,0127 m
Jumlah	:	3 buah		
Jenis penyangga	:	*Equal angles*		
Luas permukaan penyangga	:	26,4 in²	=	0,017 m²
Tinggi penyangga	:	15,021 ft	=	4,5783 m

9. EXPANDER (G-150)

Fungsi : Memindahkan ammonia dari F-130 menuju R-220
Type : *Gear pump with globe valve*
Kondisi operasi :
Tekanan dalam : 17 atm
Tekanan keluar : 1 atm
Suhu : 30 °C

Densitas campuran = 37,6608 lb/cuft
Rate massa = 6799,398 lb/jam
Rate volumetrik = 180,5432 cuft/jam
= 3,009053 cuft/menit
= 0,050151 cuft/s
= 22,50928 gpm
= 0,00142 m³/s

Asumsi aliran turbulen

Diameter optimum = $3.9 \times q_f^{0.45} \times \rho^{0.13}$ ***eq. 15; Peters 4-ed; 496***

Dengan :
q_f = Fluid flow rate; (cuft/detik)
ρ = Fluid Density; (lb/cuft)
Di = Diameter dalam pipa optimum, (in)

Di = 3,9 x 0,0502 ^{0,45} cuft/s x 37,6608 ^{0,13} lb/cuft
= 1,6258 in

Diameter dalam pipa di standardkan berdasarkan Steel pipe ***McCabe 7ed: App 3; 1090***

Nominal Pipe Size 1 1/2 in sch 40
OD = 1,9 in = 0,1583 ft
ID = 1,61 in = 0,1342 ft = 0,040894 m
A = 0,0114 ft²

Kecepatan aliran (v) = $\frac{\text{Rate volumetrik}}{\text{Area pipa}}$
= $\frac{0,050151 \text{ cuft/s}}{0,0114 \text{ ft}^2}$
= 4,3992 ft/s

sg campuran bahan = $\frac{\text{Densitas campuran}}{\text{Densitas reff air}} \times \text{sg reff air}$
= $\frac{37,6608 \text{ lb/cuft}}{62,43 \text{ lb/cuft}} \times 1$
= 0,603248

μ campuran bahan = $\frac{\text{Sg campuran bahan}}{\text{sg reff air}} \times \mu \text{ reff air}$
= $\frac{0,603248}{1} \times 1 \text{ cps}$

= 0,603248 cps
= 0,000405 lb/ft.s

$$NRe = \frac{D\ v\ \rho}{\mu}$$

$$= \frac{0,1342\ ft \times 4,3992\ ft/s \times 37,6608\ lb/cuft}{0,000405\ lb/ft.s}$$

Nre = 54835,584
Nre > 2100 (asumsi aliran turbulen benar)
percepatan gravitasi bumi (g) = 32 ft/s²
konstanta grafitasi bumi (gc) = 32,174 ft.lb/lbf.s²
1 atm = 14,7 lbf/in²
= 2116,8 lbf/ft²
a (aliran turbulen) = 1
g/gc = 0,9946 lbf/lbm

Menentukan pressure head
H bahan = 25,35 ft
P hidrostatis = ρ campuran x H bahan x g/gc
= 37,6608 lb/cuft x 25,35 ft x 0,9946 lbf/lbm
= 949,5564 lbf/ft²
P in = 17 atm = 249,83 psi = 35976 lbf/ft²
P out = 1 atm = 14,696 psi = 2116,2 lbf/ft²

$$Presssure\ head = \frac{P\ in + P\ h - P\ out}{\rho\ campuran}$$

$$= \frac{(\ 35976 + 949,56 - 2116,2\ )\ lbf/ft^2}{37,6608\ lb/cuft}$$

= 924,2777 ft.lbf/lbm

Menentukan Friksi karena valve (Globe Valve Half Open)
Dipilih pipa dengan bahan Commercial Steel dari ***Geankoplis: F 2.10-3 ; 88*** , sehingga:
ε = 0,000046 m
ε/D = 0,000046 m / 0,040894 m
= 0,0011249
f = 0,005
Kf = 9,5 ***Geankoplis 3ed : T.2.10-1; 93***

$$F = \frac{Kf \times v^2}{2}$$

$$= \frac{9,5 \times 4,3992^2\ ft^2/s^2}{2 \times 32,174\ ft.lbm/lbf.s^2}$$

= 2,8572 ft.lbf/lbm

$$Hp = \frac{-\ Wf \times flowrate(gpm) \times sg}{3960}$$

$$= \frac{927{,}13 \text{ ft.lbf/lbm} \times 22{,}509 \text{ gpm} \times 0{,}6032}{3960}$$

= 3,1791 Hp

E = 75 - 85 % ***Perry 7ed; 11-101***

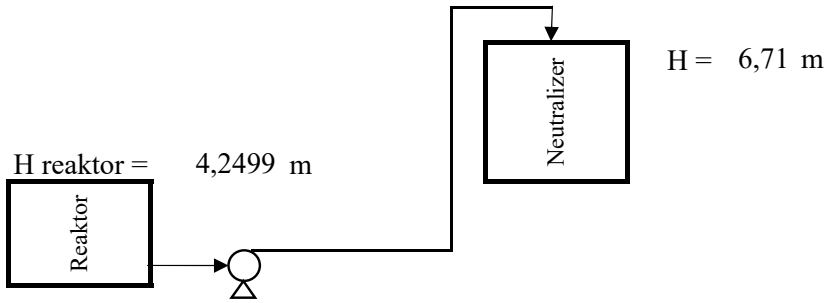
$$\text{Power} = \frac{3{,}1791 \text{ Hp}}{75\%} = 4{,}2388 \text{ Hp}$$

Spesifikasi

Bahan	:	Commercial steel
Ukuran pipa	:	1 1/2 in sch 40
Rate volumetrik	:	22,50928 gpm
Kecepatan aliran	:	4,3992 ft/s
Power	:	4,2388 Hp
Jumlah	:	1 buah

10. Pompa-3 (L-211)

Fungsi	:	Mengalirkan Akrilamida sulfat menuju Neutrallizer
Type	:	Centrifugal Pump
Dasar pemilihan	:	Sesuai untuk liquid dengan viskositas < 10cp



Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$C_3H_5NO.H_2SO_4$	15330,0648	0,95	1,1837
C_3H_3N	253,034393	0,0157	0,2503
$H_2SO_4.H_2O$	553,811124	0,0343	1,7518
Total	16136,9103	1	

Yaws

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}95}{1{,}1837} + \frac{0{,}0157}{0{,}2503} + \frac{0{,}0343}{1{,}7518}} \times 62{,}43$$

= 70,5578 lb/cuft

Rate massa = 16136,91 kg/jam = 35575,8 lb/jam

Rate volumetrik = $\frac{\text{Rate massa}}{\rho \text{ campuran}}$

$= \frac{35575{,}8 \text{ lb/jam}}{70{,}5578 \text{ lb/cuft}}$

$= 504{,}2075 \text{ cuft/jam} = 8{,}403459 \text{ cuft/menit}$

$= 62{,}86628 \text{ gpm} = 0{,}140058 \text{ cuft/s}$

Menghitung diameter optimum dengan persamaan :

Asumsi aliran turbulen

Diameter optimum = $3.9 \times q_f^{0.45} \times \rho^{0.13}$ ***eq. 15; Peters 4-ed; 496***

Dengan :

q_f = Fluid flow rate; (cuft/detik)

ρ = Fluid Density; (lb/cuft)

Di = Diameter dalam pipa optimum, (in)

Di = 3,9 x 0,1401 0,45 cuft/s x 70,5578 0,13 lb/cuft

= 2,8004 in

Dari diameter optimum, dipilih pipa 3,00 in, sch 80 berdasarkan McCabe

OD = 3,5 in = 0,2917 ft ***McCabe: App 3; 1090***

ID = 2,9 in = 0,2417 ft = 0,0737 m

A = 0,04587 ft²

Kecepatan linier (v) = $\frac{qf}{A}$

$= \frac{0{,}1401 \text{ cuft/s}}{0{,}0459 \text{ ft}^2}$

$= 3{,}0534 \text{ ft/s}$

ρ reference = 62,43 lb/cuft

sg reference = 1

μ reference = 1 cps

sg bahan = $\frac{\rho \text{ bahan}}{\rho \text{ reference}} \times \text{sg reference}$

$= \frac{70{,}5578 \text{ lb/cuft}}{62{,}43 \text{ lb/cuft}} \times 1$

$= 1{,}1302$

μ berdasarkan sg bahan :

μ bahan = $\frac{\text{sg bahan}}{\text{sg reference}} \times \mu$ reference

$= \frac{1{,}1302}{1} \times 1 \text{ cps}$

$= 1{,}1302 \text{ cps}$

$= 0{,}0008 \text{ lb/ft.s}$

$NRe = \frac{D \, v \, \rho}{\mu}$

$= \frac{0{,}2417 \text{ ft} \times 3{,}0534 \text{ ft/s} \times 70{,}5578 \text{ lb/cuft}}{0{,}000759 \text{ lb/ft.s}}$

Nre = 68554,971
Nre > 2100 (asumsi aliran turbulen benar)

Dipilih pipagalvanized iron, dengan :
ε = 0,00015 m ***Geankoplis: F 2.10-3; 88***
ε/D = 0,00015 m / 0,07366 m
= 0,0020364
f = 0,007 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2\,\alpha\,gc} + \Sigma F$$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***
Panjang pipa lurus = 10,5 m = 34,449 ft
- 1 gate valve = n x Le/D x ID
(wide open) = 1 x 9 x 0,2417 ft
2,175 ft
- 3 elbow 90° = 3 x 35 x 0,2417
= 25,375 ft
Panjang total pipa = 2,175 ft + 34,449 ft + 25,375 ft
= 61,999 ft

Friksi yang terjadi
karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ ***Geankoplis 3ed, eq 2.10-6; 89***

$$= \frac{2 \times 0,007 \times (3,0534\ ft/s)^2 \times 61,999\ ft}{32,174\ ft.lbm/s^2.lbf \times 0,2417\ ft}$$

= 1,0407486 ft.lbf/lbm

karena kontraksi dalam pipa

$$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :
α = 1
Kc = 0,5 , maka :

$$F2 = \frac{0,5 \times (3,0534\ ft/s)^2}{2 \times 1 \times 32,174\ ft.lbm/s^2.lbf}$$

= 0,072442 ft.lbf/lbm

karena gate valve , Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$$

$$= \frac{1 \times 0{,}17 \times (3{,}0534\ ft/s)^2}{32{,}174\ ft.lbm/s^2.lbf \times 2}$$
$$= 0{,}0246\ ft.lbf/lbm$$

karena ekspansi pipa ke neutrallizer

$$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc} \qquad (A1 < A_2, \text{ maka V1 dianggap} = 0)$$
$$\frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$$
$$= \frac{(3{,}0534\ ft/s)^2 - 0}{2 \times 1 \times 32{,}174\ ft.lbm/s^2.lbf}$$
$$= 0{,}1449\ ft.lbf/lbm$$

karena elbow 90° , Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2} \qquad n = \text{jumlah elbow}$$
$$= \frac{3 \times 0{,}75 \times (3{,}0534\ ft/s)^2}{32{,}174\ ft.lbm/s^2.lbf \times 2}$$
$$= 0{,}326\ ft.lbf/lbm$$

Sehingga :

$$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$$
$$= 1{,}60869\ ft.lbf/lbm$$

Energi Tekanan

$$EP = \frac{\Delta P}{\rho}$$
$$P1 = 1\ atm + P\ h$$
$$= 2116{,}8\ lbf/ft^2 + \rho\ g/gc\ h$$
$$= 2116{,}8\ lbf/ft^2 + 70{,}5578\ lbm/ft^3 \times 1\ lbf/lbm \times 11{,}155\ ft$$
$$= 2899{,}5939\ lbf/ft^2$$
$$P_2 = 2116{,}8\ lbf/ft^2$$
$$\Delta P = 2116{,}8\ lbf/ft^2 - 2899{,}6\ lbf/ft^2$$
$$= -782{,}7939\ lbf/ft^2$$
$$EP = \frac{-782{,}7939\ lbf/ft^2}{70{,}5578\ lbm/ft^3}$$
$$= -11{,}09436\ ft.lbf/lbm$$

Energi Kinetik

$$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$$
$$= \frac{3{,}0534\ ft/s^2}{2 \times 1 \times 32{,}174\ lbm.ft/s^2.lbf}$$
$$= 0{,}1449\ ft.lbf/lbm$$

Energi Potensial

ΔZ = 10,962 m Z1 = 0 m Z2 = 10,962 m
35,965 ft

$EP = \Delta Z \frac{g}{gc}$

= 35,965 ft x 1 lbf/lbm = 35,77 ft.lbf/lbm

Persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$

= (-11,09 + 35,77005 + 0,1449 + 1,6087) ft.lbf/lbm

= 26,429273 ft.lbf/lbm

Power Pompa

$Hp = \frac{- Wf \times flowrate(gpm) \times sg}{3960}$

$= \frac{26,429 \text{ ft.lbf/lbm} \times 62,866 \text{ gpm} \times 1,1302}{3960}$

= 0,4742 Hp

Effisiensi Pompa

E = 50% ***Peters 4ed ; Figure 14 - 37; 520***

$BHP = \frac{0,4742}{50\%}$

= 0,9484 Hp

Effisiensi Motor

E = 80% ***Peters 4ed ; Figure 14 - 38; 521***

$BHP = \frac{0,9484}{80\%}$

= 1,1855 Hp

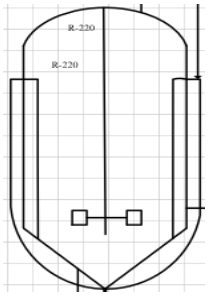
Spesifikasi :

Fungsi	:	Mengalirkan akrilamida sulfat menuju neutrallizer
Type	:	Centrifugal pump
Power	:	1 Hp = 745,7 watt
Rate volume	:	62,86628 gpm = 0,238 m^3/menit
Effisiensi pompa	:	50%
Effisiensi motor	:	80%
Bahan konstruksi	:	Galvanized Iron
Jumlah	:	1 buah

11. Neutrallizer (R-220)

Fungsi : Menetralkan asam sulfat dengan ammonia

Type : Silinder tegak dengan tutup atas standard dishead dan tutup bawah conical dengan sudut 90°, dilengkapi dengan pengaduk dan jaket pendingin



Kondisi operasi :
Tekanan operasi : 1 atm
Suhu : 40 °C

Komponen	A	B	n	Tc	T
C_3H_3N	0,2503	0,2293	0,2894	535	313,15
$H_2SO_4.H_2O$	0,4217	0,1936	0,2857	925	
NH_3	0,2369	0,2547	0,2885	405,65	
H_2O	0,3471	0,274	0,2857	647,13	

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$C_3H_5NO.H_2SO_4$	15330,0648	0,40364224	1,2105
C_3H_3N	253,034393	0,00666242	0,78383238
$H_2SO_4.H_2O$	553,811124	0,01458191	1,81445281
NH_3	3084,15505	0,08120613	0,5784688
C_3H_5NO	6313,76265	0,16624204	0,2734
H_2O	12444,5091	0,32766525	1,01364532
Total	37979,3372	1	

Yaws

Densitas Akrilamida Sulfat

ρ $C_3H_5NO.H_2SO_4$ = 75,567914 lb/cuft
= 1,21048186 g/cc

Rate massa = 37979,34 kg/jam = 83730,11 lb/jam

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62{,}43 = \text{lb/cuft}$$

$$= \frac{1}{\frac{0{,}40}{1{,}21} + \frac{0{,}007}{0{,}7838} + \frac{0{,}015}{1{,}8145} + \frac{0{,}081}{0{,}5785} + \frac{0{,}166}{0{,}2734} + \frac{0{,}328}{1{,}0136}} \times 62{,}43$$

= 43,91277 lb/cuft

$$\text{Rate volum} = \frac{\text{Rate massa}}{\text{densitas}}$$

$$= \frac{83730{,}11 \text{ lb/jam}}{43{,}91277 \text{ lb/cuft}}$$

= 1906,737 cuft/jam

Volume bahan = 1906,737 cuft/jam x 1 jam
= 1906,737 cuft
Asumsi bahan mengisi 80% dari volume tangki
Volume tangki = $\frac{1906,737 \text{ cuft}}{80\%}$
= 2383,421 cuft

1. PERANCANGAN DIMENSI BEJANA
Asumsi rasio dimensi : H/D =2 , maka H = 2 D ***Ulrich: T 4-27; 248***
α = 90 °
(1/2 α) = 45 °
tg (1/2α) = 1
Volume tangki = Vol. silinder + Vol. tutup atas + Vol tutup bawah
2383,42 cuft = $\pi/4\ D^2\ (2D)$ + 0,0847 D^3 + $\pi/(24 \text{ tg } (1/2\alpha))\ D^3$
2383,42 cuft = 1,57 D^3 + 0,0847 D^3 + 0,1308333 D^3
D^3 = 1334,851 cuft
D = 11 ft = 132,13 in H = 22,0212 ft = 264,2544 in

Menentukan tekanan design
P hidrostatis = (ρ.(g / gc). H)
= 43,913 lb/ft³ x 1 lbf/lbm x 17,6 ft
= 769,43 lbf/ft²
= 5,3432 lbf/in² = 5,3432 psig
P operasi = 14,7 psig
Faktor keamanan 10% :
P design = 1,1 x (5,3432 + 14,7)
= 22,048 Psig

Direncanakan :
1. Bahan konstruksi : Low-Alloy Steels SA-202 Grade A
f = 18750 psi ***B&Y : T 13.1; 251***
2. Pengelasan double welded butt joint
E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Menentukan tebal shell
Tebal shell berdasarkan ASME Code untuk tangki silinder :
$t_s = \frac{P.\ ri}{f.\ E - 0.6\ P} + C$ ***B&Y: eq 13.1; 254***
$ts = \frac{22,04756 \text{ psig} \times 66,064 \text{ in}}{18750 \text{ psi} \times 0,8 - 0,6 \times 22,048 \text{ psig}} + 1/8$
= 0,22219 in
ts distandardkan pada ***B&Y T 5.7; 90***

ts = 1/4 in

Menentukan tebal tutup atas standard dishead

OD = ID + 2 ts
= 132,13 in + 2 x 1/4 in
= 132,63 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 120
icr = 7,25
rc = 114
6%rc = 6,84

Karena icr > 6% rc, maka digunakan ***pers. 7.76 & 7.77 B&Y; 138***

$$Th = \frac{P \times rc \times W}{2 f E - 0.2P} + C$$

$$W = 1/4 \left(3 + (rc/icr)^{0.5} \right)$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)
rc = Crown radius (in)
C = Faktor korosi
f = Allowable strees
E = Tipe pengelasan
W = Faktor intensifikasi stress

$$W = 1/4 \times \left(3 + \sqrt{\frac{114}{7,25}} \right)$$

= 1,74134

maka tebal tutup (th) dapat dihitung

Asumsi th = 5/16

$$5/16 = \frac{22,048 \text{ psig} \times 114 \times 1,7413}{2 \times f \times 0,8 - 0,2 \times 22,048 \text{ psig}} + 1/8$$

$$3/16 = \frac{22,048 \text{ psi} \times 114 \times 1,7413}{2 \times f \times 0,8 - 0,2 \times 22,048 \text{ psig}}$$

f = 14591,84 psig

f actual < f allowable, maka t 5/16 in dapat digunakan

Menentukan tebal tutup bawah conical

OD = ID + 2 ts
= 132,13 in + 2 x 1/4 in
= 132,63 in

Berdasarkan T 5.7 B&Y; 90 diperoleh :

OD = 120
icr = 7,25
rc = 114
6%rc = 6,84

$$th = \frac{P \times di}{4(f.E - 0,6.\,Pd) \cos 1/2\,\alpha} + C$$

Dimana :
P = Tekanan design (Psi)
t_h = Tebal tutup (in)

rc = Crown radius (in)
(1/2α) = 45 °
C = Faktor korosi
Cos (1/2α) = 0,7071
f = Allowable strees
E = Tipe pengelasan

maka tebal tutup (th) dapat dihitung
Asumsi tl = 3/16

$$3/16 = \frac{22,048 \text{ psig} \times 132,13 \text{ in}}{4 \times (f \times 0,8 - 0,6 \times 22,048 \text{ psig}) \times 0,7071} + 1/8$$

$$1/16 = \frac{22,048 \text{ psig} \times 132,13 \text{ in}}{4 \times (f \times 0,8 - 0,6 \times 22,048 \text{ psig}) \times 0,7071}$$

f = 20615,13 psi

f actual < f allowable, maka tl 3/16 in dapat digunakan

Menentukan tinggi tutup atas (ha) dan tutup bawah (hb)

ha = 0,169 d
= 0,169 x 11,011 ft = 1,8608 ft = 22,329 in = 0,5672 m

$$hb = \frac{0,5}{tg\ (1/2\alpha)}\ d = \frac{5,505299 \text{ ft}}{1}$$

= 5,5053 ft = 66,064 in = 1,678 m
tinggi silinder = 22,0212 ft = 264,2544 in = 6,712061 m
Tinggi total bejana = 29,3873 ft = 8,96 m

2. PERANCANGAN SISTEM PENGADUK

Penentuan Dimensi pengaduk

Tinggi bahan total (Hl) = 17,61696 ft = 211,4035 in
Diameter tangki (Dt) = 11,0106 ft = 132,1272 in
Ukuran pengaduk diambil dari ***McCabe ed 5; 243***

$\frac{Da}{Dt} = 1/3$	$\frac{E}{Da} = 1$	$\frac{L}{Da} = 1/4$	$\frac{J}{Dt} = \frac{1}{12}$
$\frac{W}{Da} = 1/5$			

Keterangan :
Da = Diameter Impeller
Dt = Diameter Tangki
L = Panjang Blade
W = Lebar Blade
E = Jarak Impeller dr Dasar tangki
J = Lebar baffle

Diameter impeller Da = 1/3 Dt = 1/3 x 11,0106
= 3,7 ft
Lebar Balde W = 1/5 Da = 1/5 x 3,7
= 0,73 ft
Jarak impeller dari dasar E = 1 Da = 1 x 3,7
= 3,67 ft
Lebar Baffle J = 0,08 Dt = 0,0833 x 11,0106
= 0,9175 ft

Tebal Pengaduk = 0,1 J = 0,1 x 0,9175
= 0,0918 ft
Panjang Balde L = 1/4 Da = 1/4 x 3,7
= 0,92 ft
Tinggi Pengaduk H = 1 Dt = 1 x 11,0106
= 11,0106 ft

Penentuan jumlah pengaduk

Tinggi bahan total (Hl) = 17,61696 ft = 211,4035 in
Diameter tangki (Dt) = 11,0106 ft = 132,1272 in

$$Sg = \frac{\rho \text{ Bahan}}{\rho \text{ reference } (H_2O)}$$

$$= \frac{43,9128 \text{ lb/cuft}}{62,43 \text{ lb/cuft}} = 0,7034$$

$$\text{Jumlah Impeler} = \frac{\text{Tinggi Bahan}}{\text{Diameter Bejana}} \times Sg$$

$$= \frac{17,617}{11,0106} \times 0,7034$$

= 1,1254 Jadi jumlah impeler = 1 buah

Penentuan power motor

Sg Reference = 1 ***Kern: T.6; 808***
μ Reference = 0,95 Cps ***Kern: F. 14; 822-823***

$$\mu \text{ Bahan} = \frac{Sg \text{ Bahan} \times \mu \text{ Reference}}{Sg \text{ Reference}}$$

$$= \frac{0,703 \times 0,95}{1}$$

= 0,6682 cps
= 0,0004 lb/ft.s

Penentuan putaran pengaduk :
V = π x Da x N
Dimana :
V = pheripheral speed (m/menit)
Da = diameter pengaduk (m)
N = putaran pengaduk (rpm)

V = 200 - 250 m/menit ***Joshi; 415***
dipilih putaran pengaduk = 70 rpm = 1,17 rps
Da = 3,7 ft = 1,1187 m
V = π x Da x N
= 3,14 x 1,1187 m x 70 rpm
= 245,885 m/menit
(memenuhi range 200-250 m/menit)

$$\text{Bilangan Reynold} = \frac{\rho \times Da^2 \times N}{\mu}$$

$$= \frac{43{,}913 \text{ lb/cuft} \times 13{,}5 \text{ ft}^2 \times 1{,}17 \text{ rps}}{0{,}000449 \text{ lb/ft.s}}$$

= 1536904

Untuk Nre > 2100, diperlukan 4 buah baffle

Untuk Nre > 10000, perhitungan power pompa menggunakan pers:

$P = \frac{K \rho N^3 D^5}{g}$ Dengan :

g : konstanta grafitasi 32,2 ft.lbm/s².lbf

Ludwig: eq. 5-5; 299

H : tingi liquid, ft

P : Power, ft lbf/s

W : lebar impeller, ft

μ : viskositas liquid, lb/ft.s

ρ : densitas liquid, lb/cuft

N : kecepatan putar pengaduk, rps

K = 4,5 ***Ludwig: T 5.1; 301***

$$P = \frac{4{,}5 \times 43{,}913 \text{ lb/cuft} \times 1{,}588 \text{ (rps)}^3 \times 666 \text{ ft}^5}{32{,}2 \text{ ft.lbm/s}^2\text{.lbf}}$$

= 6495,12 ft.lbf/s

= 11,8093 Hp

Power losses pada gland 10 % Hp = 10% x 11,809

= 1,1809 Hp

Power input dengan gland losses = 11,809 hp + 1,1809 hp

= 12,990 HP

Transsmision sistem losses 20% = 20% x 12,990 HP

= 2,598 HP

Power total = 12,990 + 2,5980

= 15,5883 HP

Effisiensi motor = 80%

Sehingga power motor = $\frac{15{,}5883}{80\%}$

= 19,485 HP

3. PERANCANGAN SISITEM PENDINGIN

Sebagai media pendingin digunakan air pendingin suhu = 30 °C

Untuk menjaga suhu dalam neutrallizer tetap = 40 °C

Q serap = 23945377 kJ/jam = 22695838 BTU/jam

T bahan masuk = 90 °C = 194 °F

T bahan keluar = 40 °C = 104 °F

T pendingin masuk = 30 °C = 86 °F

T pendingin keluar = 45 °C = 113 °F

ΔT_1 = 81 °F

ΔT_2 = 18 °F

ΔT LMTD = 41,886 °F

Kebutuhan air pendingin = 484785,3 kg/jam = 1E+06 lb/jam

Volume pendingin = $\frac{\text{massa air}}{\text{densitas air}}$

= $\frac{484785,3 \text{ kg/jam}}{1000 \text{ kg/m}^3}$

= 484,7853 m^3/jam

= 17120,03 ft^3/jam

= 4,755565 ft^3/s

Koefisien perpindahan panas bagian luar jaket : ***Kern: Eq. 20.4; 722***

$$hc = 0,87 \times \frac{k}{Di} \times \left(\frac{L^2.N.\rho}{\mu}\right)^{2/3} \times \left(\frac{C.\mu}{k}\right)^{1/3} \times \left(\frac{\mu}{\mu w}\right)^{0,14}$$

Keterangan:

L = diameter impeller = 3,7 ft

N = putaran pengaduk = 70 rpm = 4200 rph

ρ = densitas bahan = 43,913 lb/cuft

μ = viskositas bahan = 0,000449 lb/ft.s = 0,0269 lb/ft.jam

= 0,6682 cps

C = kapasitas panas campuran (Btu/lb.°F)

Komposisi	% Berat	Cp (J/mol)	BM (kg/kmol)	Cp (kkal/kg)
$C_3H_5NO.H_2SO_4$	0,404	1914	169	0,00272
C_3H_3N	0,007	4466	53	0,02022
$H_2SO_4.H_2O$	0,015	13929,5	116	0,02882
NH_3	0,081	180,138975	17	0,00254
C_3H_5NO	0,166	1482,24653	71	0,00501
H_2O	0,328	829,800311	18	0,01106
Total	1,000	20489	444	0,07038

1 Joule = 0,00024 kkal

1 kkal/kg °C = 0,053254 Btu/lb°F

C = 9,9E-05 Btu/lb°F

K = konduktifitas larutan

K mix = $\frac{0,0677}{sg\ [\ 1 - 0,0003\ (\ t - 32\ )\ ]}$

= $\frac{0,0677}{0,7034\ [\ 1 - 0,0003\ (\ 41,886 - 32\ )\ ]}$

= 0,096534 Btu/jam.ft².°F

Perry ed 5: eq 3-89; 3-243

Re p = $\frac{[\ L^2\ N\ \rho\ ]^{2/3}}{\mu}$

= $\frac{(\ 13,5\ ft^2 \times 4200\ rph \times 43,913\ lb/cuft\ )^{2/3}}{0,0269\ lb/ft.jam}$

= 680860,4

$\left[\frac{C\ \mu}{k}\right]^{1/3}$ = $\left(\frac{1E\text{-}04\ Btu/lb°F \times 0,0269\ lb/ft.jam}{0,096534\ Btu/jam.ft^2.°F}\right)^{1/3}$

= 0,143645

$\frac{\mu}{\mu w}^{0,14} = \frac{0,026941}{1}^{0,14}$
$= 0,6029$

Maka, koefisien perpindahan panas diluar jaket dapat dihitung :

$hc = 0,87 \times \frac{k}{Di} \times \left(\frac{L^2.N.\rho}{\mu}\right)^{2/3} \times \left(\frac{C.\mu}{k}\right)^{1/3} \times \left(\frac{\mu}{\mu w}\right)^{0,14}$
$= 0,87 \times \frac{0,0965 \text{ Btu/jam.ft.°F}}{11,011 \text{ ft}} \times 680860 \times 0,1436 \times 0,6029$
$= 449,778 \text{ Btu/jam.ft.°F}$

Koefisien perpindahan panas bagian dalam jaket (hi)

Dari Kern: T 10, dipilih pipa 1 1/2 in 16 BWG dengan ukuran :

OD = 1,5 in = 0,125 ft
ID = 1,37 in = 0,1142 ft
flow area = 1,47 in² = 0,0102 ft²
surface per lin ft (a) = 0,3925 ft²
kecepatan aliran (v) $= \frac{W}{\rho \times A}$
$= \frac{1068769 \text{ lb/jam}}{62,43 \text{ lb/cuft} \times 0,0102 \text{ ft}^2}$
$= 1677010 \text{ ft/jam}$
$= 465,836 \text{ ft/s}$
hi = 2000 Btu/jam.ft².°F ***Kern: F. 25; 835***
$hio = hi \times \frac{ID}{OD}$
$= 2000 \text{ Btu/jam.ft}^2\text{.°F} \times \frac{0,1142 \text{ ft}}{0,125 \text{ ft}}$
$= 1826,667 \text{ Btu/jam.ft}^2\text{.°F}$
$Uc = \frac{hi \times hio}{hi + hio}$
$= \frac{2000 \text{ Btu/jam.ft}^2\text{.°F} \times 1826,7 \text{ Btu/jam.ft}^2\text{.°F}}{2000 \text{ Btu/jam.ft}^2\text{.°F} + 1826,7 \text{ Btu/jam.ft}^2\text{.°F}}$
$= 954,7038 \text{ Btu/jam.ft}^2\text{.°F}$
Rd = 0,0005 ***Kern: T.12; 845***
$\frac{1}{Ud} = \frac{1}{Uc} + Rd = \frac{1}{954,7 \text{ Btu/jam.ft}^2\text{.°F}} + 0,0005$
$= 0,001547 \text{ jam.ft}^2\text{.°F/Btu}$
maka nilai dari Ud = 646,2264 Btu/jam.ft².°F

$A = \frac{Q}{UD \times LMTD}$
$= \frac{22695838,1 \text{ BTU/jam}}{646,23 \text{ Btu/jam.ft}^2\text{.°F} \times 41,886 \text{ °F}}$
$= 838,477 \text{ ft}^2$

Menentukan tinggi jaket

Tinggi jaket = Tinggi shell + Tinggi tutup bawah
= 22,0212 ft + 5,5053 ft
= 27,5265 ft

Asumsi :

Tebal air pendingin = 2 in
Tebal jaket (tj) = 3/16 in
Do shell = di + 2 ts
= 11 in + 2 x 3/16 in
= 11,3856 in
Di jaket = Do shell + 2 s
= 11,386 in + 2 x 2 in
= 15,386 in
Do jaket = Di jaket + 2 tebal jaket
= 15,386 in + 2 x 3/16
= 15,7606 in

Menghitung tebal jaket

Tebal jaket berdasarkan ASME Code :

$$ts = \frac{P \times Di}{f.E - 0{,}6.P} + C$$

P operasi jaket = 14,7 psig
P hidrostatis = 62,43 lb/cuft x 0,99 lbf/lbm x 27,5265 ft
= 1709,186 lbf/ft²
= 11,869 Psig
P desain jaket = 26,56934 Psig

Direncanakan :

1. Bahan konstruksi : *Low-Alloy Steels SA-202 Grade A*
   f = 18750 psi ***B&Y : T 13.1; 251***
2. Pengelasan double welded butt joint
   E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Menentukan tebal shell jaket

Asumsi ts = 3/16 in

$$3/16 = \frac{26{,}56934 \times 15{,}386}{f \quad 0{,}8 - \quad 0{,}6 \quad 26{,}569} + 1/8$$

$$1/16 = \frac{26{,}56934 \times 15{,}386}{f \quad 0{,}8 - \quad 0{,}6 \quad 26{,}569}$$

f = 8195,632324 psi

f actual < f allowable, sehingga ts = 3/16 in dapat digunakan

4. PERANCANGAN SPARGER

Berdasarkan ***Mass Transdfer Operations Robert Treybal*** , terdapat parameter untuk mendesain sparger, yaitu :

A. Diameter gelembung
B. gas hold up
C. interfacial area

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
NH_3	3084,15505	0,19861045	0,5785
H_2O	12444,5091	0,80138955	1,0136
Total	15528,6642	1	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}1986}{0{,}5785} + \frac{0{,}8014}{1{,}0136}} \times 62{,}43$$

$$= 55{,}0558 \text{ lb/cuft}$$

Rate massa = 15528,66 kg/jam = 34234,84 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{34234{,}84 \text{ lb/jam}}{55{,}0558 \text{ lb/cuft}}$$

= 621,8205 cuft/jam = 10,36367 cuft/menit
= 77,53065 gpm = 0,172728 cuft/s

viskositas bahan pada suhu 40 °C = 104 F

μ bahan = 0,011 Cp ***Kern: F 15; 825***
= 0,000011 kg/m.s

Menentukan Sparger Ring

Direncanakan diameter sparger ring Ds = 30% diameter tangki

Ds = 30% x 11,0106 ft
= 3,3032 ft
= 1,0068 m

Luas plate sparger (As)

As = $1/4\pi$ Ds^2
= 8,5651 ft^2
= 0,7957 m^2

Untuk mencari banyak lubang, maka trial luas oriface dengan % luas saprger : 3,3%

At = 0,0329 x 0,7957
= 0,0262 m^2

Luas tiap lubang orifice (Ao)

Ao = 1/4π Do² Do = 2/16 in (1/16 - 1/4) in
= 0,00000791 m² = 0,0032 m ***Treyball 140***
= 0,00008518 ft² = 0,0104 ft

Banyak lubang oriface

$$O = \frac{At}{Ao} = \frac{0,02616843\ m^2}{0,00000791\ m^2} = 3306,896 \text{ Lubang} = 3307 \text{ lubang}$$

At koreksi = Jumlah lubang x Luas lubang
= 3307 x 0,00000791 m²
= 0,026169 m²
= 0,281683 ft²

$$\text{Rate volume tiap oriface} = \frac{\text{Rate volume}}{\text{Jumlah lubang}} = \frac{0,172728\ \text{cuft/s}}{3307} = 0,000052231\ \text{cuft/s}$$

Perhitungan Nre Orifice

$$Nre = \frac{\rho \times D \times v}{\mu}$$

Dengan : ρ = Densitas 55,056 lb/cuft
D = Diameter Orifice 2/16 in = 0,010417 ft
μ = Viskositas 0,011 Cps = 0,00000739 lb/ft.s
v = Kecepatan linier ga: $= \frac{\text{Rate Volume Oriface}}{\text{Luas Penampang}} = \frac{0,00005223\ \text{cuft/s}}{0,000085\ ft^2} = 0,6132$ ft/s

Maka Nre dapat dihitung :

$$Nre = \frac{55,056\ \text{lb/cuft} \times 0,010417\ \text{ft} \times 0,6132\ \text{ft/s}}{0,00000739\ \text{lb/ft.s}} = 47574,177$$

Untuk Nre = 10000 - 50000, menggunakan ***pers. 6.5 Treyball; 141***

A. Diameter gelembung (Dp)

$$Dp = 0,0071\ Nre^{-0,05}$$ ***eq. 6.5 Treyball; 141***

Dp = 0,0041437 m

Jarak minimum Orifice = 3 Dp ***Treyball; 141***
= 3 x 0,004144 m
= 0,012431 m
= 0,040785 ft

B. Gas Hold Up

$$Vs = \frac{Vg}{\varphi g} - \frac{Vliq}{1-\varphi g}$$ ***Treyball: eq. 6.8; 143***

Massa gas = 15528,66 kg/jam

= 4,313518 kg/s = 9,509679 lb/s

Luas penampang tangki = 1/4 π D²

= 95,16813 ft²

= 8,841409 m²

Volume liquid = $\frac{\text{Rate massa}}{\rho \text{ campuran}}$

= $\frac{83730,11 \text{ lb/jam}}{43,91277 \text{ lb/cuft}}$

= 1906,737 cuft/jam

= 0,529649 cuft/s

Kecepatan gas

$Vg = \frac{\text{Massa Gas}}{A \times \rho \text{ gas}}$ ρ gas = 43,91277 lb/cuft

$= \frac{9,509679 \text{ lb/s}}{95,168 \text{ ft}^2 \times 43,913 \text{ lb/cuft}}$

= 0,0022755 ft/s = 0,000694 m/s

Kecepatan liquid

$Vliq = \frac{\text{Volume liquid}}{\text{Luas penampang}} = \frac{0,5296 \text{ cuft/s}}{95,168 \text{ ft}^2} = 0,0055654 \frac{\text{ft}}{\text{s}} = 0,002 \frac{\text{m}}{\text{s}}$

Dari ***Grafik 6.2 Treybal*** didapatkan :

Vg / Vs = 0,035

Vs = 0,0007 / 0,035 = 0,0198 m/s

$Vs = \frac{Vg}{\varphi g} - \frac{Vl}{1-\varphi g}$

$0,0198 = \frac{0,0007}{\varphi g} - \frac{0,0017}{1-\varphi g}$ Kedua Sisi di x 1- φg

0,01982 - 0,0198 φg = 0,0007 - 0,0007 φg - 0,0017

φg = 1,0887

C. Interfacial Area

$\alpha = \frac{6 \times \varepsilon}{d_p}$ ***Treyball; 144***

$= \frac{6 \times 1,089}{0,0041}$

= 1576,4208 m^2/m^3

= 480,8084 ft^2/ft^3

5. PERANCANGAN PENYANGGA BEJANA

Jumlah penyangga = 4

Menentukan Berat total

Vol. tangki = 2383,421 cuft
Vol. bahan 1906,737 cuft
ρ material = 490 lb/cuft
W bejana kosong = (Vol. tangki - Vol bahan) x ρ material
= 233575,3 lb
W isi = 37979,34 kg/jam = 83730,11 lb/jam
= 83730,11 lb/jam x 1 jam
= 83730,11 lb
W pendingin = 484785,3 kg/jam
= 1068769 lb

$$A = \frac{V}{ha} = \frac{113,06\ ft^3}{1,8608\ ft}$$

= 60,76 ft^2
W tutup = luas tutup x th x (ρ /1728)
= 60,76 ft^2 x 0,026 ft x 0,2836 lb/ft^3
= 0,448683 lb
W aksesoris = 69303,73 lb
Σ W = 1455378,3 lb

Menentukan tinggi penyangga (L)

tinggi total bejana (H) = 29,3873 ft
tinggi tutup bawah ke permukaan tanah (l) = 5 ft
L = l + 0,5 H
= 5 ft + 0,5 x 29,3873 ft
= 19,6936 ft
= 236,324 in

Menentukan beban tiap penyangga

$$P = \frac{\Sigma W}{n}$$

$$= \frac{1455378\ lb}{4} = 363844,6\ lb = 165037,1\ kg$$

Menentukan fc allowable

$$fc = \frac{P}{A} = \frac{363845\ lbm \times 1\ lbf/lbm}{19,8\ in^2} = 18376\ lbf/in^2$$

Direncanakan :
Jenis penyangga = Two Channels
dari B&Y: App G; 354

Axis 1-1		Axis 2-2	
A =	19,8 in^2	A =	19,8 in^2

$r_{1\,1}$ = 5,78 in $r_{2\,2}$ = 4,02 in

$\frac{L}{r_{1\,1}}$ = 40,8865 $\frac{L}{r_{2\,2}}$ = 58,787

untuk L/r x x < 120 menggunakan persamaan berikut:

fc = 17000 - 0,485 x $(L/r_{1\,1})$

= 16980,2 Psi fc 16998,05 psi

fc actual > fc allowable, maka penyangga dengan luas permukaan penyangga 19,8 in² dapat digunakan

Spesifikasi

Fungsi : Menetralkan asam sulfat dengan ammonia

Type : Silinder tegak dengan tutup atas dan tutup bawah standard dishead, dilengkapi dengan pengaduk dan penyangga bejana

Operasi : Continous Strirred - Tank Reactor (CSTR)

Kapasitas : 2383,421 ft³

Dimensi shell :

Diameter shell	:	11,0	ft	=	3,356 m
Tinggi shell	:	22	ft	=	6,7121 m
Tebal shell	:	1/4	in	=	0,0064 m
Tebal tutup atas	:	5/16	in	=	0,0079 m
Tebal tutup bawah	:	3/16	in	=	0,0048 m

Sistem pengaduk

Dipakai impeller jenis turbin dengan 4 buah flat blade dengan 1 impeller

Diameter impeller	:	3,7	ft	=	1,1187 m
Jarak impeller dari dasar	:	3,7	ft	=	1,1187 m
Panjang blade	:	0,92	ft	=	0,2797 m
Tinggi pengaduk	:	11,0	ft	=	3,356 m
Power motor	:	19,485	HP	=	14530 W

Sistem pendingin

Diameter jaket	:	15,39	in	=	0,3908 m
Tinggi jaket	:	27,53	ft	=	8,3901 m
Jaket spacing	:	2,19	in	=	0,0556 m
Tebal jaket	:	3/16	in	=	0,0048 m

Penyangga

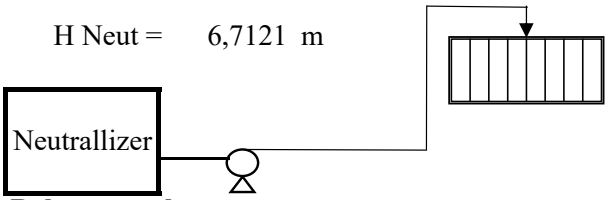
Luas permukaan penyangga	:	19,8	in²	=	0,0128 m²
Tinggi penyangga	:	20	ft	=	6,0026
Jenis penyangga	:	Two Channels			
Jumlah penyangga	:	4 buah			

Sistem Sparger

Rate Gas	:	9,51	lb/s
Diameter	:	3,30	ft
Luas Plate	:	8,57	ft²
Jumlah lubang	:	3307	Lubang
Luas Lubang	:	0,000085	ft²
Laju Volumetrik/oriface	:	0,000052	ft³/s

Kecepatan gas : 0,0022755 ft/s
Diameter gelembung : 0,0041 m
Bahan Konstruksi : *Low-Alloy Steels SA-202 Grade A*
Jumlah : 1 Buah

12. Pompa-4 (L-221)
Fungsi : Mengalirkan bahan dari Neutrallizer menuju Filter press
Type : Centrifugal pump
Dasar pemilihan : Sesuai untuk bahan liquid dengan viskositas < 10 cp



Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_5NO	12754,2041	0,2511	0,7838
$(NH_4)_2SO_4$	11973,7784	0,2357	1,8145
C_3H_3N	501,091784	0,0099	0,2734
$H_2SO_4.H_2O$	553,811124	0,0109	1,7690
H_2O	25013,0275	0,4924	1,0136
Total	50795,913	1	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}2511}{0{,}7838} + \frac{0{,}2357}{1{,}8145} + \frac{0{,}0099}{0{,}2734} + \frac{0{,}0109}{1{,}7690} + \frac{0{,}4924}{1{,}0136}} 62{,}43$$

= 126,7634 lb/cuft
Rate massa = 50795,91 kg/jam = 111985,8 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{111985{,}8 \text{ lb/jam}}{126{,}7634 \text{ lb/cuft}}$$

= 883,4236 cuft/jam = 14,72373 cuft/menit
= 110,1482 gpm = 0,245395 cuft/s

Menghitung diameter optimum dengan persamaan :
Asumsi aliran turbulen

$$\text{Diameter optimum} = 3.9 \times q_f^{0.45} \times \rho^{0.13}$$ ***eq. 15; Peters 4-ed; 496***

Dengan :
q_f = Fluid flow rate; (cuft/detik)
ρ = Fluid Density; (lb/cuft)

Di = Diameter dalam pipa optimum, (in)

Di = 3,9 x 0,2454 ^{0,45} cuft/s x 126,7634 ^{0,13} lb/cuft
= 3,8895 in
Dari diameter optimum, dipilih pipa 4,00 in, sch 40 berdasarkan McCabe
OD = 4,5 in = 0,375 ft ***McCabe: App 5; 1087***
ID = 4,03 in = 0,3355 ft = 0,1023 m
A = 0,0884 ft²
Kecepatan linier = $\frac{qf}{A}$
(v) = $\frac{0,2454 \text{ cuft/s}}{0,0884 \text{ ft}^2}$
= 2,776 ft/s
ρ reference = 62,43 lb/cuft
sg reference = 1
μ reference = 1 cps
sg bahan = $\frac{\rho \text{ bahan}}{\rho \text{ reference}}$ x sg reference
= $\frac{126,7634 \text{ lb/cuft}}{62,43 \text{ lb/cuft}}$ x 1
= 2,0305

μ berdasarkan sg bahan :
μ bahan = $\frac{\text{sg bahan}}{\text{sg reference}}$ x μ reference
= $\frac{2,0305}{1}$ x 1 cps
= 2,0305 cps
= 0,0014 lb/ft.s
$N_{Re} = \frac{D \, v \, \rho}{\mu}$
$= \frac{0,3355 \text{ ft} \times 2,776 \text{ ft/s} \times 126,7634 \text{ lb/cuft}}{0,001364 \text{ lb/ft.s}}$
Nre = 86526,847
Nre > 2100 (asumsi aliran turbulen benar)
Dipilih pipa galvanized iron, dengan :
ε = 0,00015 m ***Geankoplis: F 2.10-3; 88***
ε/D = $\frac{0,00015 \text{ m}}{0,1022604 \text{ m}}$
= 0,0014668
f = 0,007 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***

Panjang pipa lurus = 7 m = 22,966 ft
- 1 gate valve = n x Le/D x ID
  (wide open) = 1 x 9 x 0,3355 ft
  3,0195 ft
- 2 elbow 90° = 2 x 35 x 0,3355
  = 23,485 ft

Panjang total pipa = 3,0195 ft + 22,966 ft + 23,485 ft
= 49,47 ft

Friksi yang terjadi

karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ ***Geankoplis 3ed, eq 2.10-6; 89***

$$= \frac{2 \times 0,007 \times 2,776 \text{ ft/s}^2 \times 49,47 \text{ ft}}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 0,3355 \text{ ft}}$$

= 0,4944293 ft.lbf/lbm

karena kontraksi dalam pipa

$$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :

α = 1

Kc = 0,5 , maka :

$$F2 = \frac{0,5 \times 2,776 \text{ ft/s}^2}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

= 0,059877 ft.lbf/lbm

karena gate valve , Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$$

$$= \frac{1 \times 0,17 \times 2,776 \text{ ft/s}^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$$

= 0,0204 ft.lbf/lbm

karena ekspansi pipa ke filter press

$$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 < A2, maka V1 dianggap = 0)

$$\frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$$

$$= \frac{2,776 \text{ ft/s}^2 - 0}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

= 0,1198 ft.lbf/lbm

karena elbow 90° , Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2}$$ n = jumlah elbow

$$= \frac{2 \times 0{,}75 \times 2{,}776 \text{ ft/s}^2}{32{,}174 \text{ ft.lbm/s}^2\text{.lbf} \times 2}$$
$$= 0{,}1796 \text{ ft.lbf/lbm}$$

Sehingga :

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$
$= 0{,}87405$ ft.lbf/lbm

Energi Tekanan

$EP = \frac{\Delta P}{\rho}$

$P1 = 1 \text{ atm} + P\,h$
$= 2116{,}8 \text{ lbf/ft}^2 + \rho\, g/gc\, h$
$= 2116{,}8 \text{ lbf/ft}^2 + 126{,}7634 \text{ lbm/ft}^3 \times 1 \text{ lbf/lbm} \times 17{,}617 \text{ ft}$
$= 4337{,}9089 \text{ lbf/ft}^2$
$P_2 = 2116{,}8 \text{ lbf/ft}^2$
$\Delta P = 2116{,}8 \text{ lbf/ft}^2 - 4337{,}9 \text{ lbf/ft}^2$
$= -2221{,}109 \text{ lbf/ft}^2$
$EP = \frac{-2221{,}109 \text{ lbf/ft}^2}{126{,}7634 \text{ lbm/ft}^3}$
$= -17{,}52168$ ft.lbf/lbm

Energi Kinetik

$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$
$= \frac{2{,}776 \text{ ft/s}^2}{2 \times 1 \times 32{,}174 \text{ lbm.ft/s}^2\text{.lbf}}$
$= 0{,}1198$ ft.lbf/lbm

Energi Potensial

$\Delta Z = 6{,}7121$ m
$22{,}021$ ft
$EP = \Delta Z \frac{g}{gc}$
$= 22{,}021 \text{ ft} \times 1 \text{ lbf/lbm} = 21{,}902$ ft.lbf/lbm

Persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$
$= (-17{,}52 + 21{,}9021 + 0{,}1198 + 0{,}8741)$ ft.lbf/lbm
$= 5{,}3742284$ ft.lbf/lbm

Power Pompa

$Hp = \frac{-Wf \times \text{flowrate(gpm)} \times sg}{3960}$

$$= \frac{5{,}3742 \text{ ft.lbf/lbm} \times 110{,}15 \text{ gpm} \times 2{,}0305}{3960}$$

= 0,3035 Hp

Effisiensi Pompa

E = 40% ***Peters 4ed ; Figure 14 - 37; 520***

$$BHP = \frac{0{,}3035}{40\%}$$

= 0,7588 Hp

Effisiensi Motor

E = 80% ***Peters 4ed ; Figure 14 - 38; 521***

$$BHP = \frac{0{,}7588}{80\%}$$

= 0,9485 Hp

Spesifikasi :

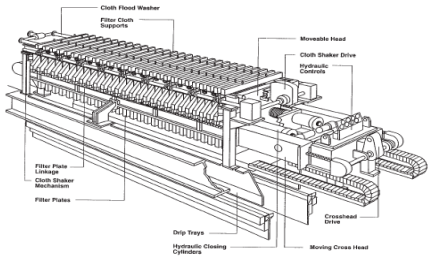
Fungsi	:	Mengalirkan bahan menuju filter press		
Type	:	Centrifugal pump		
Power	:	1 Hp	=	745,7 watt
Rate volume	:	110,1482 gpm	=	0,417 m^3/menit
Effisiensi pompa	:	40%		
Effisiensi motor	:	80%		
Bahan konstruksi	:	Galvanized Iron		
Jumlah	:	1 buah		

13. Filter Press (H-230)

Fungsi : Memisahkan cake ammonium sulfat dari filtrat akrilamida

Type : Plate & Frame Filter Press

Dasar pemilihan : Memisahkan berdasarkan perbedaan densitas cake dan filtrat



Feed masuk dari Neutrallizer

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_5NO	12754,2041	0,2511	0,7838
$(NH_4)_2SO_4$	11973,7784	0,2357	1,8145
C_3H_3N	501,091784	0,0099	0,2734

$H_2SO_4.H_2O$	553,811124	0,0109	1,7690
H_2O	25013,0275	0,4924	1,0136
Total	50795,913	1	

Waktu pembersihan = waktu pembongkaran + pengambilan cake + pencucian cake + pencucian plate and frame +

Waktu siklus operasi = 2 jam (terdiri dari 1 jam bongkar pasang dan 1 jam operasi)

Komposisi filtrat :

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_5NO	12627,5253	0,3344	0,7838
C_3H_3N	248,057391	0,0066	0,2734
H_2O	24889,0182	0,6591	1,0136
Total	37764,6009	1	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62,43$$

$$= \frac{1}{\frac{0,3344}{0,7838} + \frac{0,0066}{0,2734} + \frac{0,6591}{1,0136}} \times 62,43 \text{ lb/cuft}$$

$$= 56,7133 \text{ lb/cuft}$$

Rate massa = 24889,02 kg/jam = 54870,89 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{54870,89 \text{ lb/jam}}{56,7133 \text{ lb/cuft}}$$

= 967,5134 cuft/jam = 16,12522 cuft/menit

= 120,6328 gpm = 0,268754 cuft/s

Volume Filtrat = 967,5134 cuft/jam x 1 jam

= 967,5134 cuft

= 7237,502 gal

Komposisi cake :

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$(NH_4)_2SO_4$	11973,7784	0,9367	1,8145
$H_2SO_4.H_2O$	553,811124	0,0433	1,7690
Filtrat terikut	255,665093	0,0200	0,9085
Total	12783,2547	1	

1 lb = 453,59 g

1 cuft = 28317 cc

ρ filtrat terikut = 56,7133 lb/cuft

= 0,90846 g/cc

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}9367}{1{,}8145} + \frac{0{,}0433}{1{,}7690} + \frac{0{,}0200}{0{,}9085}} \times 62{,}43$$

= 110,9400 lb/cuft

Rate massa = 12783,25 kg/jam = 28182,25 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{28182{,}25 \text{ lb/jam}}{110{,}9400 \text{ lb/cuft}}$$

= 254,0314 cuft/jam = 4,233857 cuft/menit

= 31,67349 gpm = 0,070564 cuft/s

Volume cake = 254,0314 cuft/jam x 1 jam

= 254,0314 cuft

= 1900,287 gal

Rata-rata laju filtrasi untuk larutan dengan viskositas tinggi = 1 - 2

Dipilih 2 gal/ft².jam ***Perry 5 ed T. 19-18***

$$\text{Luas frame total} = \frac{\text{Volume filtrat}}{\text{Rate filtrasi}}$$

$$= \frac{7237{,}502 \text{ gal}}{2 \text{ gal/ft}^2\text{.jam}}$$

= 3618,751 ft².jam

Direncanakan ukuran plate & frame = 36 x 36 in

dan jenis metal dari Perry: T. 19-17 , diperoleh data:

Luas efektif = 40 ft²

Total kapasitas = 0,75 cuft

$$\text{Jumlah frame (N)} = \frac{\text{Luas frame}}{\text{Luas efektif}}$$

$$= \frac{3618{,}751 \text{ ft}^2}{40 \text{ ft}^2}$$

= 90,46878 ~ 50

Dipakai 50 plate → 50 frame

Plate & frame yang dipakai = (2xN)-1 = (2 x 50) - 1

= 99 buah

Diketahui range tebal frame = 0,25 - 8 in ***Perry 9th: 18-81***

$$\text{Volume cake tiap frame} = \frac{\text{Volume cake}}{\text{jumlah frame}}$$

$$= \frac{1900{,}3 \text{ gal}}{50}$$

= 38,00574 gal = 5,0806 cuft

Tebal tiap frame = $\frac{\text{Volume cake tiap frame}}{\text{Luas efektif}}$

= $\frac{5,080629 \text{ cuft}}{40 \text{ ft}^2}$

= 0,127016 ft = 1,5242 in

Diambil tebal frame = 1,3 in

Panjang total plate & frame filter press = 99 x 1,3

= 128,7

= 10,725 ft

= 3,269 m

Spesifikasi

Fungsi	:	Memisahkan cake ammonium sulfat dari filtrat akrilamida
Type	:	Plate & frame filter press
Jumlah plate &frame	:	99 buah
Panjang filter press	:	3,269 m
Ukuran filter press	:	36 x 36 in
Tebal tiap frame	:	1,3 in = 0,033 m
Luas area filtrasi	:	3960 ft² = 368 m²
Suhu	:	36 ℃
Cycle operasi	:	2 jam
Jenis filter	:	metal
Jumlah	:	2 buah

14. Screw Conveyor Ammonium sulfat (J-231)

Fungsi	:	Memindahkan ammonium sulfat dari filter press ke silo
Type	:	Standard screw-plain spouts of chutes
Dasar pemilihan	:	Sesuai untuk padatan dengan sistem tertutup dengan jarak transfer dekat

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$(NH_4)_2SO_4$	11973,7784	0,9367	1,8145
$H_2SO_4.H_2O$	553,811124	0,0433	1,7690
Filtrat terikut	255,665093	0,0200	0,9085
Total	12783,2547	1	

ρ Campuran = $\frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}}$ x 62,43 = lb/cuft

ρ Campuran $= \dfrac{1}{\frac{0,9367}{1,8145} + \frac{0,0433}{1,7690} + \frac{0,0200}{0,9085}} \times 62,43 = 110,94$ lb/cuft

Rate Massa = 12783,25 kg/jam = 28187,08 lb/jam

Rate Volume = $\dfrac{\text{Rate Massa}}{\text{Densitas}} = \dfrac{28187,0765 \text{ lb/jam}}{110,9400 \text{ lb/cuft}}$

= 254,0749 cuft/jam

= 4,2346 cuft/menit

= 31,6789 gpm

Power motor (Hp) = $\dfrac{K.C.\rho.L}{2000000}$ ***Badger; 627***

Dimana :

K = 4 (untuk bahan bertekstur mirip dengan pasir)

C = kapasitas, cuft/jam

ρ = densitas bahan, lb/cuft

L = Panjang screw conveyor, ft

Badger; 627

Direncanakan panjang screw conveyor, (L) = 30 ft = 9,144 m

Hp = $\dfrac{4 \times 254,0749 \text{ cuft/jam} \times 110,94 \text{ lb/cuft} \times 30 \text{ ft}}{2000000}$

= 1,691225 Hp

Effisiensi motor = 80%

Power motor = $\dfrac{1,6912 \text{ Hp}}{80\%}$

= 2,114 Hp

Dari ***Perry ed 7: T 21-6; Section 21-8*** , diperoleh :

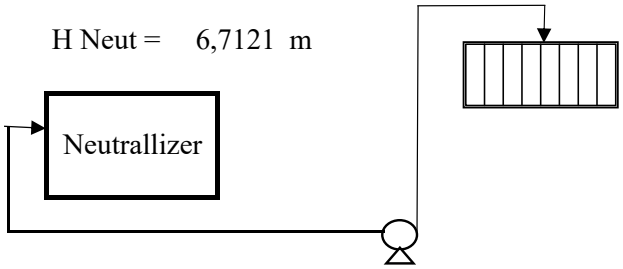
Kapasitas maksimum	=	10	ton/jam
Diameter flight	=	10	in
Diameter pipa	=	2 1/2	in
Diameter of shaft	=	2	in
Hanger center	=	10	ft
Diameter feed section	=	9	in
Kecepatan screw conveyor	=	55	rpm

Spesifikasi :

Fungsi	:	Memindahkan cake ammonium sulfat dari filter press ke penampungan
Type	:	Standard screw- plain spouts of chutes
Kapasitas	:	254,0749 cuft/jam = 7,1946 m^3/jam
Diameter flight	:	10 in = 0,254 m
Diameter pipa	:	2 1/2 in = 0,0635 m
Diameter shaft	:	2 in = 0,0508 m
Kecepatan	:	55 rpm
Elevasi	:	horizontal

Panjang : 30 ft = 9,144 m
Effisiensi : 80%
Power : 2,114 Hp
Jumlah : 1 buah

15. Pompa-5 (L-232)
Fungsi : Mengalirkan filtrat dari Filter Press ke Neutrallizer
Type : Centrifugal pump
Dsar pemilihan : Sesuai untuk bahan dengan viskositas <10 cp



Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_5NO	6313,76265	0,3322	0,7838
C_3H_3N	248,057391	0,0131	0,2734
H_2O	12444,5091	0,6548	1,0136
Total	19006,3292	1	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}3322}{0{,}7838} + \frac{0{,}0131}{0{,}2734} + \frac{0{,}6548}{1{,}0136}} \times 62{,}43$$

= 55,8665 lb/cuft

Rate massa = 19006,33 kg/jam = 41901,78 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{41901{,}78 \text{ lb/jam}}{55{,}8665 \text{ lb/cuft}}$$

= 750,0337 cuft/jam = 12,50056 cuft/menit
= 93,5167 gpm = 0,208343 cuft/s

Menghitung diameter optimum dengan persamaan :
Asumsi aliran turbulen

$$\text{Diameter optimum} = 3.9 \times q_f^{0.45} \times \rho^{0.13}$$

eq. 15; Peters 4-ed; 496

Dengan :
q_f = Fluid flow rate; (cuft/detik)
ρ = Fluid Density; (lb/cuft)
Di = Diameter dalam pipa optimum, (in)

Di = 3,9 x 0,2083 0,45 cuft/s x 55,8665 0,13 lb/cuft
= 3,2482 in
Dari diameter optimum, dipilih pipa 2 1/2 in, sch 40 berdasarkan McCabe
OD = 2,88 in = 0,2396 ft ***McCabe: App 3; 1090***
ID = 2,47 in = 0,2058 ft = 0,0627 m
A = 0,03322 ft²
Kecepatan linier = $\frac{qf}{A}$
(v)
= $\frac{0,2083}{0,0332}$ cuft/s ft²
= 6,2716 ft/s
ρ reference = 62,43 lb/cuft
sg reference = 1
μ reference = 1 cps
sg bahan = $\frac{\rho \text{ bahan}}{\rho \text{ reference}}$ x sg reference
= $\frac{55,8665 \text{ lb/cuft}}{62,43 \text{ lb/cuft}}$ x 1
= 0,8949
μ berdasarkan sg bahan :
μ bahan = $\frac{\text{sg bahan}}{\text{sg reference}}$ x μ reference
= $\frac{0,8949}{1}$ x 1 cps
= 0,8949 cps
= 0,0006 lb/ft.s
NRe = $\frac{D \, v \, \rho}{\mu}$
= $\frac{0,2058 \text{ ft} \times 6,2716 \text{ ft/s} \times 55,8665 \text{ lb/cuft}}{0,000601 \text{ lb/ft.s}}$
Nre = 119884,37
Nre > 2100 (asumsi aliran turbulen benar)

Dipilih commercial steels, dengan :
ε = 0,000046 m ***Geankoplis: F 2.10-3; 88***
ε/D = $\frac{0,000046 \text{ m}}{0,0627126 \text{ m}}$
= 0,0007335
f = 0,0055 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***
Panjang pipa lurus = 25,5 m = 83,661 ft

- 1 gate valve = n x Le/D x ID
  (wide open) = 1 x 9 x 0,2058 ft
  1,8518 ft
- 3 elbow 90° = 3 x 35 x 0,2058
  = 21,604 ft

Panjang total pipa = 1,8518 ft + 83,661 ft + 21,604 ft
= 107,12 ft

Friksi yang terjadi

karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ ***Geankoplis 3ed, eq 2.10-6; 89***

$$= \frac{2 \times 0,0055 \times 6,2716 \text{ ft/s}^2 \times 107,12 \text{ ft}}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 0,2058 \text{ ft}}$$

= 7,0010 ft.lbf/lbm

karena kontraksi dalam pipa

$$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :

α = 1

Kc = 0,5 , maka :

$$F2 = \frac{0,5 \times 6,2716 \text{ ft/s}^2}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

= 0,305627 ft.lbf/lbm

karena gate valve , Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$$

$$= \frac{1 \times 0,17 \times 6,2716 \text{ ft/s}^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$$

= 0,1039 ft.lbf/lbm

karena ekspansi pipa ke neutrallizer

$$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 < A2, maka V1 dianggap = 0)

$$\frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$$

$$= \frac{6,2716 \text{ ft/s}^2 - 0}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$$

= 0,6113 ft.lbf/lbm

karena elbow 90° , Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2}$$ n = jumlah elbow

$$= \frac{3 \times 0{,}75 \times 6{,}2716 \text{ ft/s}^2}{32{,}174 \text{ ft.lbm/s}^2\text{.lbf} \times 2}$$
$$= 1{,}3753 \text{ ft.lbf/lbm}$$

Sehingga :

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$
$= 9{,}3972$ ft.lbf/lbm

Energi Tekanan

$$EP = \frac{\Delta P}{\rho}$$

$P1 = 1$ atm $+ P\,h$
$= 2116{,}8$ lbf/ft² $+ \rho\, g/gc\, h$
$= 2116{,}8$ lbf/ft² $+ 55{,}8665$ lbm/ft³ $\times 1$ lbf/lbm $\times 6{,}7121$ ft
$= 2489{,}7517$ lbf/ft²
$P_2 = 2116{,}8$ lbf/ft²
$\Delta P = 2116{,}8$ lbf/ft² $- 2489{,}8$ lbf/ft²
$= -372{,}9517$ lbf/ft²

$$EP = \frac{-372{,}9517 \text{ lbf/ft}^2}{55{,}8665 \text{ lbm/ft}^3}$$
$$= -6{,}675762 \text{ ft.lbf/lbm}$$

Energi Kinetik

$$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$$
$$= \frac{6{,}2716 \text{ ft/s}^2}{2 \times 1 \times 32{,}174 \text{ lbm.ft/s}^2\text{.lbf}}$$
$$= 0{,}6113 \text{ ft.lbf/lbm}$$

Energi Potensial

$\Delta Z = 6{,}7121$ m
$22{,}021$ ft

$$EP = \Delta Z \frac{g}{gc}$$
$$= 22{,}021 \text{ ft} \times 1 \text{ lbf/lbm} = 21{,}902 \text{ ft.lbf/lbm}$$

Persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$$
$$= (-6{,}676 + 21{,}9021 + 0{,}6113 + 9{,}3972) \text{ ft.lbf/lbm}$$
$$= 25{,}234766 \text{ ft.lbf/lbm}$$

Power Pompa

$$Hp = \frac{-Wf \times \text{flowrate(gpm)} \times sg}{3960}$$

$$= \frac{25{,}235 \text{ ft.lbf/lbm} \times 93{,}517 \text{ gpm} \times 0{,}8949}{3960}$$

= 0,5333 Hp

Effisiensi Pompa

E = 50% ***Peters 4ed ; Figure 14 - 37; 520***

$$BHP = \frac{0{,}5333}{50\%}$$

= 1,0666 Hp

Effisiensi Motor

E = 80% ***Peters 4ed ; Figure 14 - 38; 521***

$$BHP = \frac{1{,}0666}{80\%}$$

= 1,3332 Hp

Spesifikasi :

Fungsi	:	Mengalirkan filtrat menuju neutrallizer		
Type	:	Centrifugal pump		
Power	:	1,3332 Hp	=	994,16 watt
Rate volume	:	93,5167 gpm	=	0,354 m^3/menit
Effisiensi pompa	:	50%		
Effisiensi motor	:	80%		
Bahan konstruksi	:	Commersial steels		
Jumlah	:	1 buah		

16. Silo Ammonium Sulfat (F-410)

Fungsi : Menampung ammonium sulfat 3 hari

Type : Silinder tegak dengan tutup atas plat dan bawah conical

Dasar pemilihan : Sesuai untuk menampung padatan

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
$(NH_4)_2SO_4$	11973,7784	0,9367	1,8145
$H_2SO_4.H_2O$	553,811124	0,0433	1,7690
Filtrat terikut	255,665093	0,0200	0,9085
Total	12783,2547	1	

Menentukan Volume tangki

$$\rho \text{ Campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62{,}43 = \text{lb/cuft}$$

$$\rho \text{ Campuran} = \frac{1}{\frac{0{,}9367}{1{,}8145} + \frac{0{,}0433}{1{,}7690} + \frac{0{,}0200}{0{,}9085}} \times 62{,}43 = 110{,}94 \text{ lb/cuft}$$

Rate Massa = 12783,25 kg/jam = 28187,08 lb/jam

$$\text{Rate Volume} = \frac{\text{Rate Massa}}{\text{Densitas}} = \frac{28187{,}0765 \text{ lb/jam}}{110{,}9400 \text{ lb/cuft}}$$

= 254,0749 cuft/jam
= 4,2346 cuft/menit
= 31,6789 gpm

$$\text{Volume bahan} = \frac{254{,}0749 \text{ cuft/jam} \times 3 \text{ hari} \times 24 \text{ jam/hari}}{3 \text{ tangki}}$$

= 6097,798 cuft

Asumsi bahan mengisi 80% volume tangki, maka Vol Tangki :

$$V = \frac{6097{,}7979 \text{ cuft}}{80\%}$$

= 7622,2474 cuft

Menentukan dimensi tangki

Asumsi rasio dimensi : H/D = 2 ***Ulrich; T 4-27; 248***

Volume = 1/4 Π. D.²H

$$7622{,}25 = \frac{1}{4} \times \pi \times D^2 \times 2 \times D$$

$$D^3 = \frac{7622{,}247 \text{ cuft}}{1{,}57}$$

$D^3 = 4854{,}9$

D = 16,93276 ft = 203,1931 in = 5,2 m
H = 33,86552 ft = 406,3863 in = 10,3 m

Menentukan tekanan design

P operasi = 14,7 psi
P bahan = ρ Campuran x H
= 110,94 lb//cuft x 0,99 lbf/lbm x 33,866 ft
= 3757 lbf/ft²
= 26,091 lbf/in² = 26,091 psi
P operasi = 40,791 psig
P design 10% lebih besar dari P operasi untuk faktor keamanan
P design = 110% x 40,791 psig
= 44,87 Psig

Direncanakan :

1. Bahan konstruksi = Carbon steel SA-285 grade C

f = 13750 psi ***T 13.1 B&Y; 251***

2. Pengelasan double welded butt joint

E = 0,8 ***T 13.2 B&Y; 254***

3. Faktor korosi (C) = 1/8

Menentukan tebal shell minimum :

Tebal shell berdasarkan ASME code untuk tangki silinder :

$$ts = \frac{P \times ri}{f\ E - 0{,}6\ P} + C \qquad \textit{eq. 13.1 B\&Y; 254}$$

Dimana :

ts = tebal shell (in) C = faktor korosi

P = tekanan design (Psi) f = alllowable stress

ri = jari-jari dalam (in)

E = faktor pengelasan

Mencari tebal shell (ts) menggunakan f yang diijinkan

$$ts = \frac{44{,}870\ psig \times 101{,}6\ in}{13750\ psi \times 0{,}8 - 0{,}6 \times 44{,}87\ psig} + 1/8$$

$$= 0{,}5404\ in$$

ts yang diperoleh di standarkan dengan tebal shell yang dijual dipasaran dengan melihat T 5.7 B&Y; 90

ts = 8/16 in

Untuk tebal tutup atas disamakan dengan tebal tutup bawah, karena tutup bawah lebih banyak menerima beban

Tebal tutup bawah

Untuk tutup berbentuk conical dengan sudut tidak lebih besar dari 30° menggunakan persamaan 6.154 B&Y

α = 30 ° Cos α = 0,866

(1/2α) = 15 ° (tan 1/2α) = 0,2679

$$th = \frac{P \cdot D}{2 \cos \alpha\ (f.E - 0{,}6\ P)} + 1/8 \qquad \textit{B\&Y: eq. 6.154; 118}$$

Asumsi th = 5/8 in

$$10/16\ in = \frac{44{,}87\ psig \times 203{,}1931\ in}{2 \times 0{,}866\ (f \times 0{,}8 - 0{,}6 \times 44{,}87\ psig)} + 1/8$$

$$8/16\ in = \frac{44{,}87\ psig \times 203{,}1931\ in}{2 \times 0{,}866\ (f \times 0{,}8 - 0{,}6 \times 44{,}87\ Psig)}$$

f = 13193,1971

f actual < f allowable, maka th = 5/8 in dapat digunakan

Tinggi total bejana

Menentukan tinggi tutup bawah conical (hb)

$$h = \frac{tg\ \alpha \times (D-m)}{2}$$

$$= \frac{0{,}57735 \times (16{,}933 - 1)}{2}$$

= 4,5993921 ft = 1,401895 m
tinggi silinde = 33,8655 ft = 406,3863 in = 10,322212 m
Tinggi total bejana = 38,4649 ft = 11,7 m

Perancangan Penyangga
Jumlah penyangga = 4
Menentukan Berat total
Vol. tangki = 7622,247 cuft
Vol. bahan 6097,798 cuft
ρ material = 490 lb/cuft
W bejana kosong = (Vol. tangki - Vol bahan) x ρ material
= 746980,2 lb
W isi = 12783,25 kg/jam = 28182,25 lb/jam
= 28182,25 lb/jam x 1 jam
= 28182,25 lb
Vol tutup = $\frac{\pi \quad D^3}{24 \quad tg\ (1/2\ \alpha)}$
= $\frac{\pi \ x \ 16{,}933^{\ 3}}{24 \ x \ 0{,}2679}$
= 2370,551 ft³
W tutup = Vol. tutup x ρ material
= 2370,6 ft³ x 490 lb/cuft
= 1161570 lb
W aksesoris = 96836,63 lb
Σ W = 2033569,2 lb

Menentukan tinggi penyangga (L)
tinggi total bejana (H) = 38,4649 ft
tinggi dari permukaan tanah (l) = 5 ft
L = l + 0,5 H
= 5 ft + 0,5 x 38,4649 ft
= 24,2325 ft
= 290,789 in
Menentukan beban tiap penyangga
P = $\frac{\Sigma W}{n}$
= $\frac{2033569 \text{ lb}}{4}$ = 508392,3 lb = 230602,9 kg
Menentukan fc allowable
fc = $\frac{P}{A}$ = $\frac{508392 \text{ lbm} \ x \ 1 \ \text{lbf/lbm}}{35{,}13 \ \text{in}^2}$ = 14393 lbf/in²

Direncanakan :
Jenis penyangga = Beams
dari B&Y: App G; 354

Axis 1-1
A = 35,13 in²
$r_{1\,1}$ = 9,26 in
$\frac{L}{r_{1\,1}}$ = 31,4028

Axis 2-2
A = 35,13 in²
$r_{2\,2}$ = 1,56 in
$\frac{L}{r_{2\,2}}$ = 186,4

untuk L/r x x < 120 menggunakan persamaan berikut:

$$fc = 17000 - 0{,}485 \times (L/r_{1\,1})$$
$$= 16984{,}8 \text{ Psi}$$

untuk L/r x x > 120 menggunakan persamaan berikut:

$$fc = \frac{18000}{1 + \frac{1}{18000} \times (L/r_{2\,2})^{2}}$$
$$= 17065{,}086 \text{ psi}$$

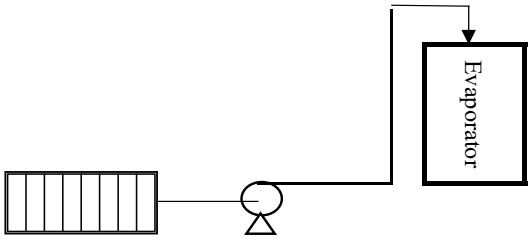
fc actual > fc allowable, maka jenis penyangga beams dengan luas permukaan penyangga 35,13 in² dapat digunakan

Spesifikasi:

Fungsi	:	Menampung ammonium sulfat		
Type	:	Silinder tegak dengan tutup atas plat dan bawah conical		
Bahan	:	Carbon steel SA-285 grade C		
Diameter tangki	:	16,933 ft	=	5,1611 m
Tinggi tangki	:	33,866 ft	=	10,322 m
Tebal shell	:	8/16 in	=	0,0127 m
Tebal tutup	:	5/8 in	=	0,0159 m
Jumlah	:	4 buah		
Jenis penyangga	:	Beams		
Luas permukaan penyangga	:	35,13 in²	=	0,0227 m²
Tinggi penyangga	:	24,232 ft	=	7,3861 m

17. Pompa-6 (L-233)

Fungsi : Mengalirkan filtrat dari Filter Press menuju Evaporator
Type : Centrifugal pump
Dasar pemilihan : Sesuai untuk bahan dengan viskositas < 10 cp



H evap = 7,2261 m
= 23,708 ft

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_5NO	6313,76265	0,3366	0,7838
H_2O	12444,5091	0,6634	1,0136
Total	18758,2718	1	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}3366}{0{,}7838} + \frac{0{,}6634}{1{,}0136}} \times 62{,}43$$

$$= 57{,}5979 \text{ lb/cuft}$$

Rate massa = 18758,27 kg/jam = 41354,91 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{41354{,}91 \text{ lb/jam}}{57{,}5979 \text{ lb/cuft}}$$

= 717,9935 cuft/jam = 11,96656 cuft/menit
= 89,52183 gpm = 0,199443 cuft/s

Menghitung diameter optimum dengan persamaan :

Asumsi aliran turbulen

$$\text{Diameter optimum} = 3.9 \times q_f^{0.45} \times \rho^{0.13}$$ ***eq. 15; Peters 4-ed; 496***

Dengan :

q_f = Fluid flow rate; (cuft/detik)
ρ = Fluid Density; (lb/cuft)
Di = Diameter dalam pipa optimum, (in)

Di = 3,9 x 0,1994 0,45 cuft/s x 57,5979 0,13 lb/cuft
= 3,1977 in

Dari diameter optimum, dipilih pipa 2 1/2 in, sch 40 berdasarkan McCabe
OD = 2,88 in = 0,2396 ft ***McCabe: App 3; 1090***
ID = 2,47 in = 0,2058 ft = 0,0627 m
A = 0,03322 ft²

$$\text{Kecepatan linier (v)} = \frac{qf}{A}$$

$$= \frac{0{,}1994 \text{ cuft/s}}{0{,}0332 \text{ ft}^2}$$

$$= 6{,}0037 \text{ ft/s}$$

ρ reference = 62,43 lb/cuft
sg reference = 1
μ reference = 1 cps

$$\text{sg bahan} = \frac{\rho \text{ bahan}}{\rho \text{ reference}} \times \text{sg reference}$$

$$= \frac{57,5979 \text{ lb/cuft}}{62,43 \text{ lb/cuft}} \times 1$$
$$= 0,9226$$

μ berdasarkan sg bahan :

$$\mu \text{ bahan} = \frac{\text{sg bahan}}{\text{sg reference}} \times \mu \text{ reference}$$
$$= \frac{0,9226}{1} \times 1 \text{ cps}$$
$$= 0,9226 \text{ cps}$$
$$= 0,0006 \text{ lb/ft.s}$$

$$NRe = \frac{D \, v \, \rho}{\mu}$$
$$= \frac{0,2058 \text{ ft} \times 6,0037 \text{ ft/s} \times 57,5979 \text{ lb/cuft}}{0,00062 \text{ lb/ft.s}}$$
$$Nre = 114763,12$$

Nre > 2100 (asumsi aliran turbulen benar)

Dipilih commercial steels, dengan :

ε = 0,000046 m ***Geankoplis: F 2.10-3; 88***

$$\varepsilon/D = \frac{0,000046 \text{ m}}{0,0627126 \text{ m}}$$
$$= 0,0007335$$

f = 0,0055 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***

Panjang pipa lurus = 7,5 m = 24,606 ft

- 1 gate valve = n x Le/D x ID
  (wide open) = 1 x 9 x 0,2058 ft
  1,8518 ft
- 2 elbow 90° = 2 x 35 x 0,2058
  = 14,403 ft

Panjang total pipa = 1,8518 ft + 24,606 ft + 14,403 ft
= 40,861 ft

Friksi yang terjadi

karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$$ ***Geankoplis 3ed, eq 2.10-6; 89***

$$= \frac{2 \times 0,0055 \times 6,0037 \text{ ft/s}^2 \times 40,861 \text{ ft}}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 0,2058 \text{ ft}}$$
$$= 2,4473 \text{ ft.lbf/lbm}$$

karena kontraksi dalam pipa

$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :

$\alpha = 1$

$Kc = 0,5$, maka :

$F2 = \frac{0,5 \times 6,0037 \text{ ft/s}^2}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$

$= 0,280073$ ft.lbf/lbm

karena gate valve , Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$

$= \frac{1 \times 0,17 \times 6,0037 \text{ ft/s}^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$

$= 0,0952$ ft.lbf/lbm

karena ekspansi pipa ke evaporator

$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc}$ ($A1 < A_2$, maka V1 dianggap = 0)

$\frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$

$= \frac{6,0037 \text{ ft/s}^2 - 0}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2.\text{lbf}}$

$= 0,5601$ ft.lbf/lbm

karena elbow 90° , Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2}$ n = jumlah elbow

$= \frac{2 \times 0,75 \times 6,0037 \text{ ft/s}^2}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 2}$

$= 0,8402$ ft.lbf/lbm

Sehingga :

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$

$= 4,2230$ ft.lbf/lbm

Energi Tekanan

$EP = \frac{\Delta P}{\rho}$

$P1 = 1$ atm

$= 2116,8$ lbf/ft²

$= 2116,8$ lbf/ft²

$= 2116,8$ lbf/ft²

$P_2 = 0,61$ atm $= 9,0086$ lbf/in²

P_2 = 1297,2408 lbf/ft²
ΔP = 1297,24 lbf/ft² - 2116,8 lbf/ft²
= -819,5592 lbf/ft²
EP = $\frac{-819,5592 \text{ lbf/ft}^2}{57,5979 \text{ lbm/ft}^3}$
= -14,22898 ft.lbf/lbm

Energi Kinetik

$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$
$= \frac{6,0037 \text{ ft/s}^2}{2 \times 1 \times 32,174 \text{ lbm.ft/s}^2.\text{lbf}}$
= 0,5601 ft.lbf/lbm

Energi Potensial

ΔZ = 23,708 ft Z1 = 0 ft Z2 = 23,708 ft

$EP = \Delta Z \frac{g}{gc}$
= 23,708 ft x 1 lbf/lbm = 23,579 ft.lbf/lbm

Persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$
= (-14,23 + 23,57942 + 0,5601 + 4,223) ft.lbf/lbm
= 14,133558 ft.lbf/lbm

Power Pompa

$Hp = \frac{-Wf \times \text{flowrate(gpm)} \times sg}{3960}$
$= \frac{14,134 \text{ ft.lbf/lbm} \times 89,522 \text{ gpm} \times 0,9226}{3960}$
= 0,2948 Hp

Effisiensi Pompa

E = 40% ***Peters 4ed ; Figure 14 - 37; 520***
$BHP = \frac{0,2948}{40\%}$
= 0,737 Hp

Effisiensi Motor

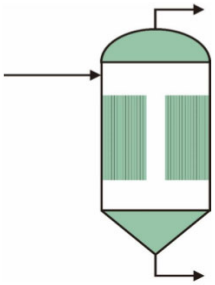
E = 80% ***Peters 4ed ; Figure 14 - 38; 521***
$BHP = \frac{0,737}{80\%}$
= 0,9212 Hp

Spesifikasi :

Fungsi	:	Mengalirkan filtrat menuju evaporator			
Type	:	Centrifugal pump			
Power	:	1	Hp	=	745,7 watt
Rate volume	:	89,52183	gpm	=	0,3389 m^3/menit
Effisiensi pompa	:	40%			
Effisiensi motor	:	80%			
Bahan konstruksi	:	Commersial steels			
Jumlah	:	1 buah			

18. Evaporator (V-240)

Fungsi	:	Memekatkan larutan akrilamida hingga 80%
Type	:	Standard Vertikal Tube Evaporator
Dasar pemilihan	:	Sesuai untuk memekatkan larutan



Kondisi Operasi
Tekanan = 0,613 atm
Suhu = 80 °C

Q steam	=	32877825	kJ/jam	=	31162165	Btu/jam	
W steam	=	14240,3	kg/jam	=	31394,48	lb/jam	
Suhu steam masuk	=	148 °C	=	298 °F			T_1
Suhu steam keluar	=	148 °C	=	298 °F			T_2
Suhu bahan masuk	=	36 °C	=	96,8 °F			t_1
Suhu bahan keluar	=	80 °C	=	176 °F			t_2
ΔTh	=	298 -	176 °F	=	122 °F		
ΔTc	=	298 -	96,8 °F	=	202 °F		

Log Mean Temperatur Difference

$$\Delta T\ LMTD = \frac{\Delta Th - \Delta Tc}{\ln \frac{\Delta Th}{\Delta Tc}}$$

$$= \frac{122\ °F - 202\ °F}{\ln \frac{122\ °F}{202\ °F}}$$

$$= 159\ °F$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = 0$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = 0{,}3929$$

Ft = 1 ***Kern: F 18; 828***

ΔT = Ft x ΔT LMTD
= 1 x 158,72 °F
= 158,72 °F

Komponen	A	B	n	Tc	T
C_3H_5NO	0,27378	0,252	0,28571	710	309,15
H_2O	0,3471	0,274	0,28571	647,13	309,15

$$\rho = A \times B^{-(1 - T / Tc)^n}$$ ***Yaws: T 8-2***

Feed masuk

Komponen	erat (kg/jan	Fraksi	ρ (g/cc)
C_3H_5NO	6313,763	0,3366	0,8827
H_2O	12444,51	0,6634	1,0173
Total	18758,27	1,0000	

$$\rho \text{ Campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62,43 = \text{lb/cuft}$$

$$\rho \text{ Campuran} = \frac{1}{\frac{0,3366}{0,8827} + \frac{0,6634}{1,0173}} \times 62,43 = 60,4104 \text{ lb/cuft}$$

$$\text{Sg Bahan} = \frac{\rho \text{ Campuran}}{\rho \text{ reference}} = \frac{60,4104}{62,43} = 0,9677$$

Menghitung viskositas bahan

μ berdasarkan sg bahan

Sg reference : 1 ***Kern: T.6; 808***

μ reference : 0,9 ***Kern: F.14; 822-823***

$$\mu \text{ Bahan} = \frac{\text{Sg Bahan}}{\text{Sg Reference}} \times \mu \text{ reference} = \frac{0,9677}{1} \times 0,9 = 0,8709 \text{ cp}$$

Evaporator Termasuk Heater Karena :

Hot Fluid : Steam

Cold Fluid : Larutan Akrilamida

Sehingga :

Range UD = 200 - 700 Btu/j ft².°F

Di Trial UD = 225 Btu/j ft².°F ***Kern: T 8; 840***

Menghitug Tc dan tc :

$$Tc = \frac{T1 + T2}{2}$$
$$= 298{,}40 \text{ F}$$
$$tc = \frac{t1 + t2}{2}$$
$$= 136{,}4 \text{ F}$$

Luas Penampang Evaporator = $Q = A \cdot UD \cdot \Delta T$ ***Kern Hal 383***

$$A = \frac{31162164{,}9617 \text{ Btu/jam}}{225 \text{ Btu/jam ft}^2.\text{°F} \times 159 \text{ °F}}$$
$$= 872{,}5951 \text{ ft}^2$$

Dari ***Kern: T 10; 843*** diperoleh :

Pipa (Tube)

OD = 0,75 in

BWG = 18

ID = 0,652 in

Flow Area (a't) = 0,334 in^2

Surface Per Lin ft (a") = 0,1963 ft^2

Disusun Triangular

Pitch = 1 in

Panjang Tube = 6 ft

Jumlah Tube :

$$Nt = A' / a'' \times L$$
$$Nt = \frac{872{,}5951}{0{,}1963 \times 6}$$
$$= 740{,}8687$$

Nt distandardkan berdasarkan ***Kern: T 9; 842***

Nt = 526 Buah

IDs = 29 in

n = 2 Passes

$$\text{UD koreksi} = \frac{Nt}{Nt \text{ Standard}} \times \text{UD Trial}$$
$$= \frac{740{,}87}{526} \times 225$$
$$= 316{,}91 \text{ Btu/jam ft}^2.\text{°F}$$

Perancangan HE

Type HE = 1 - 2

Artinya = 1 Lewatan Pada Shell
2 Lewatan Maks Pada Bagian Tube

Bagian Shell

IDs = 29 in

n = 2

B = 1 - 1/5 x IDs
= 29 in

Bagian Tube

OD	=	0,75 in	
BWG	=	18	
ID	=	0,652 in	
Flow Area Per Tube (a't)	=	0,334 in^2	
Surface per lin ft (a")	=	0,1963 ft^2	
Disusun	=	Triangular	
Pitch (Pt)	=	1	
Panjang (l)	=	6 ft	
Nt	=	526 Buah	
De	=	0,72 in^2	***Kern: F 28; 838***

Perpindahan Panas

Bagian Tube (Steam)	Bagian Shell (Larutan Akrilamida)
Menghitung Nre Tube	**Menghitung Nre Shell**
at = $\frac{Nt \times a't}{n \times 144}$	as = $\frac{IDs \times C' \times B}{144 \times Pt}$ C' = Pt - OD = 1 - 1 = 1/4
= $\frac{526 \times 0,334}{2 \times 144}$	as = $\frac{29 \times 1/4 \times 29}{144 \times 1}$
= 0,61 ft^2	= 1,4601 ft^2
Gt = $\frac{W\ Steam}{at}$	Gs = $\frac{W\ Bahan}{as}$
= $\frac{31394,48414}{0,6100}$ lb/jam ft^2	= $\frac{41361,9892}{1,4601}$ lb/jam ft^2
= 51465,19566 lb/ jam ft^2	= 28328,78217 lb/ jam ft^2
μ Steam Pada Tc = 298,40 F	μ Bahan Pada tc = 136,4 F
μ Steam = 0,014 Cp ***Kern; 825***	μ = 0,9677 x μ Air ***Kern; 823***
= 0,0339 lb/ft jam	= 0,9677 x 0,5
	= 0,4838 Cp
ID = 0,65 in = 0,0543 ft	= 1,1706 lb/ft jam
Nre t = $\frac{Gt \times ID}{\mu\ Steam}$	De = $\frac{4 \times as}{Watted\ Perimeter}$ ***Kern; 105***
= $\frac{51465,19566 \times 0,0543}{0,033874}$	= $\frac{4 \times 1,4601}{Nt \cdot \pi \cdot (OD/12)}$
= 82517,03	= $\frac{4 \times 1,4601}{526 \times \pi \times 0,06}$
	= 0,0566 ft
Koefisien Perpindahan Panas	Nre = $\frac{Gs \times De}{\mu\ Bahan}$
hio = 1500 Btu/jam ft^2 F	= $\frac{28328,782 \times 0,0566}{1,1706}$
tw = tc + $\frac{hio}{hio + ho}$ x (Tc - tc)	= 1369,1242
= 136 + $\frac{1500}{1500 + 619}$ x 162	**Koefisien Perpindahan panas**
= 251,076 F	

jH = 25 ***Kern: F 28; 838***

Pada tc = 136,4 F = 331,15 K

A	B	C
0,2075	-4E-05	-3E-07

Yaws

$k = A + BT + CT^2$
= 0,165 W/m K
= 0,1152 Btu/jam.ft.°F

A	B	C	D
55,686	0,4863	-1E-03	1E-06

$Cp = A + BT + CT^2 + DT^3$
= 138,39 J/mol K ***Yaws***
= 9,8258 Kj/kg K
= 2,3484 Btu/lb F

$\frac{\lceil Cp\,\mu \rceil^{1/3}}{k} = \frac{2,35 \times 1,1706\ \text{^0.3}}{0,1152}$
= 12,157

$ho = jH \times \frac{k}{de} \times \lceil Cp\,\mu \rceil^{1/3} \times \varphi s$

$\frac{ho}{\varphi s} = 25 \times \frac{0,1152}{0,0566} \times 12,157$
= 619,0100 Btu/jam.ft².°F

Pada Tw = 251,08 F

μ = 0,9677 x μ Air ***Kern; 823***
= 0,9677 x 0,17
= 0,1645 Cp
= 0,398 lb/ft jam

$\varphi w = \frac{\lceil \mu \rceil^{0.14}}{\mu}$
$= \frac{1,1706\ \text{^0.14}}{0,398}$
= 1,163

$ho = \frac{ho}{\varphi w} \varphi s$
= 619,0100 x 1,163
= 719,93 Btu/jam.ft².°F

Clean Overall Coefficient, Uc

$Uc = \frac{hio \times ho}{hio + ho}$
$= \frac{1500\ \text{Btu/jam.ft}^2\text{.°F} \times 720\ \text{Btu/jam.ft}^2\text{.°F}}{1500\ \text{Btu/jam.ft}^2\text{.°F} + 720\ \text{Btu/jam.ft}^2\text{.°F}}$
= 486,45 Btu/jam.ft².°F

Design Overall Coefficient, UD

$$Ud = \frac{Q}{A \times \Delta T\ LMTD}$$

$$A = Nt \times l \times a''$$
$$= 526 \times 6 \times 0{,}1963$$
$$= 619{,}52\ ft^2$$

$$= \frac{31162164{,}9617\ Btu/jam}{619{,}52\ ft^2 \times 158{,}72\ °F}$$
$$= 316{,}91\ Btu/jam.ft^2.°F$$

Dirt Factor Rd

$$Rd = \frac{Uc - Ud}{Uc \times Ud}$$
$$= \frac{486{,}45\ Btu/jam.ft^2 - 316{,}91\ Btu/jam.ft^2.°F}{486{,}45\ Btu/jam.ft^2 \times 316{,}91\ Btu/jam.ft^2.°F}$$
$$= 0{,}0011$$

Rd Ketentuan = 0,002 ***Kern: T 12; 845***

Rd Hitung > Rd Ketentuan, Maka Alat dapat digunakan

PRESSURE DROP

Bagian Tube (Steam)	**Bagian Shell (larutan akrilamida)**
Suhu Steam = 148 C = 298,4 F ***Kern: T7***	Nre = 1369,1242 f = 0,003 ***Kern: T7***
Didapat Spesifik Volume = 6,655	IDs = 29 in = 2,4167 ft
$s = \frac{1 / 6{,}655}{62{,}43}$	N+1 = 12 L / B = 29,793
= 0,0024	
Nre = 82517,031	$\Delta Ps = \frac{f.Gs^2.Ds.(N+1)}{5.22 \times 10\text{^}10 \times De \times s \times \phi s}$
f = 0,0019 ***Kern: F 29***	= 0,004 < 10 psia
$\Delta Pt = \frac{f.Gt^2.L.n}{5{,}22 \times 10\text{^}10 \times Di \times s \times \phi t}$	**Memenuhi**
= 0,6339 psia < 2 psia **Memenuhi**	

Volume Tangki

Densitas Bahan = 60,4104 lb/cuft

Rate Bahan = 41361,99 lb/jam

Rate Volume = $\frac{41361{,}99\ lb/jam}{60{,}4104\ lb/cuft}$

= 684,683 cuft/jam

Waktu Operasi : 1 Jam

Volume bahan = 684,683 cuft

Volume Tube = Jumlah Tube x Panjang Tube x Luas Tube

= Nt x L x 1/4 3.14 OD^2

= 526 x 6 x (0,25 x 3,14 x 0,75 ^2)

= 1393,571 cuft

Volume Total = Volume Bahan + Volume Tube
= 684,683 + 1393,571
= 2078,254 cuft

Volume bahan mengisi 80 % volume tangki, maka V tangki

Volume tangki = $\frac{2078,254}{80}$
= 2597,818 cuft

Asumsi H/D = 2 D ***Ulrich T4.7***

Volmue Tangki = 0,25 x 3,14 x D^2 x H

2597,8178 = 0,25 x 3,14 x D^2 x H

D = 11,828 ft = 141,93 in = 3,6051 m

H = 23,656 ft = 283,87 in = 7,2102 m

Ketinggian Bahan

684,68299 = 0,25 x 3,14 x D^2 x H
= 0,25 x 3,14 x 139,9 x H

H = 6,2347 ft

Menentukan tekanan design

Bejana Tekanan Luar

P in = 0,613 atm = 9,0086 psi

P out = 14,7 psi

P h = ρ x g/gc x H liq
= 60,4104 lbm/ft³ x 0,9946 lbf/lbm x 6,2347 ft
= 374,6 lbf/ft²
= 2,6014 lbf/in² = 2,6014 psi

P op = P out - P in + P h
= 14,7 - 9,0086 + 2,6014
= 8,2928 psig

P design 10% lebih besar dari P operasi untuk faktor keamanan

P design = 110% x 8,2928 Psig
= 9,1221 Psig

Direncanakan :

1. Bahan konstruksi = Low Alloy Steels SA 203 Grade A
   f = 16250 ***B&Y: T 13.1***
2. Pengelasan double welded butt joint
   E = 0,8 ***B&Y: T 13.2***
3. Faktor korosi (C) = 1/8

Menentukan Tebal Shell :

Asumsi ts = 10/16 in

di = 141,933 in

do = di + 2. ts
= 143,183 in

$\frac{L}{do} = \frac{283,867 \text{ in}}{143,183 \text{ in}} = 1,9825$

$\frac{do}{ts} = \frac{143,183 \text{ in}}{10/16 \text{ in}} = 229,09$

Nilai faktor B = 2300 ***B&Y: F 8.8; 147***

$$P \text{ allow} = \frac{B}{do/ts} = \frac{2300}{229,09} = 10,04 > 9,1221$$

P allowable > P design, maka ts = 10/16 in dapat digunakan

Menentukan tebal tutup atas standard dishead

Asumsi th = 6/16 in

rc = do = 142,68 in

$\frac{rc}{100\ th} = \frac{142,68 \text{ in}}{37,5 \text{ in}} = 3,8049$

Faktor B = 3500 ***B&Y: F 8.8; 147***

$$P \text{ allow} = \frac{3500}{100 \frac{rc}{100\ th}} = 9,1987 > 9,1221$$

P allowable > P design, maka th = 6/16 in dapat digunakan

Menentukan tebal tutup bawah conical

Asumsi th = 4/16 in

do = 142,433 in

α = 90 ° (tg 1/2α) = 1

$$L = \frac{do}{2 \text{ tg } (0,5\alpha)} = \frac{142 \text{ in}}{2} = 71,2166 \text{ in} = 5,9347 \text{ ft}$$

L/do = 0,5

do/th = 569,73

Faktor B = 5500 ***B&Y: F 8.8; 147***

$$P \text{ allow} = \frac{B}{do/th} = \frac{5500}{569,73} = 9,6536 > 9,1221$$

P allowable > P design, maka th = 4/16 in dapat digunakan

Menentukan tinggi total bejana

Tinggi silinder = 23,656 ft = 283,87 in

Tinggi conical = 5,9347 ft = 71,217 in

Tinggi standard dishead = 0,169 d

= 1,9989 ft = 23,987 in

Tinggi total = 31,589 ft = 379,07 in

Perancangan Penyangga
Jumlah penyangga = 3

Menentukan Berat total
Vol. tangki = 2597,818 cuft
Vol. bahan 2078,254 cuft
ρ material = 490 lb/cuft
W bejana kosong = (Vol. tangki - Vol bahan) x ρ material
= 254586,1 lb
W isi = 18758,27 kg/jam = 41354,91 lb/jam
= 41354,91 lb/jam x 1 jam
= 41354,91 lb
Vol tutup b = $\frac{\pi \quad D^3}{24 \quad tg\ (1/2\ \alpha)}$ Vol. tutup a = 0,0847 d^3
= 140,15 ft^3
= $\frac{\pi \text{ x } 11,828^{\ 3}}{24 \text{ x } 1}$
= 216,4848 ft^3
W tutup = Vol. tutup x ρ material
= 356,63 ft^3 x 490 lb/cuft
= 174751 lb
W aksesoris = 23534,6 lb
Σ W = 494226,61 lb

Menentukan tinggi penyangga (L)
tinggi total bejana (H) = 31,5892 ft
tinggi dari permukaan tanah (l) = 5 ft
L = l + 0,5 H
= 5 ft + 0,5 x 31,5892 ft
= 20,7946 ft
= 249,535 in

Menentukan beban tiap penyangga
$P = \frac{\Sigma W}{n}$
$= \frac{494227 \text{ lb}}{3} = 164742,2 \text{ lb} = 74725,81 \text{ kg}$

Menentukan fc allowable
$fc = \frac{P}{A} = \frac{164742 \text{ lbm x } 0,99 \text{ lbf/lbm}}{14,57 \text{ in}^2} = 11246 \text{ lbf/in}^2$
Direncanakan :
Jenis penyangga = Beams
dari B&Y: App G; 354
Axis 1-1 Axis 2-2

A = 14,57 in² A = 14,57 in²
$r_{1\,1}$ = 4,55 in $r_{2\,2}$ = 1,05 in
$\frac{L}{r_{1\,1}}$ = 54,8429 $\frac{L}{r_{2\,2}}$ = 237,65

untuk L/r x x < 120 menggunakan persamaan berikut:

$$fc = 17000 - 0{,}485 \times (L/r_{1\,1})$$
$$= 16973{,}4 \text{ Psi}$$

untuk L/r x x > 120 menggunakan persamaan berikut:

$$fc = \frac{18000}{1 + \frac{1}{18000} \times (r_{2\,2})^{2}}$$
$$= 4350{,}2405 \text{ psi}$$

fc actual > fc allowable, maka jenis penyangga Beams dengan luas permukaan penyangga 14,57 in² dapat digunakan

Spesifikasi:

Fungsi	:	Menampung ammonium sulfat		
Type	:	Silinder tegak dengan tutup atas standard dishead dan bawah conical		
Bahan	:	*Low Alloy Steels SA 203 Grade A*		
Diameter tangki	:	11,828 ft	=	3,6051 m
Tinggi tangki	:	23,656 ft	=	7,2102 m
Tebal shell	:	10/16 in	=	0,0159 m
Tebal tutup atas	:	3/8 in	=	0,0095 m
Tebal tutup bawah	:	2/8 in	=	0,0064 m
Jumlah	:	3 buah		
Jenis penyangga	:	Beams		
Luas permukaan penyangga	:	14,57 in²	=	0,0094 m²
Tinggi penyangga	:	20,795 ft	=	6,3382 m

19. Barometrik Kondensor (E-241)

Fungsi : Mengubah fase H_2O (g) dari evaporator menjadi H_2O (l)
Type : Barometrik kondensor
Dasar pemilihan : Sesuai dengan kondisi tekanan yang vakum

Q serap = 31266846 kJ/jam
= 29635252 BTU/jam
W cw = 1098536 lb/jam

Suhu Vapor Masuk	=	80 C	=	176 F	T_1
Suhu Vapor Keluar	=	80 C	=	176 F	T_2
Suhu C.W Masuk	=	30 C	=	86 F	t_1
Suhu C.W Keluar	=	45 C	=	113 F	t_2
ΔTh	=	63 F			
ΔTc	=	90 F			

Log Mean Temperatur Difference

$$\Delta T\ LMTD = \frac{\Delta Th - \Delta Tc}{\ln \frac{\Delta Th}{\Delta Tc}}$$

$$= \frac{63\ °F - 90\ °F}{\ln \frac{63\ °F}{90\ °F}}$$

$$= 75{,}699\ °F$$

*Proses Isothermal (Tin=Tout)

Ft = 1 ***Kern: F 18; 828***

ΔT = Ft x ΔT LMTD

= 1 x 75,699 °F

= 75,699 °F

Menghitug Tc dan tc :

$$Tc = \frac{T1 + T2}{2} = 176\ F$$

$$tc = \frac{t1 + t2}{2} = 99{,}5\ F$$

Komponen	A	B	n	Tc	T
H_2O	0,3471	0,274	0,28571	647,13	353,15

$$\rho = A \times B^{-(1 - T/Tc)^n}$$ ***Yaws: T 8-2***

Bahan Masuk

Komponen	Berat kg/jam	Fraksi	ρ (g/cc)
H_2O	12324,8723	1,0000	0,9755
Total	12324,8723	1,0000	

Menghitung viskositas bahan

ρ = 0,9755 x 62,43

= 60,9001 lb/cuft

$$\text{Sg Bahan} = \frac{\rho\ \text{Bahan}}{\rho\ \text{reference}} = \frac{60{,}9001}{62{,}4300} = 0{,}975494$$

μ berdasarkan sg bahan

Sg reference : 1 ***Kern: T.6; 808***

μ reference : 0,9 ***Kern: F 14; 822-823***

$$\mu\ \text{Bahan} = \frac{\text{Sg Bahan}}{\text{Sg Reference}} \times \mu\ \text{reference}$$

$$= \frac{0{,}9755}{1} \times 0{,}9$$

= 0,8779 cp
= 2,1246 lb/ft h

Condensor Termasuk Cooler Karena :
Hot Fluid : H_2O_g
Cold Fluid : Water
Sehingga :
Range UD = 2 - 50 Btu/j ft^2 F ***Kern: T 8; 840***
Di Trial UD = 50 Btu/j ft^2 F

$$Q = A \cdot UD \cdot \Delta T$$

$$A = \frac{29635252,336 \text{ Btu/jam}}{50 \text{ Btu/jam.ft}^2.\text{°F} \times 75,7 \text{ °F}}$$ ***Kern; 383***

= 7829,742 ft^2
= 727,3831 m^2

Dari ***Kern: T 10; 843*** diperoleh :
Pipa (Tube)
OD = 1 in
BWG = 8
ID = 0,165 in
Flow Area (a't) = 0,355 in^2
Surface Per Lin ft (a") = 0,2618 ft^2
Disusun Triangular
Pitch = 1 1/4 in
Panjang Tube = 35 ft
Jumlah Tube :

$$Nt = A' / a'' \times L$$

$$Nt = \frac{7829,7422}{0,2618 \times 35}$$

= 854,4955

Nt distandardkan berdasarkan ***Kern: T 9; 842***
Nt = 766 Buah
IDs = 39 in
n = 1 Passes

$$\text{UD koreksi} = \frac{Nt}{Nt \text{ Standard}} \times \text{UD Trial}$$

$$= \frac{854,5}{766} \times 50$$

= 55,776 Btu/jam ft².°F

Perancangan HE
Type HE = 1 - 2
Artinya = 1 Lewatan Pada Shell
2 Lewatan Maks Pada Bagian Tube

Bagian Shell
IDs = 39 in
n = 1
B = 1 - 1/5 x IDs
= 39 in

Bagian Tube
OD = 1,00 in
BWG = 8
ID = 0,165 in
Flow Area Per Tube (a't) = 0,355 in^2 = 0,0025 ft^2
Surface per lin ft (a") = 0,2618 ft^2
Disusun = Triangular
Pitch (Pt) = 1,25
Panjang (l) = 35 ft
Nt = 766 Buah
De = 0,72 in^2 ***Kern: F 28; 838***
Kecepatan alir tube = 2032,488 ft/s

Evaluasi Perpindahan Panas

Bagian Tube (C W)	**Bagian Shell (H_2O)**
Menghitung Nre Tube	**Menghitung Nre Shell**
$at = \frac{Nt \times a't}{n \times 144}$ $= \frac{766 \times 0,355}{1 \times 144}$ $= 1,8884\ ft^2$	$as = \frac{IDs \times C' \times B}{144 \times Pt}$ C' = Pt - OD = 1 - 1 = 1/4 $as = \frac{39 \times 1/4 \times 39}{144 \times 1,25}$ $= 2,1125\ ft^2$
$Gt = \frac{W\ cw}{at}$ $= \frac{1098535,741\ lb/jam}{1,8884\ ft^2}$ $= 581727,4547\ lb/\ jam\ ft^2$	$Gs = \frac{W\ Bahan}{as}$ $= \frac{27176,3434\ lb/jam}{2,1125\ ft^2}$ $= 12864,54125\ lb/\ jam\ ft^2$
µ C W Pada Tc = 176 F µ C W = 0,011 Cp ***Kern H 825*** = 0,0266 lb/ft jam	$G" = \frac{W\ Bahan}{L \times Nt^{2/3}}$ $= \frac{27176,3434}{35 \times 83,718}$ = 9,2748 lb/ jam.lin.ft
ID = 0,165 in = 0,0137 ft $Nre\ t = \frac{Gt \times ID}{\mu\ Steam}$ $= \frac{581727,4547 \times 0,0137}{0,0266}$ = 300414,7	**Koefisien Perpindahan Panas** Asumsi ho = 250 (150 - 300) $tw = tc + \frac{ho}{hio + ho}(Tc-tc)$ $= 99,5 + \frac{250}{173,3 + 250}\ 76,5$
Koefisien Perpindahan Panas	

hi = 1000 Btu/jam ft^2 F ***Kern 835***	= 144,69 F
Faktor Koreksi = 1,05	tf = $\frac{Tc + tw}{2}$
Maka hio = 1050 Btu/jam ft^2 F	= $\frac{176 + 144,69}{2}$
hio = hi x ID/OD	= 160,34 F
= 1050 x $\frac{0,165}{1,00}$	Berdasarkan tf, didapat :
= 173,25 Btu/jam ft^2 F	kf = 0,013 ***Kern: T 5; 802***
	sf = s* = 1 ***Kern: T 6; 808***
	μf = 0,45 ***Kern: F 14; 823***
	Dari ***F 12.9 Kern; 267*** didapat :
	ho = 100 Btu/jam ft^2 F

Clean Overall Coefficient, Uc

$$Uc = \frac{hio \times ho}{hio + ho}$$

$$= \frac{173,25 \text{ Btu/jam ft}^2.\text{°F} \times 100 \text{ Btu/jam ft}^2.\text{°F}}{173,25 \text{ Btu/jam ft}^2.\text{°F} + 100 \text{ Btu/jam ft}^2.\text{°F}}$$

$$= 63,403 \text{ Btu/jam ft}^2.\text{°F}$$

Dirt Factor Rd

$$Rd = \frac{Uc - \text{UD koreksi}}{Uc \times \text{UD koreksi}}$$

$$= \frac{63,403 \text{ Btu/jam ft}^2.\text{°F} - 55,776 \text{ Btu/jam ft}^2.\text{°F}}{63,403 \text{ Btu/jam ft}^2.\text{°F} \times 55,776 \text{ Btu/jam ft}^2.\text{°F}}$$

$$= 0,00216 \text{ Ft}^2 \text{ F/Btu}$$

Rd = 0,0005 Ft^2 F/Btu ***Kern: T 12; 845***

Rd Hitung > Rd Ketentuan, Maka Alat dapat digunakan

PRESSURE DROP

Bagian Tube (CW)	**Bagian Shell (H_2O_g)**
Nre = 300415	Pada Tc = 0 F
f = 0,0001 ft^2/in^2 ***Kern; 836***	μ uap = 0,011 cp *Kern F15*
	= 0,0266 lb/ft jam
	de = 0,72 in
Kern eq 7.45 ;148	Nre = $\frac{de \times Gs}{\mu \text{ uap}}$
ΔPt = $\frac{f \times Gt^2 \times L \times n}{5.22 \times 10\text{^}10 \times ID \times s \times \varphi t}$	= $\frac{0,72 \times 12864,54}{0,0266}$
= 0,1375	= 348016,25
	f = 0,0012 ft^2/in^2
ΔPr = $\frac{4n}{s} \times \frac{V^2}{2g}$	N +1 = 12 L/ B
Gt = 581727,45 lb/jam ft^2	= 10,769231
Maka $\frac{V^2}{2g}$ = 0,014 ***Kern; 837***	BM = 18
	IDs = 39 ft

Sehingga :

$\Delta Pr = \frac{4n}{s} \times \frac{V^2}{2g}$

$= \frac{4}{1} \times 0{,}014$

$= 0{,}056$ Psi

$\Delta Pt\ Total = \Delta Pt + \Delta Pr$

$= 0{,}1375 + 0{,}056$

$= 0{,}1935$ Psi

$Jadi\ Pi = \Delta Ps + \Delta Pt\ Total$

$= 0{,}0011 + 0{,}1935$

$= 0{,}1946$ Psi

$s = 1$

Kern: eq 12.47; 273

$\Delta Ps = \frac{1}{2} \frac{f \cdot Gs^2\ IDs\ (N+1)}{5.22\ 10\text{^}10\ De\ s}$

$= 0{,}0011$ Psi

Dimensi Kondensor

ID = 39 in

= 3,25 ft

Asumsi Panjang Total = Panjang Tube + 2Di

= 35 ft + 6,5 ft

= 41,5 ft = 498 in = 12,7 m

Menentukan tekanan design

Bejana Tekanan Luar

P in = 0,6136 atm = 9,0174 psi

P out = 14,7 psi

P op = P out - P in

= 14,7 - 9,0174

= 5,6826 psig

P design 10% lebih besar dari P operasi untuk faktor keamanan

P design = 110% x 5,6826 Psig

= 6,2508 Psig

Direncanakan :

1. Bahan konstruksi = Carbon Steels SA 285 Grade A
   f = 11250 ***B&Y: T 13.1***
2. Pengelasan double welded butt joint
   E = 0,8 ***B&Y: T 13.2***
3. Faktor korosi (C) = 1/8

Menentukan Tebal Shell :

Asumsi ts = 3/16 in

di = 39 in

do = di + 2. ts

= 39,375 in

$\frac{L}{do} = \frac{420\ in}{39{,}375\ in} = 10{,}667$

$\frac{do}{ts} = \frac{39,375 \text{ in}}{3/16 \text{ in}} = 210$

Nilai faktor B = 1600 ***B&Y: F 8.8; 147***

$P\ allow = \frac{B}{do/ts}$

$= \frac{1600}{210}$

$= 7,619 > 6,2508$

P allowable > P design, maka ts = 3/16 in dapat digunakan

Menentukan tebal tutup bawah conical

Asumsi th = 3/16 in

do = 39,375 in

α = 30 ° tg 1/2 α = 0,2679

$L = \frac{do}{2 \text{ tg } (1/2\ \alpha)}$

$= \frac{39,4 \text{ in}}{0,54}$

= 73,4748 in = 6,1229 ft = 1,8663 m

L/do = 1,866

do/th = 210

Faktor B = 4000 ***B&Y: F 8.8; 147***

$P\ allow = \frac{B}{do/th}$

$= \frac{4000}{210}$

$= 19,048 > 6,2508$

P allowable > P design, maka th = 3/16 in dapat digunakan

Spesifikasi:

Fungsi	:	Mengubah fase H_2O (g) dari evaporator menjadi H_2O (l)			
Type	:	Brometrik kondensor			
Bahan	:	Carbon Steels SA 285 Grade A			
Diameter shell	:	3,25	ft	=	0,9906 m
Tinggi shell	:	41,5	ft	=	12,649 m
Tebal shell	:	3/16	in	=	0,0048 m
Tebal tutup bawah	:	3/16	in	=	0,0048 m
Tinggi tutup bawal	:	73,475	in	=	1,8663 m

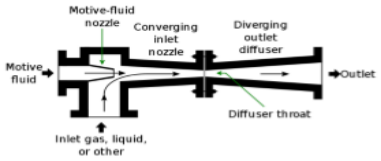
Bagian tube

OD	:	1,00	in	=	0,0254 m
BWG	:	8			
ID	:	0,17	in	=	0,0042 m
Flow Area Per Tube (a't)	:	0,3550	in^2	=	0,0002 m
Surface per Lin ft (a")	:	0,2618	ft^2	=	0,0243 m
Disusun	:	Triangular			m

Pitch : 1,25 in = 0,0318 m
Panjang Tube : 35 ft = 10,668 m
Jumlah Tube : 766 buah

20. Steam Jet Ejector (G-242)

Fungsi : Untuk memvakumkan Evaporator
Type : Single stage Steam Jet Ejector
Dasar pemilihan : Sesuai dengan kondisi tekanan vacum



Kondisi operasi
Tekanan : 0,6136 atm
Suhu : 80 °C
176 F

Tekanan Ejector = 0,6136 atm ***Ludwig; 352***
= 466,34 mmHg
Tekanan steam = 4,5 bar = 65,268 psig = 132,89 inHg
Karena termasuk low pressure, maka digunakan tekanan tersebut ***(Ulrich; 426)***

Uap yang masuk = 123,2487 kg/jam = 271,7169 lb/jam
Pemilihan ukuran berdasarkan ***Ludwig: F 6-26A; 373***
Kebutuhan steam = 147,8985 kg/jam = 326,06031 lb/jam
Ukuran steam jet ejector = 4 in = 0,1016 m

Faktor tekanan steam bberdasarkan ***Ludwig: F 6-26B; 373***
pada P steam = 65,268 psig
faktor P steam = 1,2
Jadi kebutuhan steam sebenarnya = 1,2 x 326,0603 lb/jam
= 391,2724 lb/jam
= 177,4782 kg/jam

Waktu Evakuasi
Volume pada 176 °F = 54,55 cuft/lb ***Ludwig: 6-14; 379***
Sistem volum = 54,55 cuft/lb x 271,72 lb/jam
= 14822 cuft/jam = 247,04 cuft/menit
E = 1,3 ***Ludwig: T 6-9; 375***
W'm = 60 ***Ludwig: F 6-28A; 375***

$$W'm = \frac{E \times V}{t}$$

t = 5,352446 menit

Ditetapkan :
Kecepatan superficial = 6000 ft/menit

Luas Penampang Pipa = $\frac{\text{Rate Volumetric uap}}{\text{Kecepatan Superficial}}$

= $\frac{247,0360 \text{ cuft/menit}}{6000 \text{ ft/menit}}$

= 0,0412 ft²

Diambil ukuran nozzle steam yaitu 12 inch 20

Data dari Ludwig

C2 = 30 in = 2,5 ft

C1 = 1 ft

P = 0,005 psi / 100 ft

Maka didapatkan Panjang total Pipa

L = 2,5 + 1 + 67 ft

= 70,09 ft

Diperoleh panjang pipa total = 70,09 ft

= 21,03 m

Spesifikasi

Kapasitas : 123,2487 kg/jam

Waktu Evakuasi : 5,35 menit

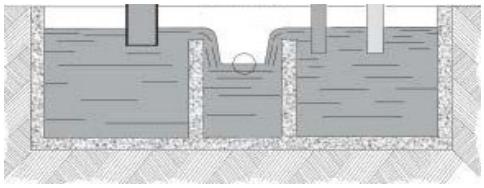
Panjang : 4,00 in

Jumlah : 1 buah

21. Hot well (F-243)

Fungsi : Menampung kondensat dari barometric condensor dan steam jet ejector

Type : Balok terbuka



Kondisi operasi

Tekanar : 1

Suhu : 80 °C

Rate Massa = 12324,87 kg/jam

Waktu = 0,5 jam

ρ bahan (air) saat 80°C = 0,9755 g/cc

= 60,9 lb/cuft

Massa bahan = 12324,87 kg/jam x 0,5 jam

= 6162,436 kg

= 13585,85 lb

Volume bahan = $\frac{13585,85 \text{ lb}}{60,90008 \text{ lb/cuft}}$

= 223,0842 ft³

Volume bahan mengisi 80% volume tangki, maka

Volume tangki = $\frac{223,08 \text{ ft}^3}{80\%}$

= 278,86 ft³

Faktor keamanan 10%

Volume tangki = 1,1 x 278,86 ft³
= 306,74 ft³
= 8,6859 m³

Menghitung dimensi Hot well

Asumsi : P = 2 L
H = 1 L

Sehingga :

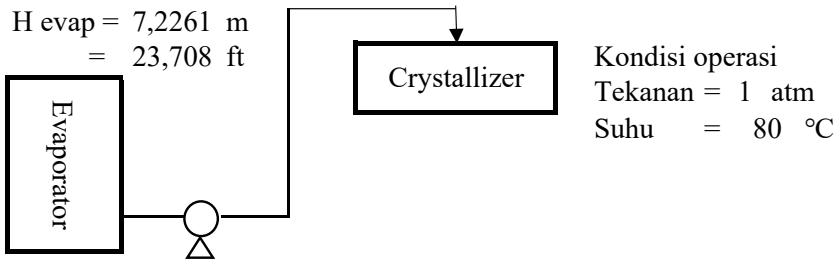
Vol Tangki = P x L x H
8,68593 m³ = 2 L x L x 1 L
L = 1,6315 m
P = 3,2631 m
H = 1,6315 m

Spesifikasi

Fungsi : Menampung kondensat dari barometric condensor dan steam
: jet ejector
Bentuk : Balok terbuka
Kapasitas : 8,685932 m³
Ukuran Hot well
Panjang : 3,2631 m
Lebar : 1,6315 m
Tinggi : 1,6315 m
Bahan konstruksi Beton
Jumlah : 1 buah

22. Pompa-7 (L-244)

Fungsi : Mengalirkan akrilamida dari Evaporator ke Crystallizer
Type : *Centrifugal pump*
Dasar pemilihan : Sesuai untuk bahan dengan viskositas < 10 cp



Komponen	A	B	n	Tc	T
C_3H_5NO	0,27378	0,252	0,28571	710	353,15
H_2O	0,3471	0,274	0,28571	647,13	353,15

$\rho = A \times B^{-(1 - T/Tc)^n}$ ***Yaws: T 8-2***

Bahan masuk

Komponen	Berat kg/j	Fraksi	ρ (g/cc)
C_3H_5NO	6359,2246	0,7266	0,8495
H_2O	2392,737	0,2734	0,9755
Total	8751,9612	1,0000	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62{,}43$$

$$= \frac{1}{\frac{0{,}7266}{0{,}8495} + \frac{0{,}2734}{0{,}9755}} \times 62{,}43$$

$$= 54{,}9776 \text{ lb/cuft}$$

Rate massa = 8751,961 kg/jam = 19294,77 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{19294{,}77 \text{ lb/jam}}{54{,}9776 \text{ lb/cuft}}$$

= 350,9568 cuft/jam = 5,84928 cuft/menit

= 43,75846 gpm = 0,097488 cuft/s

Menghitung diameter optimum dengan persamaan :

Asumsi aliran turbulen

$\text{Diameter optimum} = 3.9 \times q_f^{0.45} \times \rho^{0.13}$ ***eq. 15; Peters 4-ed; 496***

Dengan :

q_f = Fluid flow rate; (cuft/detik)

ρ = Fluid Density; (lb/cuft)

Di = Diameter dalam pipa optimum, (in)

$Di = 3{,}9 \times 0{,}0975^{0{,}45} \text{ cuft/s} \times 54{,}9776^{0{,}13} \text{ lb/cuft}$

= 2,3031 in

Dari diameter optimum, dipilih pipa 2 in, sch 40 berdasarkan McCabe

OD = 2,38 in = 0,1979 ft ***McCabe: App 3; 1090***

ID = 2,07 in = 0,1723 ft = 0,0525 m

A = 0,0233 ft²

$$\text{Kecepatan linier (v)} = \frac{qf}{A}$$

$$= \frac{0{,}0975 \text{ cuft/s}}{0{,}0233 \text{ ft}^2}$$

= 4,184 ft/s

ρ reference = 62,43 lb/cuft

sg reference = 1

μ reference = 1 cps

sg bahan = $\frac{\rho \text{ bahan}}{\rho \text{ reference}}$ x sg reference

= $\frac{54,9776 \text{ lb/cuft}}{62,43 \text{ lb/cuft}}$ x 1

= 0,8806

μ berdasarkan sg bahan :

μ bahan = $\frac{\text{sg bahan}}{\text{sg reference}}$ x μ reference

= $\frac{0,8806}{1}$ x 1 cps

= 0,8806 cps

= 0,0006 lb/ft.s

$NRe = \frac{D \, v \, \rho}{\mu}$

$= \frac{0,1723 \text{ ft} \times 4,184 \text{ ft/s} \times 54,9776 \text{ lb/cuft}}{0,000592 \text{ lb/ft.s}}$

Nre = 66957,393

Nre > 2100 (asumsi aliran turbulen benar)

Dipilih *commercial steels* , dengan :

ε = 0,000046 m ***Geankoplis: F 2.10-3; 88***

ε/D = $\frac{0,000046 \text{ m}}{0,0525018 \text{ m}}$

= 0,0008762

f = 0,008 ***Geankoplis: F 2.10-3; 88***

Digunakan persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$

Perhitungan friksi berdasarkan ***Geankoplis 3ed; T 2.10-1; 93***

Panjang pipa lurus = 13,5 m = 44,291 ft

- 1 gate valve = n x Le/D x ID
  (wide open) = 1 x 9 x 0,1723 ft
  1,5503 ft
- 4 elbow 90° = 4 x 35 x 0,1723
  = 24,115 ft

Panjang total pipa = 1,5503 ft + 44,291 ft + 24,115 ft

= 69,957 ft

Friksi yang terjadi

karena gesekan bahan dalam pipa

$F_1 = \frac{2f \times v^2 \times Le}{gc \times D}$ ***Geankoplis 3ed, eq 2.10-6; 89***

$= \frac{2 \times 0,008 \times (4,184 \text{ ft/s})^2 \times 69,957 \text{ ft}}{32,174 \text{ ft.lbm/s}^2.\text{lbf} \times 0,1723 \text{ ft}}$

= 3,5357 ft.lbf/lbm

karena kontraksi dalam pipa

$F_2 = \frac{Kc \times v^2}{2 \times \alpha \times gc}$ ***Geankoplis 3ed eq. 2.10-16; 93***

untuk aliran turbulen :

α = 1

Kc = 0,5 , maka :

$F2 = \frac{0,5 \times (4,184 \text{ ft/s})^2}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2\text{.lbf}}$

= 0,136027 ft.lbf/lbm

karena gate valve , Kf = 0,17 dari ***Geankoplis; T 2.10-1; 93***

$F3 = \frac{n \times Kf \times V1^2}{gc \quad 2}$

$= \frac{1 \times 0,17 \times (4,184 \text{ ft/s})^2}{32,174 \text{ ft.lbm/s}^2\text{.lbf} \times 2}$

= 0,0462 ft.lbf/lbm

karena ekspansi pipa ke crystallizer

$F4 = \frac{\Delta v^2}{2 \times \alpha \times gc}$ (A1 < A2, maka V1 dianggap = 0)

$\frac{v_2^2 - v_1^2}{2 \times \alpha \times gc}$

$= \frac{(4,184 \text{ ft/s})^2 - 0}{2 \times 1 \times 32,174 \text{ ft.lbm/s}^2\text{.lbf}}$

= 0,2721 ft.lbf/lbm

karena elbow 90° , Kf = 0,75 dari ***Geankoplis; T 2.10-1; 93***

$F_5 = \frac{n \times Kf \times v1^2}{gc \quad 2}$ n = jumlah elbow

$= \frac{4 \times 0,75 \times (4,184 \text{ ft/s})^2}{32,174 \text{ ft.lbm/s}^2\text{.lbf} \times 2}$

= 0,8162 ft.lbf/lbm

Sehingga :

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$

= 4,8062 ft.lbf/lbm

Energi Tekanan

$EP = \frac{\Delta P}{\rho}$

P1 = 0,613 atm

= 1297,6 lbf/ft²

= 1297,6 lbf/ft²

= 1297,5984 lbf/ft²

P_2 = 1 atm = 14,696 lbf/in²
P_2 = 2116,2166 lbf/ft²
ΔP = 2116,22 lbf/ft² - 1297,6 lbf/ft²
= 818,61822 lbf/ft²
EP = $\frac{818,61822 \text{ lbf/ft}^2}{54,9776 \text{ lbm/ft}^3}$
= 14,890024 ft.lbf/lbm

Energi Kinetik

$EK = \frac{\Delta v^2}{2 \times \alpha \times gc}$
$= \frac{(4,184 \text{ ft/s})^2}{2 \times 1 \times 32,174 \text{ lbm.ft/s}^2.\text{lbf}}$
= 0,2721 ft.lbf/lbm

Energi Potensial

ΔZ = 23,708 ft
$EP = \Delta Z \frac{g}{gc}$
= 23,708 ft x 1 lbf/lbm = 23,579 ft.lbf/lbm

Persamaan Bernoulli

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \alpha gc} + \Sigma F$
= (14,89 + 23,57942 + 0,2721 + 4,8062) ft.lbf/lbm
= 43,547683 ft.lbf/lbm

Power Pompa

$Hp = \frac{-Wf \times \text{flowrate(gpm)} \times sg}{3960}$
$= \frac{43,548 \text{ ft.lbf/lbm} \times 43,758 \text{ gpm} \times 0,8806}{3960}$
= 0,4238 Hp

Effisiensi Pompa

E = 40% ***Peters 4ed ; Figure 14 - 37; 520***
BHP = $\frac{0,4238}{40\%}$
= 1,0594 Hp

Effisiensi Motor

E = 80% ***Peters 4ed ; Figure 14 - 38; 521***
BHP = $\frac{1,0594}{80\%}$
= 1,3243 Hp

Spesifikasi :

Fungsi : Mengalirkan filtrat menuju Crystallizer
Type : *Centrifugal pump*
Power : 1 Hp = 745,7 watt
Rate volume : 43,75846 gpm = 0,1656 m^3/menit
Effisiensi pompa : 40%
Effisiensi motor : 80%
Bahan konstruksi : *Commersial steels*
Jumlah : 1 buah

23. Crystallizer (S-310)

Fungsi : Mengkristalkan akrilamida
Type : Swenson-Walker Crystallizer (Crystallizer dengan Pendingin)
Dasar pemilihan : Sesuai dengan kristalisasi metode pendinginan

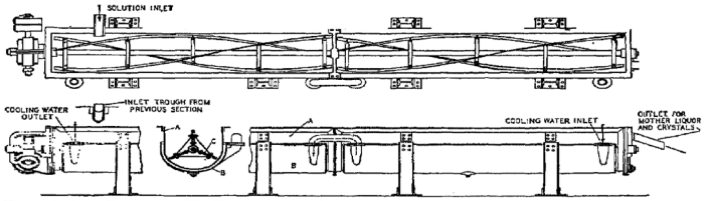


FIG. 209.—Swenson-Walker crystallizer. *A*. Trough. *B*. Jacket. *C*. Stirrer.

Kondisi operasi
Tekanan : 1 atm
Suhu : 30 °C = 303,15 K

Komponen	A	B	n	Tc
C_3H_5NO	0,27378	0,252	0,28571	710
H_2O	0,3471	0,274	0,28571	647,13

$$\rho = A \times B^{-(1 - T / Tc)^n}$$

Yaws: T 8-2

Bahan masuk

Komponen	Berat kg/j	Fraksi	ρ (g/cc)
C_3H_5NO	6359,2246	0,7266	0,8871
H_2O	2392,737	0,2734	1,0229
Total	8751,9612	1,0000	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62,43$$

$$= \frac{1}{\frac{0,7266}{0,8871} + \frac{0,2734}{1,0229}} \times 62,43$$

= 57,4658 lb/cuft

Rate massa = 8751,961 kg/jam = 19294,77 lb/jam

Rate volumetrik = $\frac{\text{Rate massa}}{\rho \text{ campuran}}$

= $\frac{19294,77 \text{ lb/jam}}{57,4658 \text{ lb/cuft}}$

= 335,7608 cuft/jam = 5,596014 cuft/menit

= 41,86378 gpm = 0,093267 cuft/s

Waktu kristalisasi = 1 jam

Volume bahan mengisi 80% volume crystallizer

Volume crystallizer = $\frac{335,7608 \text{ cuft}}{80\%}$

= 419,7 cuft

Menentukan dimensi Crystallizer

Digunakan rasio m = L/D = 3,33 ***Hugot ed 3: eq. 34.7; 733)***

Volume Crystallizer = $\frac{m \times D^3}{2} \times \left(1 + \frac{\pi}{4} \right)$

419,701 cuft = 3,33 x D^3 x $\left(1 + \frac{\pi}{4} \right)$

D^3 = 70,6086

D = 4,1332 ft

L/D = 3,33

L = 4,1332 x 3,33

= 13,764 ft

Luas Cooling area

S = V x $\frac{2 (1 + 2m)}{mD}$ ***eq. 34.7 Hugot; 733***

= 419,7 ft^3 x $\frac{2 (1 + 2 \times 3,33)}{3 \times 4,13 \text{ ft}}$

= 467,1633 ft^2

Power

Power yang dibutuhkan 16 Hp tiap 1000 cuft bahan ***Hugot; 730***

Power Crystallizer = $\frac{419,7 \text{ cuft}}{1000 \text{ cuft}}$ x 16 Hp

= 6,7152 Hp

Spesifikasi

Fungsi	:	Mengkristalkan akrilamida dengan cara pendinginan		
Type	:	Swenson-Walker Crystallizer		
Kapasitas	:	419,7011 cuft	=	11,885 m^3
Panjang	:	13,764 ft	=	4,1951 m
Diameter	:	4,1332 ft	=	1,2598 m
Luas cooling area	:	467,16 ft^2	=	142,39 m
Power	:	6,7152 Hp	=	5007,5 W
Jumlah	:	1		

24. Screw Conveyor (J-311)

Fungsi : Mengangkut kristal akrilamida menuju Rotary Dryer
Type : Standard screw-plain spouts of chutes
Dasar pemilihan : Sesuai untuk padatan sistem tertutup dengan jarak transfer dekat

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
H_2O	119,636827	0,0186	1,0229
C_3H_5NO (s)	6311,36992	0,9814	1,1220
Total	6431,00674	1	

$$\rho \text{ Campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62{,}43 \text{ lb/cuft}$$

$$\rho \text{ Campuran} = \frac{1}{\frac{0{,}0186}{1{,}0229} + \frac{0{,}9814}{1{,}1220}} \times 62{,}43 = 69{,}92 \text{ lb/cuft}$$

Rate Massa = 6431,01 kg/jam = 14180,37 lb/jam

$$\text{Rate Volume} = \frac{\text{Rate Massa}}{\text{Densitas}} = \frac{14180{,}3699 \text{ lb/jam}}{69{,}9204 \text{ lb/cuft}}$$

= 202,8073 cuft/jam
= 3,3801 cuft/menit
= 25,2867 gpm

$$\text{Power motor (Hp)} = \frac{K.C.\rho.L}{2000000}$$

Dimana :
K = 4 (untuk bahan bertekstur mirip dengan pasir)
C = kapasitas, cuft/jam
ρ = densitas bahan, lb/cuft
L = Panjang screw conveyor, ft

Badger; 627

Direncanakan panjang screw conveyor, (L) = 30 ft = 9,144 m

$$Hp = \frac{4 \times 202{,}8073 \text{ cuft/jam} \times 69{,}92 \text{ lb/cuft} \times 30 \text{ ft}}{2000000}$$

= 0,850822 Hp

Effisiensi motor = 80%

$$\text{Power motor} = \frac{0{,}8508 \text{ Hp}}{80\%}$$

= 1,0635 Hp

Dari ***Perry ed 7: T 21-6; Section 21-8*** , diperoleh :

Kapasitas maksimum	=	10	ton/jam
Diameter flight	=	10	in
Diameter pipa	=	2 1/2	in
Diameter of shaft	=	2	in
Hanger center	=	10	ft
Diameter feed section	=	9	in
Kecepatan screw conveyor	=	55	rpm

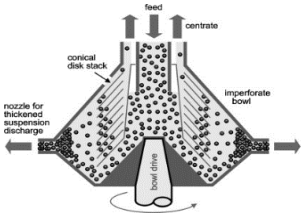
Spesifikasi :

Fungsi	:	Mengangkut kristal akrilamida menuju Rotary Dryer				
Type	:	Standard screw- plain spouts of chutes				
Kapasitas	:	202,8073	cuft/jam	=	5,742863	m^3/jam
Diameter flight	:	10	in	=	0,254	m
Diameter pipa	:	2 1/2	in	=	0,0635	m
Diameter shaft	:	2	in	=	0,0508	m
Kecepatan	:	55	rpm			
Elevasi	:	horizontal				
Panjang	:	30	ft	=	9,144	m
Effisiensi	:	80%				
Power	:	1,0635	Hp			
Jumlah	:	1	buah			

25.Centrifug (H-320)

Fungsi : Memisahkan kristal basah dengan mother liquor

Type : Disk Bowl Centrifug (Automatic Continous Dishcake)



Kondisi Operasi :

Tekanan : 1 atm

Suhu : 30 °C

Komponen	A	B	n	Tc
C_3H_5NO	0,27378	0,252	0,28571	710
H_2O	0,3471	0,274	0,28571	647,13

$$\rho = A \times B^{-(1 - T / Tc)^n}$$

Yaws: T 8-2

T = 30 °C
= 303,15 K

Feed Masuk

Kompenen	Berat (kg/jam)	Freaksi	ρ (g/ml)
C_3H_5NO (l)	47,8547307	0,005468	0,887073
C_3H_5NO (c)	6311,369917	0,721138	1,122
H_2O	2392,736535	0,273394	1,022875
Total	8751,961183	1	

$$\rho \text{ Campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62,43 = \text{lb/cuft}$$

$$\rho \text{ Campuran} = \frac{1}{\frac{0,0055}{0,8871} + \frac{0,7211}{1,122} + \frac{0,2734}{1,0229}} \times 62,4 = 68,142 \text{ lb/cuft}$$

Rate massa = 8751,961 kg/jam = 19294,77 lbm/jam

$$\text{Rate volume} = \frac{\text{Rate massa}}{\text{Densitas}} = \frac{19294,77 \text{ lbm/jam}}{68,142 \text{ lbm/cuft}}$$

= 283,1536 cuft/jam
= 4,719227 cuft/menit
= 35,30454 gpm

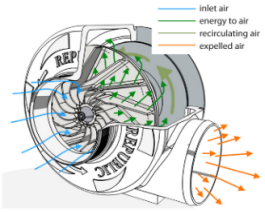
Berdasarkan rate volumetrik dipilih spesifikasi centrifuge berdasarkan ***Perry 8ed: T 18-12***

Spesifikasi :

Fungsi : Memisahkan kristal basah dengan mother liquor
Type : Disk bowl centrifuge (automatic continous dishcake)
Bahan : Carboon steel
Kapasitas Centrifug : 5 - 50 gal/menit
Kapasitas maksimum : 50 gal/menit
Diameter bowl : 13
Speed : 7500 rpm
Centrifuge Force : 10400
Power motor : 6 Hp
Jumlah : 1 buah

26. Blower (G-321)

Fungsi : Menarik udara dari udara bebas menuju molecular sieve tray
Type : Centrifugal Blower
Dasar pemilihan : Sesuai dengan jenis bahan dan effisiensi tinggi



Rate massa udara = 12252,46 kg/jam = 27012,05 lb/jam
ρ udara pada 30°C = 545,7 °R
Kondisi standard = 491,67 °R = 32 °F
Tekanan = 1 atm ***Himmelblau 6***
Spesific volume, V = 359,05 ft³/lbmol ***ed: T 4.1; 266***
BM udara = 28,951 ***Perry 7 ed: T 2-30; p 2-97***
ρ udara = $\frac{491,67\ °R}{545,7\ °R} \times \frac{28,951\ lb/lbmol}{359,05\ ft^3/lbmol}$
= 0,0726 lb/cuft

Maksimum differential pressure = 1,5 psi ***Perry ed.7; p 10-45; 746***
Pemilihan tekanan operasi = 1 psi 1 Psi = 27,7 in H_2O
= 27,7 inH_2O

Rate Volumetrik (Q) = $\frac{\text{Rate massa}}{\rho \text{ udara}}$
= $\frac{27012,05\ lb/jam}{0,072649\ lb/cuft}$
= 371816,9 cuft/jam
= 6196,948 cuft/menit

Power yang dibutuhkan untuk menghembuskan udara :
Hp = 0,000157 x Q x P

Dimana: Q = Rate volumetrik, cuft/menit
P = Tekanan operasi, inH_2O
Perry ed.7; eq.10-88

Hp = 0,000157 x 6196,9 cuft/menit x 27,7 inH_2O
= 26,95 Hp

Effisiensi = $\frac{\text{Hp}}{\text{Hp shaft}}$ ***Perry ed.7; eq.10-89***

Efisiensi = 40% - 80% ***Perry ed.7; p 10-46; 747***
Diambil = 80%
Hp shaft = $\frac{26,9\ Hp}{80\%}$

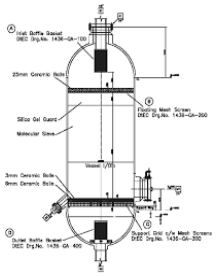
= 33,687 Hp

Spesifikasi

Fungsi : Menarik udara dari udara bebas menuju molecular sieve tray
Type : Centrifugal blower
Bahan : Carbon Steel
Rate volume : 6196,948 cuft/menit
Power : 33,687 Hp
Effisiensi : 80%
Jumlah : 1 buah

27. Molecular Sieve Tray (D-322)

Fungsi : Mengurangi impurities dalam udara bebas yang masuk
Type : 3 A
Dasar pemilihan : Sesuai dengan jenis bahan yang dikeringkan



H_2O tertahan = 144,7515 kg/jam
Kapasitas serap MS 3A = 30 (w/w)%
Densitas MS 3A = 0,6
1 kg MS 3A mampu menyerap 300 g senyawa H_2
Gas yang tertahan dalam 1 hari = 144,7515 kg/jam x 24 jam
= 3474,036 kg

$$\frac{1}{x}\text{kg} = \frac{0,3}{3474}\text{kg}$$

Kebutuhan MS 3A = 11580,12 kg
Bila regenerasi dilakukan 8 jam sekali maka MS 3A yang dibutuhkan
3 x sehari = 3860,04 kg

$$\text{Volume MS} = \frac{\text{kebutuhan MS}}{\text{Densitas MS}} = \frac{3860,04}{0,6} = 6433,4 \text{ L}$$

Efisiensi = 85%

$$\text{Volume Tangki} = \frac{6433,4}{85\%} = 7568,7 \text{ L} = 7,569 \text{ m}^3$$

Jumlah tangki = 1 buah
= 8 m^3

Asumsi : H = 2 D

Volume resin = $\frac{\pi}{4}$ x D^2 x H

7,569 = 0,79 D^2 x 2 D

4,8208 = D^3

D = 1,6893 m

H = 3,3786 m

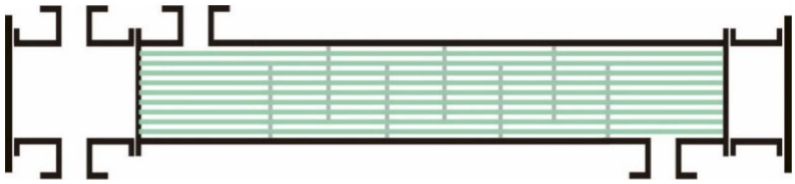
Ruang kosong di atas resin = 1 m
Ruang kosong di bawah resin = 1 m
Tinggi total = 4,88 m

Spesifikasi

Fungsi	:	Mengurangi impurities dalam udara bebas yang masuk
Kapasitas	:	6433,3995 L
Dimensi	:	Diameter = 1,6893 m
	:	Tinggi = 3,3786 m
Bahan resin	:	3A
Bahan konstruksi	:	Carbon steel SA-283 grade C
Jumlah	:	1 buah

28. Heater Udara (E-323)

Fungsi	:	Memanaskan udara hingga 80℃
Type	:	1 - 2 Shell And Tube Heat Exchanger (Fixed Tube)
Dasar pemilihan	:	Sesuai untuk kapasitas yang besar dan memiliki luas perpindahan panas yang besar



1) Neraca Panas

m udara	=	12252,46	kg/jam	=	27012,05 lb/jam
Q supply	=	700781	kJ/jam	=	664212 Btu/jam
m steam	=	330,5033	kg/jam	=	728,635 lb/jam

2) Log Mean Temperatur Difference (LMTD)

Fluida dingin

Suhu udara					
t1 =	30	℃	=	86	°F
t2 =	80	℃	=	176	°F

Suhu steam					
T1=	148	℃	=	298,4	°F
T2=	148	℃	=	298,4	°F

Δt_1 = T2 - t1 = 298,4 - 86 = 212,4 °F

Δt_2 = T_1 - t_2 = 298,4 - 176 = 122,4 °F

Kern; 90

$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{298,4 - 298,4}{176 - 86} = 0$

$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{176 - 86}{298,4 - 86} = 0,4237$ ***Kern: eq. 5.14; 149***

$$\Delta t\ LMTD = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$$ ***Kern: eq. 5.14; 89***

$$= \frac{122,4\ °F - 212,4\ °F}{\ln \frac{122,4\ °F}{212,4\ °F}} = 163,287\ °F$$

FT = 1 ***Kern: Fg. 18; 828***

$\Delta t = \Delta t\ LMTD \times FT$ = 163,29 °F x 1 = 163,29 °F ***Kern : Pers.7.42, Hal. 149***

3) Temperatur rata-rata

tc = tav $H_2SO_4.H_2O$ = $\frac{86 + 176}{2}$ °F = 131 °F

Tc = tav steam = $\frac{298 + 298,4}{2}$ °F = 298,4 °F

0 = 0 cp

Range UD = 5 - 50 ***Kern: T 8; 840***

Trial UD = 20 Btu/jam.ft².°F

Luas penampang Heater :

Q = A. UD.ΔT

$A = \frac{664212\ BTU/jam}{20\ Btu/jam.ft^2.°F \times 163\ °F} = 203,39\ ft^2$

Dari Kern T 10; 843

Pipa (Tube)

OD = 1 in

BWG = 9

ID = 0,704 in

Flow Area (a't) = 0,389 in^2

Surface Per Lin ft (a") = 0,2618 ft²/ft panjang

Disusun Triangular

Pitch = 1 1/4 in

Panjang Tube = 6 ft

Jumlah Tube :

$$Nt = A' / a'' \times L$$

$$= \frac{203{,}39 \text{ ft}^2}{0{,}2618 \text{ ft}^2/\text{ft panjang} \times 6 \text{ ft}} = 129{,}4805$$

Nt distandardkan dengan ketetapan pada ***Kern T 9***

Nt = 140
IDs = 19,25 in
n = 4 passes

$$\text{UD koreksi} = \frac{Nt}{Nt \text{ standard}} \times \text{UD Trial}$$

$$= \frac{129}{140} \times 20 \text{ Btu/jam.ft}^2.^\circ\text{F}$$

$$= 18{,}49721 \text{ Btu/jam.ft}^2.^\circ\text{F}$$

Perancangan HE

Type HE = 1 - 2 Artinya : 1 lewatan pada shell
2 lewatan maks pada bagian tube

Bagian shell

IDs = 19,3 in
n = 4
B = 4 x IDs
= 77 in

Bagian tube

OD	=	1	in
BWG	=	9	
ID	=	0,704	in = 0,0587 ft
Flow area per tube (a't)	=	0,389	in²
surface per lin ft (a")	=	0,2618	ft²
Disusun	=	Triangular	
Pitch (Pt)	=	1,25	in
Panjang (l)	=	6	ft
Nt	=	140	buah
De	=	0,72	***Kern F 28; 838***

Bagian Tube (Steam)	Bagian Shell (Udara)
Menghitung Nre Tube	**Menghitung Nre Shell**
$at = \frac{Nt \times a't}{n \times 144}$	$as = \frac{IDs \times C' \times B}{144 \times Pt}$
$= \frac{140 \times 0{,}389}{4 \times 144}$	C' = Pt - OD
$= 0{,}0945 \text{ ft}^2$	= 1 - 1
	= 0,25
	$as = \frac{19{,}25 \times 1/4 \times 77}{144 \times 1{,}25}$
	$= 2{,}0587 \text{ ft}^2$

Gt = W Steam / at
= 728,6350214 lb/jam / 0,0945 ft²
= 7706,4593 lb/ jam ft²
μ Steam Pada Tc = 298,4 F
μ Steam = 0,013 Cp ***Kern; 825***
= 0,0315 lb/ft jam
ID = 0,7 in = 0,0586 ft
Nre t = Gt x ID / μ Steam
= 7706,4593 x 0,0586 / 0,031454
= 14367,94

Koefisien Perpindahan Panas

hio = 1500 Btu/jam.ft² F ***Kern;***
tw = tc + hio / (hio + ho) x (Tc - tc) ***164***
= 131 + 1500 / (1500 + 50) x 167
= 292,989 F
= 418,144 K

Gs = W Bahan / as
= 27012,0473 lb/jam / 2,0587 ft²
= 13121,0485 lb/ jam ft²
μ Bahan Pada tc = 131 F
μ = 0,019 Cp ***F.14; 823***
= 0,046 lb/ft jam
0,4087
De = 4 x as / Watted Perimeter ***Kern; 105***
= 4 x 2,0587 / Nt . π . (OD/12)
= 4 x 2,0587 / 140 x π x 0,08
= 0,2248 ft
Nre = Gs x De / μ Bahan
= 13121,048 x 0,22479 / 0,046
= 64158,302

Koefisien Perpindahan panas

jH = 160 ***Kern: F 28; 838***
Pada tc = 131 F
Kern: T 4; 800
k = 0,1832 Btu/jam.ft². °F
Badger: App 7; 641
Cp = 0,2405 BTU/lb. F
⌈ Cp μ ⌉ ^1/3 / k = 0,24 x 0,046 ^0.3 / 0,1832
= 0,3922
ho = Jh x k/de x ⌈ Cp μ ⌉ ^1/3 x φs
ho/φs = 160 x 0,1832/0,2248 x 0,3922
= 51,1484 Btu/jam.ft².°F
Pada Tw = 292,99 F
μ = 0,022 cp ***Badger: App***
= 0,0532 lb/ft jam ***3; 633***

φw = ⌈ μ ⌉^0.14 / μ
= 0,046 ^0.14 / 0,0532

	= 0,9797 ho = ho φs / φw = 51,1484 x 0,9797 = 50,11 Btu/jam.ft².°F

Clean Overall Coefficient, Uc

$$Uc = \frac{hio \times ho}{hio + ho}$$

$$= \frac{1500 \text{ Btu/jam.ft}^2.^\circ\text{F} \times 50{,}11 \text{ Btu/jam.ft}^2.^\circ\text{F}}{1500 \text{ Btu/jam.ft}^2.^\circ\text{F} + 50{,}11 \text{ Btu/jam.ft}^2.^\circ\text{F}}$$

$$= 48{,}48947 \text{ Btu/jam.ft}^2.^\circ\text{F}$$

Design Overall Coefficient, UD

A = Nt x l x a"

= 140 x 6 ft x 0,2618 ft²/ft panjang

= 219,91 ft²

$$Ud = \frac{Q}{A \times \Delta T \text{ LMTD}}$$

$$= \frac{664212{,}0274 \text{ Btu/jam}}{219{,}91 \text{ ft}^2 \times 163{,}29 ^\circ\text{F}}$$

= 18,497 Btu/Jam.ft². °F

Dirt Factor Rd

$$Rd = \frac{Uc - Ud}{Uc \times Ud}$$

$$= \frac{48{,}489 \text{ Btu/jam.ft}^2.^\circ\text{F} - 18{,}497 \text{ Btu/jam.ft}^2.^\circ\text{F}}{48{,}489 \text{ Btu/jam.ft}^2.^\circ\text{F} \times 18{,}497 \text{ Btu/jam.ft}^2.^\circ\text{F}}$$

= 0,033439 ft².°F.jam/BTU = 0,0334392

Rd ketentuan = 0,002 ***Kern: T 12; 845***

Rd Hitung > Rd Ketentuan, Maka Alat dapat digunakan

PRESSURE DROP

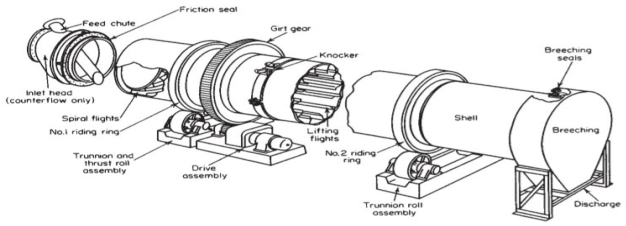
Bagian Tube (Steam)	**Bagian Shell (Udara)**
Suhu Steam = 148 C = 298,4 F ***Kern T7*** Didapat Spesifik Volume = 6,66 s = 1 / 6,655 / 62,43 = 0,0024 **Nre** = 14367,943 f = 0,0002 ***Kern: F 26; 836*** ΔPt = f.Gt².L.n / 5,22 x 10^10 x Di x s x ϕt = 0,0033 psia < 2 psia Memenuhi untuk steam	Nre = 64158,302 f = 0,0015 ***F 29; 839*** IDs = 19,25 in = 1,6042 ft N+1 = 12 L / B = 11,221 ΔPs = f.Gs².Ds.(N+1) / 5.22 x 10^10 x De x s x ϕs = 0,0004 < 2 psia Memenuhi

Spesifikasi

Fungsi	:	Memanaskan udara hingga 80°C	
Type	:	1 - 2 Shell and tube Heat Exchanger	
Tube			
OD	:	1	in
BWG	:	9	
ID	:	0,7040	in
Flow area per tube (a't)	:	0,3890	in^2
Surface per lin ft (a")	:	0,2618	ft^2
Disusun	:	Triangular	
Pitch	:	1,25	
Panjang Tube	:	6	ft
Jumlah Tube	:	140	Buah
Diameter Shell	:	19,25	in
Faktor Pengotor			
Rd ketentuan	:	0,002	m^2 C/ W
Rd hitung	:	0,033	m^2 C/ W
Preasure Drop			
Shell	:	0,0004	psi
Tube	:	0,0033	psi
Jumlah	:	1 Buah	

29. Rotari Dryer (B-320)

Fungsi : Mengeringkan akrilamida dengan udara panas
Type : Single Shell Direct-Heat Rotary Dryer
Dasar pemilihar : Sesuai untuk pengeringan bahan padatan



Kondisi operasi
Tekanan : 1 atm
Suhu : 75 °C

Bahan masuk

Komponen	Berat (kg/jam)	Fraksi	ρ (g/cc)
H_2O	119,6368	0,0186	1,0229
kristal C_3H_5NO	6311,3699	0,9814	1,1220
Total	6431,0067	1	

$$\rho \text{ Campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62,43 = \text{lb/cuft}$$

$$\rho \text{ Campuran} = \frac{1}{\frac{0,0186}{1,0229} + \frac{0,9814}{1,1220}} \times 62,43 = 69,92 \ \frac{\text{lb}}{\text{cuft}}$$

Rate Massa = 6431,01 kg/jam = 14180,37 lb/jam
Jumlah produk keluar = 6251,788 kg/jam = 13782,833 lb/jam
Massa air menguap = 118,4738 kg/jam = 261,19002 lb/jam

Dari Neraca Panas :
Total panas = 1308518 kJ/jam
Suhu bahan masuk = 30 °C = 86 °F t_1
Suhu bahan keluar = 75 °C = 167 °F t_2
Suhu udara masuk = 80 °C = 176 °F T_1
Suhu udara keluar = 42 °C = 108 °F T_2
ΔTh = 176 - 167 °F = 9 °F
ΔTc = 108 - 86 °F = 21,6 °F

Log Mean Temperatur Difference

$$\Delta T\ LMTD = \frac{\Delta Th - \Delta Tc}{\ln \frac{\Delta Th}{\Delta Tc}}$$

$$= \frac{9\ °F - 21,6\ °F}{\ln \frac{9\ °F}{21,6\ °F}}$$

= 14,4 °F = 263,37 K

Perancangan Dimeni Rotary Dryer

Rotary dryer beroperasi pada peripheral speed: 60-75 ft/menit , dipilih 75
Diamter rotary dryer, D = 1 - 3 m ***Ulrich: T 4-10; 132***
Dipilih diameter = 3 m = 9,8425 ft = 118,11 in
Rasio L/D = 4 - 6
Dipili rasio L/D = 4
maka panjang rotary dryer :

$$\frac{L}{D} = 4$$

L = 12 m = 39,37 ft
Perhitungan Area of Drum (A)

$$A_s = \frac{\pi}{4} \times D^2$$

$$= \frac{\pi}{4} \times 3^2$$

= 7,07 m² = 76,047 ft²

Perhitungan koefisien volumetrik heat transfer (Ua)

$$Ua = \frac{240 \times G^{0,67}}{D}$$ ***Ulrich: T 4-10; 132***

Dimana: Ua = koefisien volumetrik heat transfer, J/m³.s.K
G = gas massa velocity, kg/s.ı (0,5 - 5 kg/s.m²)
D = diameter dryer, m
Dipilih : G = 3 kg/s.m²

Maka, Ua = $\frac{240 \times G^{0,67}}{3}$

= 167,02 J/m³.s.K

Kecepatan putar rotary dryer (N)

Kecepatan peripheral dari putaran rotary dryer (v) = 0,25 - 0,5 m/s

dipilih : 0,5 m/s ***Perry 7ed: 12-56***

untuk merubah dalam satuan rpm, maka:

N (rpm) = $\frac{60}{2\pi \times r} \times$ v (m/s)

= $\frac{60}{2\pi \times 1,5} \times 0,5$

= 3,1847 rpm

Time Of Passage

$$\theta = \frac{0,23 \times L}{S \times N^{0,9} \times D} \pm 0,6 \frac{B \times L \times G}{F}$$ ***Perry 7th ed; 12-55***

Keterangan :

θ = time of passage, menit

L = panjang rotary dryer, ft

G = rate flue gas, lb/j ft2

F = rate feed , lb material kering / jam

B = konstanta (tergantung dari sifat material)

S = slope, ft/ft

Rotary dryer beroprasi dengan sistem counter current , maka :

$$B = 5 (Dp)^{-0,5}$$ ***Perry 7th ed; 12-55***

Diameter partikel, Dp = 10 mesh

= 2 mm

= 2000 µm

B = 0,1118

Slope rotary dryer (S) = 0 - 8 cm/m ***Perry 7th ed; 12-56***

Diambil S = 4 cm/m = 0,039 ft/ft

Rate flue gas (G) = 0,5 - 5 kg/s.m²

Diambil G = 5 kg/s.m²

= 3686,7 lb/jam.ft²

$\theta = \frac{0,23 \times 39,37}{0,04 \times 2,8364 \times 9,8425} \pm 0,6 \frac{0,1118 \times 39,37 \times 3686,7}{14180,36987}$

= 8,31167 ± 0,6866

= 8,9983 menit dan 7,625042 menit

= 539,898 s 457,5025 s

Perhitungan sudut rotary dryer :

Slope = 0,039 ft/ft

Panjang rotary dryer = 39,37 ft

Slope actual = 0,039 ft/ft x 39,37 ft
= 1,536393 ft = 0,4683 m
tg α = 0,4683
α = 28,981 °
α = 29 °

Menentukan tebal shell

P operasi = 1 atm = 14,7 psi
P design = 1,1 x 14,7 psi
= 16,17 psig

Direncanakan :

1. Bahan konstruksi = Carbon steel SA-203 grade B
   f = 17500 psi ***T 13.1 B&Y; 251***
2. Pengelasan double welded butt joint
   E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Tebal shell berdasarkan ASME code untuk tangki silinder :

$$ts = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$ ***eq. 13.1 B&Y; 254***

Dimana :

ts = tebal shell (in) C = faktor korosi
P = tekanan design (Psi) f = alllowable stress
ri = jari-jari dalam (in)
E = faktor pengelasan

Mencari tebal shell (ts) menggunakan f yang diijinkan

$$ts = \frac{16{,}170\ psig \times 59{,}055\ in}{17500\ psi \times 0{,}8 - 0{,}6 \times 16{,}17\ psig} + 1/8$$

= 0,1933 in

ts yang diperoleh di standarkan dengan tebal shell yang dijual dipasaran dengan melihat T 5.7 B&Y; 90

ts = 4/16 in

Berat Total Rotary Dryer

Berat Silinder :

$$Ws = (1/4\ \pi\ Do^2 - Di^2) \times L \times \rho$$

Do = Diameter luar silinder shell
= Di + (2 x 1/4)
= 118,1 in + 1/2 in
= 118,6 in = 9,8842 ft
Di = Diameter dalam silinder shell = 9,8425 ft
ρ = Densitas steel = 485 lb/cuft ***Perry ed 7 : T2-118***
L = Panjang Rotary Dryer = 39,37 ft

Maka Ws :

Ws = 0,25 x π (97,697 - 96,875) ft² x 39,37 ft x 485 lb/ft³
= 12320,292 lb

Berat Isolasi

$$Wt = 1/4\ \pi\ Diso^2 - Do'\ x\ L\ x\ \rho$$

Diso = Diameter luar isolasi
= Do + 2 ts
= 9,9 ft + (2 x 0,0208) ft
= 9,9259 ft

ρ = Densitas Isolasi
= 115 lb/cuft ***Perry ed 7: T2-118***

Maka Wt :

Wt = 0,25 x π x (98,523 - 97,697) ft² x 39,4 ft x 115 lb/ft³
= 2933,6 lb

Berat Flight

$$Wf = n \times L \times h \times t \times \rho$$

n = Jumlah Flight = 0.6 D - D ***Perry 7th ed; 12-53***
Diambil (n) = 0,8 D
= 0,8 x 9,88 ft
= 7,91 ft
= 8 Buah

h = Tinggi Flight = 1/8 D - 1/12 D
Diambil (h) = 1/10 D ***Perry 7th ed; 12-53***
= 1/10 x 9,9 ft
= 0,99 ft

t = Tebal Flight = π D/12
= 3,14 x $\frac{9,9}{12}$
= 2,5864 ft

Wf = n x L x h x t x ρ
= 8 x 39,4 ft x 0,99 ft x 2,59 ft x 485 lb/cuft
= 390506,4941 lb

Berat Material :

W = Rate Feed x Θ
= 14180,37 x 9 x $\frac{1}{60}$
= 2126,7 lb

Berat Gear

$$Wg = 0,25 \times \pi \times b \left(D^2 - d^2 \right) \rho$$

Keterangan :
D gear = Do + (0.636 Pc)
= 118,6 + 1,272
= 119,9 in
b = Lebar Permukaan Gear
= (2.38 Pc) + (0.25) ***Hesse T15-6; 446***
Dimana Pc = Circular = 1,8 - 2 in
Diambil Pc = 2 in
Jadi b = 4,76 + 0,25
= 5,01 in
d = Diameter Luar Shell Rotary Dryer
= 9,8842 ft
ρ = Densitas Cast Iron
= 450 lb/cuft ***Perry ed7: T2-118***

$$Wg = \frac{\pi}{4} \times \frac{5,01}{12} \times (99,804 - 97,697) \times 450$$
$$= 0,785 \times 0,4175 \times 2,1067 \times 450$$
$$= 310,7 \text{ lb}$$

Berat Riding Ring

$$Wr = 2 \times \frac{\pi}{4} \times (D^2 - d^2) \rho$$

Keterangan :
b = 5,01 in
d = 9,88 ft
D = Dimensi Riding ring ***Perry ed7: 12-60***
= d + 2
= 9,88 + 2
= 11,9 ft
Wr = 2 x 0,785 x 0,4175 (141,23 - 97,697) x 450
= 12841,762 lb
Jadi Berat Total Rotary Dryer :
W total = 12320 + 2933,6 + 390506 + 2126,7 + 310,7 + 12842
= 421039,547 lb
= 191152 kg

Power Penggerak (BHP)

$$BHP = \frac{N \times (4.75\, d\, w + 0.1925\, DW + 0.33W)}{100000}$$ ***Perry ed7: eq. 12-60***

BHP = Brake Horse Power yang dibutuhkan
d = diameter shell ,ft
D = diameter riding ring = (d+2),ft
w = berat material , lb
W = berat total rotary dryer,lb

N = putaran rotary dryer , rpm

$$BHP = \frac{8 \times ((4{,}75 \times 9{,}84 \times 2126{,}7) + (0{,}19 \times 11{,}9 \times 421040 + (0{,}33 \times 421039{,}5))}{100000}$$

= 96,127

Effisiensi Motor = 80 %

Power Motor = $\frac{96{,}13}{0{,}8}$

= 120,16 hp

= 120 hp

Spesifikasi

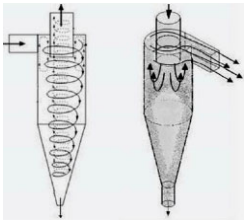
Fungsi	:	Mengeringkan kristal akrilamida dengan udara panas
Type	:	Sigle Shell Direct Rotary Dryer
Kapasitas	:	14180,37 lb/jam
Ukuran	:	Diameter = 3,0000 m = 9,8361 ft
		Panjang = 12 m = 39,3443 ft
		Slope = 0,039 ft/ft (29 °)
Putaran	:	3,185 Rpm
Kecepatan Udara	:	3686,7 lb/jam ft^2
Kecepatan Putaran	:	75 ft/menit
Time Of Passage	:	8,9983 Menit
Jumlah Flight	:	8 buah
Tinggi Radial Flight	:	0,9884 ft
Power	:	120 Hp = 89483,98 W
Jumlah	:	1 Buah

30. Cyclone (H-324)

Fungsi : Untuk memisahkan padatan yang terikut pada udara

Type : Cyclone separator

Dasar pemilihan : Sesuai untuk memisahkan padatan dari udara



Kondisi operasi :

Tekanan operasi : 1 atm

Suhu operasi : 42 °C

: 315 K

BM udara = 28,951 (kg/kmol or lb/lbmol) ***Perry 7 ed: T 2-30; p 2-97***

ρ = 0,78102 Kmol/m^3

ρ = 0,78102 kmol/m^3 x $\frac{28{,}951}{1000}$ kg/kmol x $\frac{28{,}951}{16{,}018}$ lb/lbmol = 0,0409 lb/ft^3

Komponen	C_1	C_2	C_3	C_4
Udara	2,8963	0,26733	132,45	0,27341

$$\rho = \frac{C_1}{C_2^{(1+(1-T/C_3).C_4}}$$

Perry 7 ed: T 2-30; p 2-97- 2-98

Komponen	A	B	n	Tc
H_2O	0,3471	0,274	0,28571	647,13

$$\rho = A \times B^{-(1 - T / Tc)^n}$$

Yaws

Bahan masuk

Komponen	Berat kg/j	Fraksi	ρ (g/cc)
C_3H_5NO	63,1376	0,3477	1,1220
H_2O (g)	118,4738	0,6523	1,0118
Total	181,611	1,0000	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62,43$$

$$= \frac{1}{\frac{0,3477}{1,1220} + \frac{0,6523}{1,0118}} \times 62,43$$

$$= 65,3988 \text{ lb/cuft}$$

Rate massa = 181,611 kg/jam = 400,3847 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{400,3847 \text{ lb/jam}}{65,3988 \text{ lb/cuft}}$$

= 6,122203 cuft/jam = 0,102037 cuft/menit

= 0,763337 gpm = 0,001701 cuft/s

Udara

Rate Udara Masuk Cyclone = 118,47 Kg/jam = 261,2347 lb/jam

$$\text{Rate Volume} = \frac{\text{Rate Massa}}{\text{Densitas}}$$

$$= \frac{261,2347 \text{ lb/jam}}{0,040867 \text{ lb/cuft}}$$

= 6392,4 Cuft/jam

= 1,7757 Cuft/s

Time Of Passes = 2 Detik (Asumsi)

Volume Bahan = 1,7757 x 2 Detik

= 3,5513 Cuft

Volume Cyclone = 20 % Lebih Besar Dari Volume Bahan

= 4,2616 Cuft

Berdasarkan ***Ulrich T 4-23; 220*** H/D = 3 - 8
Dipilih H/D = 4
Volume Cyclone = 1/4 x π x D^2 x H
4,2616 ft^3 = 1/4 x π x D^2 x 4 D
D = 1,1072 ft
= 13,29 in = 0,363 m
H = 6,643 Ft
= 79,716 in = 2,178 m
Dc = 13,29 in
Bc = 1/4 Dc = 3,32 in ***Perry ed7; 17-27***
De = 1/2 Dc = 6,64 in
Hc = 1/2 Dc = 6,64 in
Lc = 2 Dc = 26,6 in
Sc = 1/8 Dc = 1,66 in
Zc = 2 Dc = 26,6 in
Jc = 1/4 Dc = 3,32 in
Area Cyclone = 1/4 x π x D^2
= 3/5 in^2
= 0,004104 ft^2
Kecepatan bahan = $\frac{1,7757 \text{ cuft/s}}{0,0041 \text{ ft}^2}$
= 432,63 ft/s
= 131,87 m/s

$$Dp\ min = \left(\frac{9\ \mu\ Bc}{\pi\ Ns\ Vc\ (\rho s-\rho)}\right)^{0,5}$$ ***Perry ed7; 17-28***

Keterangan :
Dp min = Diameter partikel minimum
Bc = Besar inlet dust, ft
Ns = Jumlah belokan yang dilalui udara
Vc = Kecepatan gas masuk cyclone, ft/dt
ρs = Densitas bahan , lb/cuft
ρ = Densitas gas , lb/ft dt
μ = viskositas gas, lb/ft.dt
μ udara = 0,021 cP = 0,00001 lb/ft.dt
Ns = 6 ***Perry 7ed; Fig 17-38***

$$Dp\ min = \left(\frac{9 \text{ x } 1E\text{-}05 \text{ lb/ft.s} \text{ x } 0,2768 \text{ ft}}{3,14 \text{ x } 6 \text{ x } 432,6 \text{ ft/s} \text{ x } 65,3579 \text{ lb/cuft}}\right)^{0,5}$$
= 6,84E-06 ft

Perancangan Tebal Shell Dan Tutup
Bahan Konstruksi : Carbon Steel 283 Grade C
F Allowable : 12650 Psi ***B&Y: T 13.1; 254***
Faktor Korosi : 1/8
Sambugan Las : 0,8

Tekanan Desain (P) = 1 Atm = 14,7 Psi

Tebal Shell Minimum

Asumsi ts = 3/16

$$ts = \frac{P \times Di}{f \times E - 0.6\ P} + C$$

$$1/5 = \frac{14,7 \times 13,2860}{f \times 0,8 - 0,6 \times 14,7} + 1/8$$

$$1/16 = \frac{14,7 \times 13,2860}{f \times 0,8 - 0,6 \times 14,7}$$

$$= 3917,1166 < 12650$$

f actual kurang dari f allowable sehingga asumsi ts 3/16 dapat digunakan

Tebal Tutup Atas

Karena kondisi atmospheric Tebal tutup atas = Tebal Shell = 3/16 in

Tebal Tutup Bawah

Dengan α conis = 30

α = 1/2 Sudut Conis

= 15

Asumsi th = 3/16

$$th = \frac{P \times D}{2 \cos \alpha\ (f E - 0.6\ P)} + C$$

$$3/16 = \frac{14,7 \times 13,29}{2 \times 0,9659 \times (f \times 0,8 - 0,6 \times 14,7)} + 1/8$$

$$1/16 = \frac{14,7 \times 13,29}{2 \times 0,9659 \times (f \times 0,8 - 1 \times 14,7)}$$

$$= 2032,9668 < 12650$$

f actual kurang dari f allowable sehingga asumsi th 3/16 dapat digunakan

Spesifikasi

Fungsi	:	Untuk memisahkan padatan yang terikut udara			
Type	:	Cyclone Separator			
Kapasitas	:	261,235	lb/jam		
Tebal Shell	:	3/16	in		
Tebal Tutup Atas	:	3/16	in		
Tebal Tutup Bawah	:	3/16	in		
Ukuran	:	Bc =	3,3215	in =	0,0844 m
		Dc =	13,2860	in =	0,3375 m
		De =	6,6430	in =	0,1687 m
		Hc =	6,6430	in =	0,1687 m
		Lc =	26,6	in =	0,6749 m
		Sc =	1,66	in =	0,0422 m
		Zc =	26,6	in =	0,6749 m
		Jc =	3,32	in =	0,0844 m
Bahan Konstruksi	:	Carbon Steel SA 283 Grade C			
Jumlah	:	1 Buah			

31. Cooling Conveyor (E-330)

Fungsi : Untuk mendinginkan kristal akrilamida dari suhu 75°C menjadi 30°C
Type : Plain Spouts Of Chutes
Dasar pemilihan : Dapat mendinginkan sekaligus mentransfer bahan

Kondisi operasi :
Tekanan operasi : 1 atm
Suhu operasi : 30 °C
: 303,15 K

Komponen	A	B	n	Tc
H_2O	0,3471	0,274	0,28571	647,13

$$\rho = A \times B^{-(1 - T/Tc)^n}$$ ***Yaws***

Bahan masuk

Komponen	Berat kg/j	Fraksi	ρ (g/cc)
C_3H_5NO	6313,131	0,9998	1,1220
H_2O	1,163028	0,0002	1,0229
Total	6314,294	1,0000	

$$\rho \text{ campuran} = \frac{1}{\Sigma \frac{\text{Fraksi berat}}{\rho \text{ komponen}}} \times 62,43$$

$$= \frac{1}{\frac{0,9998}{1,1220} + \frac{0,0002}{1,0229}} \times 62,43$$

$$= 70,0452 \text{ lb/cuft}$$

Rate massa = 6314,294 kg/jam = 13920,64 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate massa}}{\rho \text{ campuran}}$$

$$= \frac{13920,64 \text{ lb/jam}}{70,0452 \text{ lb/cuft}}$$

= 198,7379 cuft/jam = 3,312298 cuft/menit
= 24,7793 gpm = 0,055205 cuft/s

$$\text{Power motor (Hp)} = \frac{K.C.\rho.L}{2000000}$$ ***Badger; 627***

Dimana :
K = 4 (untuk bahan bertekstur mirip dengan pasir)
C = kapasitas, cuft/jam
ρ = densitas bahan, lb/cuft
L = Panjang screw conveyor, ft ***Badger; 627***

Direncanakan panjang screw conveyor, (L) = 30 ft = 9,144 m

$$Hp = \frac{4 \times 198{,}7379 \text{ cuft/jam} \times 70{,}05 \text{ lb/cuft} \times 30 \text{ ft}}{2000000}$$

= 0,835238 Hp

Effisiensi motor = 80%

$$\text{Power motor} = \frac{0{,}8352 \text{ Hp}}{80\%}$$

= 1,044 Hp

Dari ***Perry ed 7: T 21-6; Section 21-8*** , diperoleh :

Kapasitas maksimum	=	5	ton/jam
Diameter flight	=	9	in
Diameter pipa	=	2 1/2	in
Diameter of shaft	=	2	in
Hanger center	=	10	ft
Diameter feed section	=	6	in
Kecepatan screw conveyor	=	40	rpm

Spesifikasi :

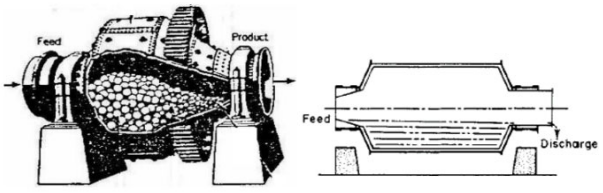
Fungsi	:	Mendinginkan kristal akrilamida dari suhu 75°C menjadi 30 °C
Type	:	Standard screw- plain spouts of chutes
Kapasitas	:	198,7379 cuft/jam = 5,62763 m^3/jam
Diameter flight	:	9 in = 0,2286 m
Diameter pipa	:	2 1/2 in = 0,0635 m 0,3048
Diameter shaft	:	2 in = 0,0508 m
Kecepatan	:	40 rpm
Elevasi	:	horizontal
Panjang	:	30 ft = 9,144 m
Effisiensi	:	80%
Power	:	1,044 Hp
Jumlah	:	1 buah

32. Ball mill (C-340)

Fungsi : Mengecilkan ukuran kristal akrilamida menjadi 45 mesh

Type : Ball Mill Grinding system , Marcy Ball Mill

Dasar pemilihan : Sesuai untuk mengecilkan ukuran 45 mesh



Rate massa = 6314,2943 kg/jam
= 13920,6361 lb/jam
= 6,314294 ton/jam

Untuk produk berukuran 45 mesh dengan kapasitas 151,54306 ton/hari
Dari ***Perry 7ed: T 20-16***

Jenis Ball Mill : Marcy Ball Mills
Power : 85 - 95 Hp
No. Sieve : 48 Mesh
Rate Maksimum : 210 Ton / day
Berat Bola Baja : 8,9 Ton
Mill Speed : 24 Rpm

Ukuran Ball Mill

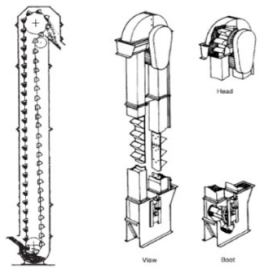
Panjang Mill : 6 ft
Diameter Mill : 4,5 ft
Tinggi Mill : 4,5 ft

Spesifikasi

Fungsi : Mengecilkan ukuran kristal akrilamida menjadi 45 mesh
Type : Ball mill Grinding system , Mercy Ball Mill
Kapasitas : 151,5431 ton/hari
Diameter mill : 4,5 ft = 1,3716 m
Panjang mill : 6 ft = 1,8288 m
No. Sieve : 48 Mesh = 0,355 mm = 355 μm
Effisiensi Sieve : 60 %
Kecepatan putar : 24 rpm
Power : 90 Hp
Bahan ball : Carbon steel
Bahan konstruksi : Carbon Steel
Jumlah : 1 buah

33. Bucket Elevator (J-341)

Fungsi : Memindahkan akrilamida dari cooling conveyor menuju ball mill
Type : Continous bucket elevator



Rate massa = 6314,2943 kg/jam
= 6,314294 Ton/jam
ρ bahan = 70,0452 lb/cuft
Dari ***Perry 7ed T 21-9*** dipilih bucket elevator dengan spesifikasi :
Tinggi Bucket = 25 ft
Putaran Head = 28 rpm
Kapasitas maksimum = 35 ton/jam
Bucket linear speed = 150 ft/min
Kecepatan Bucket elevator = $\frac{\text{Rate massa}}{\text{Kapasitas maksimum}}$ x Bucket linier speed
= $\frac{6,314294 \text{ Ton/jam}}{35 \text{ Ton/jam}}$ x 150 ft/min
= 27,06126 ft/min
Power head shaft = 1,8 Hp
Power tambahan = 0,06 Hp tiap ft
= 0,06 Hp/ft x 25 ft
= 1,5 Hp
Power total = Power head shaft + Power tambahan
= 1,8 Hp + 1,5 Hp
= 3,3 Hp
Ukuran Bucket = Lebar x Proyeksi x Kedalaman
= 8 in x 5,5 in x 7,75 in
Bucket spacing = 8 in
Effisiensi = 80%
Maka, motor penggerak yang digunaka = $\frac{\text{Power total}}{\text{Effisiensi motor}}$
= $\frac{3,3}{80\%}$
= 4,125 Hp
= 4 Hp

Spesifikasi :
Fungsi : Memindahkan kristal akrilamida menuju ball mill
Kapasitas : 6 Ton/jam
Bucket : Tinggi bucket = 25
Kecepatan bucket = 27,061 ft/min
Bucket spacing = 8 in
Ukuran bucket = 8 in x 5,5 in x 7,75 in
Putaran head shaft = 28 rpm
Power : 4 Hp
Jumlah : 1 Buah

34. Silo Akrilamida (F-420)

Fungsi : Menampung produk akrilamida selama 3 hari
Type : Silinder tegak dengan tutup atas plat dan bawah conical
Dasar pemilihan : Sesuai untuk menyimpan padatan

Bahan masuk

Komponen	Berat (kg)	Fraksi berat	ρ (g/cc)
C_3H_5NO	6313,13128	0,9998	1,1220
H_2O	1,16302799	0,0002	1,0229
Total	6314,29431	1	

Menentukan Volume tangki

$$\rho \text{ Campuran} = \frac{1}{\Sigma \frac{\text{Fraksi Berat}}{\rho \text{ Komponen}}} \times 62{,}43 = \text{lb/cuft}$$

$$\rho \text{ Campuran} = \frac{1}{\frac{0{,}9998}{1{,}1220} + \frac{0{,}0002}{1{,}0229}} \times 62{,}43 = 70{,}05 \text{ lb/cuft}$$

Rate Massa = 6314,29 kg/jam = 13923,02 lb/jam

$$\text{Rate Volume} = \frac{\text{Rate Massa}}{\text{Densitas}} = \frac{13923{,}0189 \text{ lb/jam}}{70{,}0452 \text{ lb/cuft}}$$

= 198,7719 cuft/jam
= 3,3129 cuft/menit
= 24,7835 gpm

$$\text{Volume bahan} = \frac{198{,}7719 \text{ cuft/jam} \times 3 \text{ hari} \times 24 \text{ jam/hari}}{3 \text{ tangki}}$$

= 4770,525 cuft

Asumsi bahan mengisi 80% volume tangki, maka Vol Tangki :

$$V = \frac{4770{,}5254 \text{ cuft}}{80\%}$$

= 5963,1568 cuft

Menentukan dimensi tangki

Asumsi rasio dimensi : H/D = 2 ***Ulrich; T 4-27; 248***

Volume = $1/4\ \Pi.\ D.^2H$

$$5963{,}16 = \frac{1}{4} \times \pi \times D^2 \times 2 \times D$$

$D^3 = \frac{5963,157 \text{ cuft}}{1,57}$

$D^3 = 3798,2$

D = 15,60243 ft = 187,2291 in = 4,8 m

H = 31,20486 ft = 374,4583 in = 9,5 m

Menentukan tekanan design

P operasi = 14,7 psig

P design 10% lebih besar dari P operasi untuk faktor keamanan

P design = 110% x 14,7 psig

= 16,17 Psig

Direncanakan :

1. Bahan konstruksi = *Carbon steel SA-204 Grade B*
   f = 17500 psi ***T 13.1 B&Y; 251***
2. Pengelasan double welded butt joint
   E = 0,8 ***T 13.2 B&Y; 254***
3. Faktor korosi (C) = 1/8

Menentukan tebal shell minimum :

Tebal shell berdasarkan ASME code untuk tangki silinder :

$$ts = \frac{P \times ri}{f\ E - 0,6\ P} + C \qquad \textit{eq. 13.1 B\&Y; 254}$$

Dimana :

ts = tebal shell (in) C = faktor korosi

P = tekanan design (Psi) f = alllowable stress

ri = jari-jari dalam (in)

E = faktor pengelasan

Mencari tebal shell (ts) menggunakan f yang diijinkan

$$ts = \frac{16,170 \text{ psig} \times 93,615 \text{ in}}{17500 \text{ psi} \times 0,8 - 0,6 \times 16,17 \text{ psig}} + 1/8$$

= 0,2332 in

ts yang diperoleh di standarkan dengan tebal shell yang dijual dipasaran dengan melihat T 5.7 B&Y; 90

ts = 4/16 in

Untuk tebal tutup atas disamakan dengan tebal tutup bawah, karena tutup bawah lebih banyak menerima beban

Tebal tutup bawah

Untuk tutup berbentuk conical dengan sudut tidak lebih besar dari 30° menggunakan persamaan 6.154 B&Y

α = 30 ° Cos α = 0,866

(1/2α) = 15 ° (tan 1/2α) = 0,2679

$$th = \frac{P \cdot D}{2 \cos \alpha\ (f.E - 0,6\ P)} + 1/8 \qquad \textit{B\&Y: eq. 6.154; 118}$$

Asumsi th = 4/16 in

$$4/16 \text{ in} = \frac{16{,}17 \text{ psig} \times 187{,}2291 \text{ in}}{2 \times 0{,}866 \times (f \times 0{,}8 - 0{,}6 \times 16{,}17 \text{ psig})} + 1/8$$

$$2/16 \text{ in} = \frac{16{,}17 \text{ psig} \times 187{,}2291 \text{ in}}{2 \times 0{,}866 \times (f \times 0{,}8 - 0{,}6 \times 16{,}17 \text{ Psig})}$$

f = 17491,379

f actual < f allowable, maka th = 2/8 in dapat digunakan

Tinggi total bejana

Menentukan tinggi tutup bawah conical (hb)

$$h = \frac{\text{tg } \alpha \times (D-m)}{2}$$

$$= \frac{0{,}57735 \times (15{,}602 - 1)}{2}$$

= 4,2153579 ft = 1,284841 m

tinggi silinde = 31,2049 ft = 374,4583 in = 9,5112402 m

Tinggi total bejana = 35,4202 ft = 10,8 m

Perancangan Penyangga

Jumlah penyangga = 4

Menentukan Berat total

Vol. tangki = 5963,157 cuft

Vol. bahan 4770,525 cuft

ρ material = 490 lb/cuft

W bejana kosong = (Vol. tangki - Vol bahan) x ρ material

= 584389,4 lb

W isi = 6314,29 kg/jam = 13920,64 lb/jam

= 13920,64 lb/jam x 1 jam

= 13920,64 lb

$$\text{Vol tutup} = \frac{\pi \quad D^3}{24 \text{ tg } (1/2 \alpha)}$$

$$= \frac{\pi \times 15{,}602^{\ 3}}{24 \times 0{,}2679}$$

= 1854,567 ft³

W tutup = Vol. tutup x ρ material

= 1854,6 ft³ x 490 lb/cuft

= 908737,8 lb

W aksesoris = 75352,39 lb

Σ W = 1582400,2 lb

Menentukan tinggi penyangga (L)

tinggi total bejana (H) = 35,4202 ft

tinggi dari permukaan tanah (l) = 5 ft = 1,524 m

L = l + 0,5 H

= 5 ft + 0,5 x 35,4202 ft
= 22,7101 ft
= 272,521 in

Menentukan beban tiap penyangga

$P = \frac{\Sigma W}{n}$

$= \frac{1582400 \text{ lb}}{4} = 395600{,}1 \text{ lb} = 179441{,}2 \text{ kg}$

Menentukan fc allowable

$fc = \frac{P}{A} = \frac{395600 \text{ lbm} \times 1 \text{ lbf/lbm}}{56{,}9 \text{ in}^2} = 6914{,}9 \text{ lbf/in}^2$

Direncanakan :
Jenis penyangga = Equal Angles
dari B&Y: App G; 354

Axis 1-1		Axis 2-2	
A	= 56,9 in²	A	= 56,9 in²
$r_{1\,1}$	= 2,42 in	$r_{2\,2}$	= 1,55 in
$\frac{L}{r_{1\,1}}$	= 112,612	$\frac{L}{r_{2\,2}}$	= 175,82

untuk L/r x x < 120 menggunakan persamaan berikut:
fc = 17000 - 0,485 x $(L/r_{1\,1})$
= 16945,4 Psi
untuk L/r x x > 120 menggunakan persamaan berikut:

$fc = \frac{18000}{1 + \frac{1}{18000} \times (L/r_{2\,2})^2}$

= 6624,0415 psi
fc actual > fc allowable, maka jenis penyangga beams dengan luas permukaan penyangga 56,9 in² dapat digunakan

Spesifikasi

Fungsi	:	Menampung produk akrilamida		
Type	:	Silinder tegak dengan tutup atas plat dan bawah conical		
Bahan	:	Carbon steel SA-204 Grade B		
Diameter tangki	:	15,602 ft	=	4,7556 m
Tinggi tangki	:	31,205 ft	=	9,5112 m
Tebal shell	:	4/16 in	=	0,0064 m
Tebal tutup	:	4/16 in	=	0,0064 m
Jumlah	:	4 buah		
Jenis penyangga	:	Equal Angles		
Luas permukaan penyangga	:	56,9 in²	=	0,0367 m²
Tinggi penyangga	:	22,71 ft	=	6,922 m

APPENDIX D
PERHITUNGAN ANALISA EKONOMI

Kapasitas Produksi = 50000 Ton/Tahun
= 6313,13131 kg/jam
Waktu operasi = 330 Hari/tahun
= 24 Jam/Hari

Dengan bahan baku :
Akrilonitril 99,5 % = 5060,68786 kg/jam
Asam sulfat monohidrat 65% = 17040,3423 kg/jam
Amonia 99,5% = 3084,15505 kg/jam

Menghasilkan produk
Akrilamida = 6313,13128 kg/Jam
Ammonium sulfat = 11973,7784 kg/jam

Faktor - faktor yang perlu untuk ditinjau antara lain :
1. Laju pengembalian modal (Rate of Return)
2. Lama pengembalian modal (Pay Back Periode)
3. Titik impas (Break Event Point)

Untuk meninjau faktor-faktor diatas, perlu adanya penaksiran terhadap beberapa beberapa faktor, yaitu :
1. Penaksiran modal industri (Total Capital Investment) yang terdiri atas :
   a. Modal Tetap (Fixed Capital Investment)
   b. Modal Kerja (Working Capital Investment)
2. Penentuan biaya produksi total (Production Cost) yang terdiri atas :
   a. Biaya Pembuatan (Manufaring Cost)
   b. Biaya Pengeluaran Umum (General Expences)
   c. Total Pendapatan

1. HARGA PERALATAN

Harga peralatan berubah menurut waktu resmi sesuai dengan kondisi ekonomi dunia. Untuk memperkirakan harga peralatan saat ini, digunakan indeks seperti pada persamaan sebagai berikut :

$$Cp = \frac{Ip}{Io} \times Co$$

keterangan :
Cp = Hrga alat pada tahun 2022
Co = Harga alat pada tahun 2014
Ip = Cost Index pada tahun 2022
Io = Cost Index pada tahun data 2014

Perhitungan peralatan didasarkan pada Cost Equipment sedangkan Cost Indeks didasarkan pada Peters and Timmerhauss "*Plant Design and Economic for Chemical Engineering*". Perhitungan Engineering berdasarkan Chemical Engineering Plant Cost Index (CEPCI), Chemical Tabel D-1.

Tabel D.1 Indeks Harga Peralatan

Tahun		Indeks
2012		584,6
2013		567,3
2014		576,1
2015		556,8
2016		541,7
2017		567,5
2018		603,1
2019		607,5
2020		596,2
2021		776,9

sumber : CEPCI Tahun 2020 Annual Index

Dengan metode Least Square dan data - data pada tabel di atas dilakukan pendekatan atau penafsiran indeks harga peralatan pada awal tahun dimana data - data :

keterangan :

Y = Indeks harga peralatan pada tahun ke - n

X = Tahun ke - n

n	X	Y	X²	Y²	XY
1	2012	584,6	4048144	341757	1176215
2	2013	567,3	4052169	321829	1141975
3	2014	576,1	4056196	331891	1160265
4	2015	556,8	4060225	310026	1121952
5	2016	541,7	4064256	293439	1092067
6	2017	567,5	4068289	322056	1144648
7	2018	603,1	4072324	363730	1217056
8	2019	607,5	4076361	369056	1226543
9	2020	596,2	4080400	355454	1204324
10	2021	776,9	4084441	603574	1570115
Total	20165	5978	40662805	3612813	1,2E+07

Jumlah Data (n) = 10

Persamaan 17-21, Peters and Timmerhauss:

$$\sum(\bar{x} - x)^2 = \sum x^2 - \frac{(\sum x)^2}{n} = 82{,}5$$

$$\sum(\bar{y} - y)^2 = \sum y^2 - \frac{(\sum y)^2}{n} = \quad 39523,2210$$

Persamaan 20, Peters and Timmerhauss:

$$\sum(\bar{x} - x)(\bar{y} - y) = \sum xy - \frac{\sum x \,.\, \sum y}{n} = \qquad 1127,3500$$

$$b = \frac{\sum(\bar{x} - x)(\bar{y} - y)}{\sum(\bar{x} - x)^2} = \quad 13,6648$$

Rata - rata y = ∑y / n = ε = 597,7700
Rata-rata x = ∑x / n = c = 2016,500

y = a + b (x-c)
= 597,7700 + [13,6648 (x - 2016,500)]
= 597,7700 + 13,6648 x - 27555,2
= 13,6648 x + -26957,3970

Dari persamaan di atas diperoleh indeks harga pada tahun 2025 sebesar :
y = 13,6648 x + -26957,3970
y = 713,921

Kurs dollar pada tahun 2025 (07 April 2023)
$1 = Rp 14.800 (https ://www.bca.co.id)

Contoh perhitungan Harga Peralatan :
Tangki penampung Akrilonitril
Harga pada tahun 2014 = $ 55.300
Indeks harga tahun 2014 = 576,1
Indeks harga tahun 2025 = 713,921212
Dari (Peter & Timmerhauss hal 164) :

$$\text{Harga pada tahun 2025} = \frac{\text{Indeks harga tahun 2025}}{\text{Indeks harga tahun 2014}} \times \text{Harga alat pada tahun 2014}$$

$$= \frac{713,921212}{576,1} \times \$ \quad 55.300$$

= $ 68.529
= Rp 1.014.236.551

Tabel D.2 Hasil Perhitungan Harga Peralatan Proses

No	kode	Nama Alat	Harga per unit ($)		Jumlah	Harga Total
			2014	2025		US $
1	F-110	Tangki C_3H_3N	55300	68529	4	274118
2	F-120	Tangki $H_2SO_4.H_2O$	54200	67166	4	268665
3	F-130	Tangki NH_3	63000	78072	3	234215
4	L-111	Pompa - 1	3200	3966	1	3966
5	E-112	Heater - 1	8000	9914	1	9914
6	L-141	Pompa - 2	3200	3966	1	3966
7	L-121	Pompa - 3	3700	4585	1	4585
8	E-122	Heater 2	36400	45108	1	45108
9	R-210	Reaktor	69600	86251	4	345002
10	R-220	Neutrallizer	113800	141025	1	141025
11	G-150	Ekspander	3800	4709	1	4709
12	L-221	Pompa - 4	3200	3966	1	3966
13	H-230	Filter Press	65300	80922	2	161844
14	J-231	Screw Conveyor - 1	1800	2231	1	2231
15	F-410	Silo $(NH_4)_2SO_4$	20400	25280	4	101121
16	L-232	Pompa - 5	4900	6072	1	6072
17	L-233	Pompa - 6	6300	7807	1	7807
18	V-240	Evaporator	56300	69769	3	209306
19	E-241	Barometric Condensor	113600	140777	1	140777
20	G-242	Steam Jet Ejector	3300	4089	1	4089
21	F-243	Hot Well	1800	2231	1	2231
22	L-244	Pompa - 7	6300	7807	1	7807
23	S-310	Crystallizer	87100	107937	1	107937
24	J-311	Screw Conveyor - 2	1800	2231	1	2231
25	H-320	Centrifug	37000	45852	1	45852
26	B-320	Rotary Drayer	49800	419	1	419
27	G-321	Blower	11000	13632	1	13632
28	B-322	Molekular Sieve Tray	70000	86746	1	86746
29	E-323	Heater Udara	36400	45108	1	45108
30	H-324	Cyclone	59400	73610	1	73610
31	E-330	Cooling Conveyor	3200	3966	1	3966
32	C-340	Ball Mill	216600	268418	1	268418
33	J-314	Bucket Elevator	12300	15243	1	15243
34	F-420	Silo Akrilamida	30500	37797	4	151186
Total						2796868

Tabel D.3 Hasil perhitungan Harga Peralatan Utilitas

No	Kode	Nama Alat	Harga per unit ($)		Jumlah	Harga total
			2014	2025		US $
1	L-211	Pompa air sungai	17600	21810	1	21810
2	A-210	Bak Penampung air sungai	-	128800	1	128800
3	L-212	Pompa Koagulasi	16200	20076	1	20076
4	M-220	Tangki Koagulasi	327800	406220	1	406220
5	L-221	Pompa Clarifier	16200	20076	1	20076
6	M-230	Tangki Flokulasi	468600	580704	1	580704
7	H-310	Clarifier	-	271900	1	271900
8	A-311	Bak Penampung Flok	-	50400	1	50400
9	A-312	Bak Penampung Air Bersih -1	-	27200	1	27200
10	L-313	Pompa Sand Filter	16200	20076	1	20076
11	H-320	Sand Filter	295800	366565	2	733129
12	A-321	Bak Penampung Air Bersih -2	-	27200	1	27200
13	L-322	Pompa Bak Sanitasi	7500	9294	1	9294
14	A-323	Bak Penampung Air Sanitasi	-	3500	1	3500
15	H-330	Tangki Kation Exchanger	59900	74230	1	74230
16	L-331	Pompa Tangki Kation Exchanger	6300	7807	1	7807
17	H-340	Tangki Anion Exchanger	59900	74230	1	74230
18	A-341	Bak Penampung Air Proses	-	12800	1	12800
19	L-342	Pompa Air Umpan Boiler	6300	7807	1	7807
20	Q-350	Boiler	750300	929795	1	929795
21	A-343	Bak Penampung Air Proses	-	12800	1	12800
22	L-325	Pompa Bak Air Pendingin	14700	18217	1	18217
23	A-326	Bak Air Pendingin	-	140800	1	140800
24	L-326	Pompa Recyle Pendingin	14700	18217	1	18217
25		Generator Set	165300	204845	2	409690
26		Tangki Bahan Bakar Diesel Oil	17100	21191	1	21191

27	P-360	Cooling Tower	493400	611437	1	611437
28	L-361	Pompa Cooling Tower	14700	18217	1	18217
Total						4677622

Total harga peralatan = Harga peralatan proses + harga peralatan utilitas
= $ 2.796.868 + $ 4.677.622
= $ 7.474.490
= Rp 110.622.451.702

D.4 Harga Bahan Baku

1. Akrilonitril

Jumlah kebutuhan = 5060,687858 kg/jam = 5,0607 ton/jam
Harga Akrilonitril = $ 300 / ton *(Alibaba.com)*
= Rp 4.440.000 / ton
Biaya pertahun = Rp 4.440.000 x 5,0607 x 24 x 330
= Rp 177.958.076.380
= $ 12.024.194

2. Asam Sulfat Monohidrat

Jumlah Kebutuhan = 17040,3423 kg/jam = 17,0403 ton/jam
Harga Asam Sulfat Monohidrat = $ 230 / ton *(Alibaba.com)*
= Rp3.404.000 / ton
Biaya pertahun = Rp3.404.000 x 17,0403 x 24 x 330
= Rp 459.402.174.922
= $ 31.040.687

3. Ammonia

Jumlah Kebutuhan = 3084,155053 kg/jam = 3,0842 ton/jam
Harga Amonia = Rp 5.912 / kg *(PT.Petrokimia Gresik)*
= Rp 5.912.000 / ton
Biaya Pertahun = Rp 5.912.000 x 3,0842 x 24 x 330
= Rp 144.409.515.410
= $ 9.757.400

Total biaya bahan baku = Rp 781.769.766.712
= $ 52.822.282

D.5 Harga Jual Produk

1. Akrilamida

Jumlah hasil produksi = 6313,13128 kg/jam = 6,31313 ton/jam
Harga Akrilamida = $ 2.000 / ton *(Alibaba.com)*
= Rp 29.600.000 / ton
Harga pertahun = Rp 29.600.000 x 6,31313 x 24 x 330
= Rp 1.479.999.991.565
= $ 99.999.999

2. Amonium Sulfat

Jumlah Hasil Produksi = 11973,7784 kg/jam = 11,9738 ton/jam
Harga Ammonium sulfa = $ 200 / ton *(Alibaba.com)*
= Rp 2.960.000 / ton
Harga pertahun = Rp 2.960.000 x 11,9738 x 24 x 330
= Rp 280.703.682.743
= $ 18.966.465

Total harga jual produk = Rp 1.760.703.674.308
= $ 118.966.464

D.6 Biaya Pengemasan Produk

1. Akrilamida

Produk yang dihasilkan = 40080648 kg/tahun
(Produk dikemas dalam bag 50 kg)
Kebutuhan bag = 801613 bag/tahun
Harga 1 Bag = Rp 2.000
Biaya pengemasan per tahun = Rp 1.603.225.913

2. Ammonium Sulfat

Produk yang dihasilkan = 94832325,3 kg/tahun
(Produk dikemas dalam bag 50 kg)
Kebutuhan bag = 1896647 bag/tahun
Harga 1 Bag = Rp 2.000
Biaya pengemasan per tahun = Rp 3.793.293.010

Biaya pengemasan per tahun = Rp 5.396.518.923
Biaya pendukung 10% pengemasan = Rp 539.651.892 +
Total biaya pengemasan per tahun = Rp 5.936.170.816

D.7 Gaji Karyawan

A. Gaji Pokok

No	Jabatan	Gaji/Bulan	Jumlah	Gaji/Tahun
1	Direktur Utama	Rp 50.000.000	1	Rp 600.000.000
2	Direktur Produksi & Teknik	Rp 30.000.000	1	Rp 360.000.000
3	Direktur keuangan & Administrasi	Rp 30.000.000	1	Rp 360.000.000
4	Sekertaris Direktur	Rp 8.000.000	3	Rp 288.000.000
5	Kepala Bagian Produksi	Rp 10.000.000	1	Rp 120.000.000
6	Kepala Bagian Teknik	Rp 10.000.000	1	Rp 120.000.000
7	Kepala Bagian Pemasaran	Rp 10.000.000	1	Rp 120.000.000
8	Kepala Bagian Umum	Rp 10.000.000	1	Rp 120.000.000
9	Kepala Bagian Keuangan	Rp 10.000.000	1	Rp 120.000.000
10	Kasi Proses	Rp 7.000.000	1	Rp 84.000.000
11	Kasi Riset & Pengembangan	Rp 7.000.000	1	Rp 84.000.000
12	Kasi Utilitas & Energi	Rp 7.000.000	1	Rp 84.000.000
13	Kasi Pemeliharaan & Perbaiakan	Rp 7.000.000	1	Rp 84.000.000
14	Kasi Pembelian	Rp 7.000.000	1	Rp 84.000.000
15	Kasi Gudang	Rp 7.000.000	1	Rp 84.000.000
16	Kasi Pemasaran & Penjualan	Rp 7.000.000	1	Rp 84.000.000
17	Kasi Administrasi	Rp 7.000.000	1	Rp 84.000.000
18	Kasi Personalia & Kesejahteraan	Rp 7.000.000	1	Rp 84.000.000
19	Kasi Keamanan	Rp 7.000.000	1	Rp 84.000.000
20	Karyawan Bagian Proses (Kepala)	Rp 5.000.000	4	Rp 240.000.000
21	Karyawan Bagian Proses (Regu)	Rp 4.500.000	44	Rp 2.376.000.000
22	Karyawan Bagian Laboratorium	Rp 4.500.000	6	Rp 324.000.000
23	Karyawan Bagian Utilitas	Rp 4.500.000	12	Rp 648.000.000
24	Karyawan Bagian Personalia	Rp 4.500.000	5	Rp 270.000.000
25	Karyawan Bagian Pemasaran	Rp 4.500.000	10	Rp 540.000.000
26	Karyawan Bagian Administrasi	Rp 4.000.000	5	Rp 240.000.000
27	Karyawan Bagian Pembelian	Rp 4.000.000	5	Rp 240.000.000
28	Karyawan Bagian Pemeliharaan	Rp 3.750.000	8	Rp 360.000.000
29	Karyawan Bagian Gedung	Rp 3.750.000	6	Rp 270.000.000
30	Karyawan Bagian Keamanan	Rp 3.750.000	10	Rp 450.000.000
31	Karyawan Bagian Kebersihan	Rp 3.750.000	10	Rp 450.000.000

32	Dokter	Rp 8.000.000	2	Rp 192.000.000
33	Perawat	Rp 3.500.000	3	Rp 126.000.000
34	Supir	Rp 3.500.000	6	Rp 252.000.000
35	Satpam	Rp 3.300.000	15	Rp 594.000.000
Total			172	Rp 10.620.000.000

D.8 Kebutuhan Utilitas

A. Air

Kebutuhan air tiap hari = 31742,4 m^3/hari
Biaya air tiap hari = 31742,4 x Rp 1.500
= Rp 47.613.634
Biaya pengolahan per tahun = Rp 47.613.634 x 330
= Rp 15.712.499.062

B. Kebutuhan Penunjang Pengolahan Air

1. Kebutuhan $Al_2(SO_4)_3$ = 188549,989 kg/tahun
   Harga $Al_2(SO_4)_3$ = Rp 3.400 /kg *(Bisakimia.com)*
   Biaya tawas per tahun = Rp 641.069.962

2. Kebutuhan PAC = 28284,7609 kg/tahun
   Harga PAC = Rp 12.000 /kg *(Indotrading.com)*
   Biaya PAC per tahun = Rp 339.417.131

3. Kebutuhan HCl = 23476,5351 L/tahun
   Harga HCl = Rp 25.000 /L *(Tokopedia.com)*
   Biaya HCl per tahun = Rp 586.913.377

4. Kebutuhan Dowex Anion = 146432,976 L/tahun
   Harga Dowex Anion = Rp 20.000 /L *(Alibaba.com)*
   Biaya Dowex Anion/tahun = Rp 2.928.659.517

5. Kebutuhan NaOH = 10982,4732 kg/tahun
   Harga NaOH = Rp 14.500 /kg *(Tokopedia.com)*
   Biaya NaOH per tahun = Rp 159.245.861

6. Kebutuhan Dowex Kation = 219649,464 kg/tahun
   Biaya Dowex Kation = Rp 9.000 /L *(Alibaba.com)*
   Biaya Dowex Kation/Tahun = Rp 1.976.845.174

7. Kebutuhan Chlorine = 2775,168 kg/tahun
   Harga Chlorine = Rp 31.000 /kg
   Biaya Chlorine per tahun = Rp 86.030.208

C. Bahan Bakar

1. Diesel Oil

Kebutuhan bahan bakar	=	874262,0161	L/tahun
Harga Bahan bakar/liter	=	Rp 9.400	/L
Biaya bahan bakar tiap tahun	=	Rp 8.218.062.951	

D. Listrik

Kebutuhan Listrik	=	58,3560	kWh/hari
Biaya Listrik per kWh	=	Rp 997	*(www.kompas.com)*
Biaya Listrik tiap tahun	=	Rp 58.180,9320	

Jadi, Total biaya Utilitas pertahun = Rp 33.577.460.941

D.8 Luas Tanah dan Bangunan

Luas Tanah	=	22000	m²
Harga Tanah/m²	=	Rp 2.000.000	*(www.lamudi.co.id)*
Total harga tanah	=	Rp 44.000.000.000	

Luas bangunan pabrik	=	8650	m²
Harga bangunan pabrik per m²	=	Rp2.100.000	*(www.wordpress.com)*
Harga bangunan pabrik total	=	Rp 18.165.000.000	

Luas bangunan gedung	=	5750	m²
harga bangunan gedung	=	Rp2.200.000	*(www.bappenas.go.id)*
harga bangunan gedung total	=	Rp 12.650.000.000	

Total harga bangunan	=	Rp	30.815.000.000
Total harga tanah dan bangunan	=	Rp	56.650.000.000